MAREMED Project
MAritime REgions cooperation for the MEDiterranean

Adaptation to Climate Change on Coastal Area

Book 1
Compared analysis between coastal vulnerability maps

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1. MAREMED project and the Coastal Adaptation to CC

The European project MAREMED "Maritime Regions Cooperation for the Mediterranean", approved in the MED SPACE program (2010-2013) with Region PACA leader partner and other 13 Mediterranean regions, foresees 6 sections of interest:

- Coastal Pollution
- Integrated Coastal Zone Management
- Coastal Adaptation to CC
- Fishery
- Coastal Geo-data management
- Governance

The Lazio Region is in charge for the Coastal Adaptation CC in order to develop three specific issues:

1. Compared analysis between coastal vulnerability maps
2. Shared tools for the forecast and management of the CC effects along the coast
3. Implementation of a coastal observatory network in the Mediterranean basin

This first volume concerns the "**Compared analysis between coastal vulnerability maps**" and its objective is to provide examples of geo-representation already in use, or in elaboration, near some European and International bodies in relation to the Flood Directive 2007/60/CE or in general to the CC scenarios. The more significant example (in terms of articulation and development) which has been taken into exam is the Dutch coastal protection project VNK (Veiligheid Nederland in Kaart - Safety of the Netherlands on Map) carried out by the Dutch Government (DG Water - Rijkswatersaat) in collaboration with other public bodies (Water Boards, Municipalities, etc.) . The VNK is multi-year project aimed at developing and validating a new methodology to assess the safety of the defenses protecting the Netherlands from storm surge and river flooding.

A technical report "dissemination dutch coastal protection - "analysis of the project safety of the Netherlands on Map (Veiligheid Nederland in Kaart - vnk) about the Methods adopted for hazard, exposed values and Vulnerability evaluation for flood risk assessment on Coastal areas" was prepared for Maremed Project by technical Dutch consultant Arcadis. The integral version of this report is reported on the Annex 1 at this deliverable.

The VNK choices, methodologies and standard will be compared with running projects managed by other Public Administrations (Regione Lazio, Regione Emilia-Romagna, Department of Hérault, etc.) in order to find the best and more advanced solutions and to share concepts for reaching as much as possible homogenous and comparable results. This work is started with a diagnosis phase made by a survey among Maremed partners to better understand the implementation of common tools adopted by Mediterranean partners for the:

- valorisation of transnational projects on ACC in coastal area;

- use of maps and database for the geo-representation of flood risk on coastal areas.

2. The implementation of flood risk evaluation tools on the Mediterranean coasts (MAREMED Diagnosis phase)

The objective is to provide examples of geo-representation already in use, or in elaboration, near some European and International bodies in relation to the Flood Directive 2007/60/CE or in general to the CC scenarios.

To better understand and encourage the development of tools and methods to counter the problem of climate change adaptation in coastal areas, a questionnaire was made by Lazio Region during the MAREMED DIAGNOSIS phase (July 2011).

It is addressed to Maremed partners and Mediterranean public administrations directly involved in coastal zone management.

This questionnaire took inspiration from two works already started during BEACHMED-e project and Coastance project (MED programme).

During the Obsemedi sub-project of Beachmed-e - whose aim was to realize a feasibility study to set up a Mediterranean Interregional Observatory for coastal zone management, the results led to the realisation of a list of about 40 public structures operating in coastal zone management and the publication of the activities and tools necessary to deal with the problem.

> "…Floods are natural phenomena which cannot be prevented. However, some human activities (such as increasing human settlements and economic assets in floodplains and the reduction of the natural water retention by land use) and climate change contribute to an increase in the likelihood and adverse impacts of flood events…"
>
> *EU flood directive 2007/60/CE*

Coastance questionnaire, developed by Département de l'Hérault, coordinator of component 3 "Coastal Risk: Submersion and erosion" led to the comprehension of the state of the art of the activities linked to Mediterranean coastal risks and submersion management and forecasting. Eight public Administrations coming from Italy, France, Spain, Greece, Cyprus and Slovenia took part in this work.

"White paper" on Adapting to climate change (http://www.medregions.com/pub/doc_travail/gt/66_en.pdf) suggest the integration of climate change issues for the implementation of the Floods Directive 2007/60/CE. "...Full implementation of this Directive by the EU Member States will help increase resilience and facilitate adaptation efforts.... (COM(2009) 147, p. 11)"

This work must consider European flood directive as the point of reference to regulates the problem of flood risk evaluation, taking into account climate change adaptation in coastal area. This directive states in a specific way the need to consider climate change effects during the evaluation flood risks future scenarios.

Eventually, we have a regulation explaining how to assess and manage flood risks in coastal areas and the European Commission fixes clear deadlines for Member States to comply with the requirements of the flood directive.

This directive, approved by most Mediterranean Member States (http://ec.europa.eu/environment/water/flood_risk/timetable.htm), is reference point chosen by Regione Lazio for the development of this questionnaire.

Main Objectives of the questionnaire:

- Understanding the knowledge level of the "flood directive" effectively demonstrated by the Maremed partners, and especially understanding the real capability of Mediterranean administrations to meet the milestones proposed by the European Commission.
- Research of tools and methods currently available to address the problem of risk map elaboration, also collecting some experiences and suggestions coming from MAREMED partners for the next financial programme (2014 - 2020).

2.1 EU Flood risk directive 2007/60/EC (Requirements and milestones)

The milestones fixed by the flood directive are reported below:

PRELIMINARY FLOOD RISK ASSESSMENT

Article 4

...4. Member States shall complete the preliminary flood risk assessment by

22 December 2011.

FLOOD HAZARD MAPS AND FLOOD RISK MAPS

Article 6

...8. Member States shall ensure that the flood hazard maps and flood risk maps are completed by

22 December 2013.

FLOOD RISK MANAGEMENT PLANS

Article 7

...5. Member States shall ensure that flood risk management plans are completed and published by

22 December 2015.

The Flood Directive gives Member States some suggestions for the development of flood risk maps. In particular, some detailed information is requested for the elaboration of hazard maps and risk maps.

Some of the main requirements set by the directive are the following:

FLOOD SCENARIOS...

Flood hazard maps shall cover the geographical areas which could be flooded according to the following scenarios:

(a) floods with a low probability, or extreme event scenarios;

(b) floods with a medium probability (likely return period :? 100 years);

(c) floods with a high probability, where appropriate

ELEMENTS TO BE SHOWN...

For each scenario the following elements shall be shown:
(a) the flood extent; (b) water depths or water level, as appropriate; (c) where appropriate, the flow velocity or the relevant water flow
FLOOD SCENARIOS SHOULD BE EXPRESSED IN TERMS OF:
(a) the indicative number of inhabitants potentially affected; (b) type of economic activity of the area potentially affected; (c) installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (1) which might cause accidental pollution in case of flooding and potentially affected protected areas identified in Annex IV(1)(i), (iii) and (v) to Directive 2000/60/EC; (d) other information which the Member State considers useful such as the indication of areas where floods with a high content of transported sediments and debris floods can occur and information on other significant sources of pollution.
FLOOD RISK MANAGEMENT PLAN…shall take into account relevant aspects such as:
…costs and benefits, flood extent and flood conveyance routes and areas which have the potential to retain flood water, such as natural floodplains, the environmental objectives of Article 4 of Directive 2000/60/EC, soil and water management, spatial planning, land use, nature conservation, navigation and port infrastructure. Flood risk management plans shall address all aspects of flood risk management focusing on prevention, protection, preparedness, including flood forecasts and early warning systems and taking into account the characteristics of the particular river basin or sub-basin. Flood risk management plans may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event.

2.2 Diagnosis results

This Adaptation to Climate Change Questionnaire represents the 91% of Maremed regional Partners. Eleven partners of twelve have correctly answer to the questions.

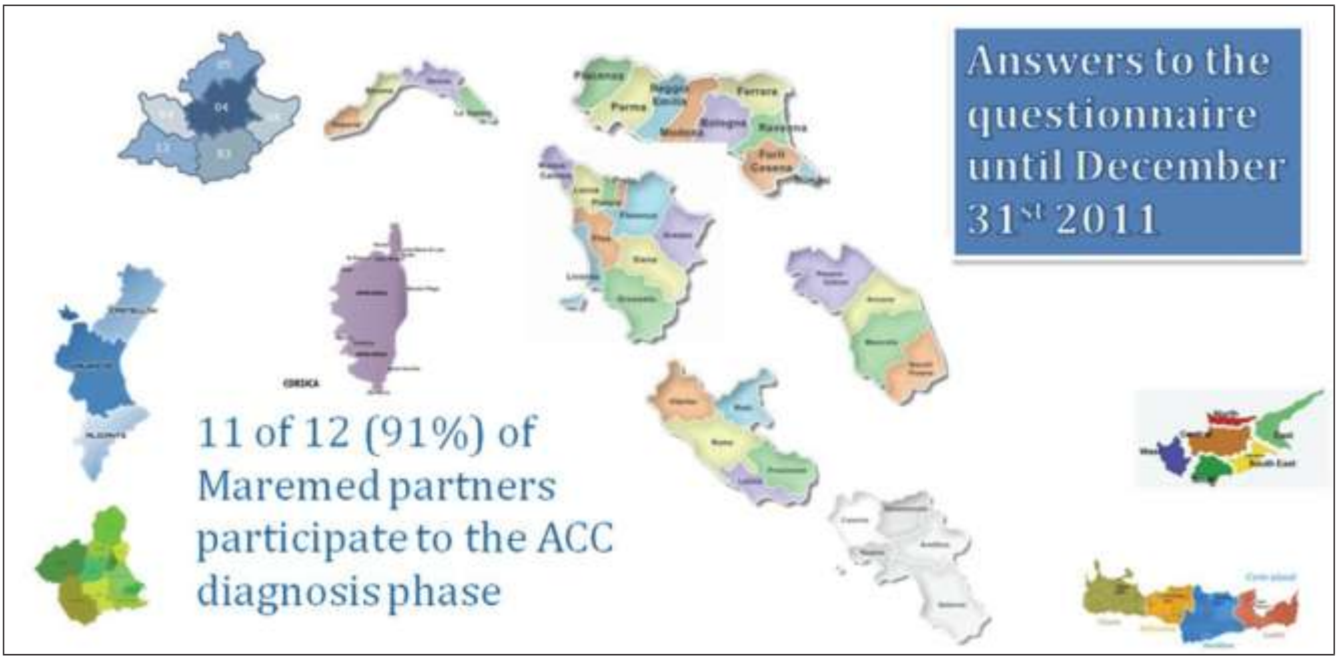


Figure 2.1 - participation of MAREMED partners to diagnosis phase

The Questionnaire is subdivided on six different sections for a total of 22 questions:

- SECTION 1 - State of the art: inventory of the cooperation projects on adaptation to climate change
- SECTION 2 - State of the art: inventory of the atlases and databases regarding coastal risks: erosion, submersion, flood
- SECTION 3 - Cartographic and morphological data
- SECTION 4 - Meteorological and wave climate data, climate change effects
- SECTION 5 - Social economic data, exposed values
- SECTION 6 - Future scenarios

All the answers are synthesised and reported on Annex 2 to this report. The integral version of questionnaires are available www.maremed.eu.

Final considerations, emerged problems and the solution and suggestions to propose for the future ERDF financial period 2014-2020, are reported on the next paragraph.

SECTION 1: State of the art: inventory of the cooperation projects on adaptation to climate change

Project	Maremed Partners involved	Project	Maremed Partners involved
Beachmed	Lazio, Toscana, Liguria	**PlanCoast**	Emilia-Romagna
Rinamed	FEPORT S	**COASTANCE**	Emilia-Romagna, Lazio, Crete
Eurosion	Toscana	**Regioclima**	Crete
Beachmed-e	Toscana, Lazio, Emilia-Romagna, Liguria, Crete	**LIFESALT**	Marche
Conscience	Toscana	**Perla**	Toscana
Resmar	Toscana, Corse, Liguria	**Cadsealand**	Emilia-Romagna
Micore	Emilia-Romagna		

SECTION 2: State of the art: inventory of the atlases and databases regarding coastal risks: erosion, submersion, flood

Question N°	Partner	Creta	Lazio	Emilia-Romagna	Toscana	FEPORTS	Murcia	PACA	Liguria	Marche	Cyprus	Corse	yes percentage
3	Have you already acquired information or been informed on floods and submersions which already occurred in the past, and which have significant adverse impact on coastal zones?	no	yes	yes	yes	yes	no	yes	yes	yes	no	yes	73%
4	Have you already defined a methodology to identify priority areas of risks (erosion, submersion, flood)?	no	yes	yes	yes	yes	no	yes	yes	yes	no	no	63%
5	Have you already produced risk maps on coastal areas?	no	no	no	yes	yes	no	yes	yes	yes	no	yes	54%
6	Did your risk maps refer to the EU flood directive (2007/60/EC) requirements?	yes	no	no	no	yes	no	no	yes	no	no	yes	36%
7	Have you produced atlases and/or databases regarding coastal area management?	no	yes	yes	yes	yes	yes	yes	yes	yes	no	no	73%
8	Have you adopted a specific guideline to produce these tools? / Should be shared and adopted by the MAREMED partnership?	no	no	yes	yes	yes	no	yes	yes	yes	no	no	54%

SECTION 3: Cartographic and morphological data

Question N°	Partner	Creta	Lazio	Emilia-Romagna	Toscana	FEPORTS	Murcia	PACA	Liguria	Marche	Cyprus	Corse	yes percentage
10	**Have you already acquired morphological data describing your coastal zone?**	yes	yes	yes	yes	yes	no	yes	yes	yes	yes	yes	91%
11	**What kind of tools do you use for coastal monitoring?**	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	100%
12	**Have you developed common cartographies together with your neighbour region?**	no	no	no	yes	yes	no	yes	no	no	no	yes	36%
13	**Have you collected information evaluating the subsidence phenomenon along your coast?**	no	yes	yes	yes	yes	no	yes	no		no	no	46%

Question N°	14	15	16	17	18
Partner	Have you collected information on [illegible] in your region?	Have you collected information evaluating [illegible] (100÷200/500 years)?	Have you collected information evaluating [illegible] (wind speed, wind direction, atmospheric pressure, water and air temperature, ...) along your coasts?	Have you collected information evaluating [illegible] (Wave heightH, Wave period T and main direction) along your coasts?	Have you collected information evaluating [illegible] (Wave height H, Wave period T and main direction) along your coasts?
Crete	yes	no	> 20 years	> 20 years	> 20 years
Lazio	yes	no	> 20 years	> 20 years	5÷20 years
Emilia-Romagna	yes	no	> 20 years	> 20 years	< 5 years
Toscana	yes	yes	5÷20 years	< 5 years	< 5 years
FEPORTS	yes	yes	< 5 years	< 5 years	< 5 years
Murcia	no	no	no	no	no
PACA	no	no	no	yes	no
Liguria	yes	no	no	> 20 years	no
Marche	no	no	5÷20 years	no	no
Cyprus	yes	no	5÷20 years	5÷20 years	5÷20 years
Corse	yes	no	5÷20 years	5÷20 years	5÷20 years
yes percentage	73%	18%	73%	82%	64%

SECTION 5: Social economic data, exposed values

Question N°	Partner	Creta	Lazio	Emilia-Romagna	Toscana	FEPORTS	Murcia	PACA	Liguria	Marche	Cyprus	Corse	yes percentage
19	Have you already developed land use maps for your coastal area?	yes	yes	yes	yes	yes	yes	yes	no	yes	yes	yes	91%
20	Have you already assigned economic values to your coastal area?	yes	yes	yes	no	no	no	no	no	no	yes	no	36%

SECTION 6: Future Scenarios

Could you identify problems that hinder the development of risk maps in coastal zones (budget; Administrative; organisational & coordination; technical competences; technical tools; lack of data or lack of shared data...)?

Problems that hinder the development of risk maps in coastal zones	Percentage of region that decleare the existence of this problem
Budget	Creta, Toscana, Murcia, PACA, Liguria, Corse (54%)
Administrative	Lazio, RER, Feport (27%)
Organisational & Coordination	Lazio, RER, Feport, Marche (36%)
Technical competences	PACA, Murcia (18%)
Lack of data	PACA (9%)
Technical tools	Toscana, Corse (18%)

Final considerations

SECTION 1 - State of the art: inventory of the cooperation projects on adaptation to climate change

- A Good participation in the diagnosis activities is registered at the end of this work. 11 regions on 12 partner have answered this questionnaire (91%). So the diagnosis on Climate Change adaptation on Coastal Area may be considered as representative of the Maremed Partnership.

SECTION 2 - State of the art: inventory of the atlases and databases regarding coastal risks: erosion, submersion, flood

- Maremed regions prove to have a good level of knowledge of the dangerous flood events occurred in the past. About 73% of them have already acquired information on floods and submersions already occurred in the past which had a significant adverse impact on coastal zones. So in general the most part of the Regions are ready to develop the 1st (preliminary) level of map requested by FRD (Preliminary flood risk assessment - art.4).
- 63% of Regions have already defined a methodology to identify priority areas of risks (erosion, submersion, flood), but only 54% have already produced risk maps on coastal areas, only 4 Regions declare to meet the Flood Risk Directive 2007/60/EC requirements for the 2nd level of map (Hazard and Risk maps - art. 6) and 3rd level of map (Flood Risk Management Plans - art. 7).
- 73% of Maremed Regions have already produced atlases and/or databases regarding coastal area management. 5 regions adopted specific guidelines. Nevertheless existing Atlases are in general only a qualitative representations of the coastal risk/hazard and cannot be compliant with the Flood Directive requirements.

SECTION 3 - Cartographic and morphological data

- The level of knowledge of coastal morphology is very high. 91% of regions have already acquired morphological and cartographic data on their coastal zone. The methodologies adopted to survey this area are very heterogeneous. Some regions have already acquired information using advanced technologies such as Lidar, WebCam or Satellite images, and other regions utilize only air-photo. This could cause some problems for the harmonization of the geographic digital data according to the INSPIRE Directive.

SECTION 4 - Meteorological and wave climate data, climate change effects

- A good level of knowledge of climate data is demonstrated. 73% of regions have collected information on offshore meteorological characteristics (wind speed, wind direction, atmospheric pressure, water and air temperature, …) and 82% have collected information evaluating offshore (about -100 m) wave characteristics (Wave height H, Wave period T and main direction), and 64% have collected the same wave characteristics nearshore (about -20 m). Only 18% of regions have collected information evaluating sea level evolution in the medium/long term (100÷200/500 years).

SECTION 5 - Social economic data, exposed values

- 91% of regions have already developed land use map on coastal area, but only 36% have assigned economic values to this areas.

SECTION 6 - Future scenarios

- 6 regions out of the 11 interviewed have already been developing adaptation measures to climate change for the last 10 years, but problems linked to budget availability and lack of technical competence and tools were reported during the diagnosis.

Emerged Problems

- Med Regions are surely the most furnished and liable dataset-keeper but they are ready to meet the Flood Risk Directive deadlines only in part. They need to better understand economic values of their coasts and how to produce the risk maps. In particular how to represent the characteristics of inundation (as requested by EU flood Directive) and the impact of inundation on coastal area. A common methodology to produce the risk map of inundation/erosion on coastal area is not yet available.
- A deepen level of knowledge of sea level rise at regional level and climate change effect on coastal area did not emerge on this diagnosis phase.
- A gap of knowledge and experiences among med regions on coastal zone management is evident. Some Regions already acquired an high level of technologies for the monitoring of coastal area, other region are not prepared to the future challengers that climate change will propose.
- The production of geographic digital data necessary to the coastal management, it is guaranteed on grand part of the partnership, but a lack of harmonization of this data among partners is evident.
- A lack of budget and technical competence and tools is expressed by grand part of partners, a coordination of local administration at Mediterranean level is not evident.

Solution to propose

- Improving current coastal Atlases along the Flood Directive lines, i.e. by a quantitative evaluation of the hazard/risk.
- Following European and extra EU realities with more experience on coastal risk evaluation and management (Netherlands, USA, etc..).
- Creating of a Mediterranean Interregional Observatory of coastal zone is recommended in order to remove the gap actually registered among Med Regions in terms of technical competences, management tools and budgets.

- Creating a Spatial Digital Infrastructure of Harmonized geographic digital data among Mediterranean local administration.

Suggestions for the next ERDF financial period 2014-2020

Following suggestions have been expressed by interviewed Regions:

- Producing of Best practices for adaptation of coastal zones to climate change;
- Re-launching EUROSION Initiative, with a particular focus on the Med basin;
- Fostering the creation of an Interregional Network of Observatories for the coast of the Med basin;
- Involving northern Africa Med Countries on future Mediterranean policies;
- Forecasting Model to evaluate the morphologic response of the coastal plains to the rise in sea level;
- Promoting Barcelona Convention and ICZM Protocol;
- Establishing a clear, well-defined and differentiating ICZM policy between coastal regions;
- Monitoring Program of Mediterranean Coast;
- Creating data and atlases shared among the Mediterranean regions, especially between neighbor regions;
- Financing of methods used to protect the coastal zone by ERDF funds, if compliant with the orientations of the white paper on adaptation to climate change;
- Implementing the EU Flood risk directive 2007/60/EC and its flood risk management plans (speaking from a regional point of view the directive appears as a good instrument but the real implementation structures from the National Government has to be done);
- Dedicating a budget line to inform, to teach operative staff (es. Municipalities directly involved in civil protection on flood risk);
- Improving prevention on urbanized coastal areas;
- Obtaining a method to reduce the risk on coastal zone.

The Atlas of Coastal Dynamics

July, 2012

3. The Atlas of Coastal Dynamics: General criteria followed for drafting the Atlas

The Atlas of Coastal Dynamics is a product of the MAREMED project, i.e. a coastal planning support tool which provides an analytical description of erosion phenomena along the coast and defence interventions. This information is represented according to the most advanced European standards, such as the standard adopted by the Rijkswaterstaat (The Dutch Governmental Water Management Authority) which has been steadily dealing with coastal monitoring for 50 years.

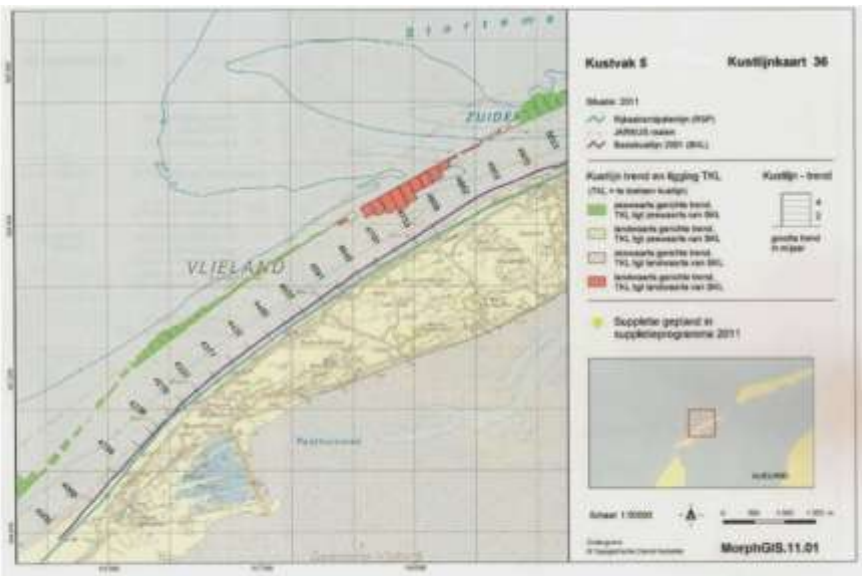
The Atlas is an organic text including qualitative assessments (high, medium and low erosion) and quantitative assessments, based on observations made at appropriate time interval and anyhow confirmed by consolidated and documented historical trends.

It presents the areal differences between beach surfaces, cumulated in discrete stretches, and represented on a cartography appropriate for coastal planning (e.g. 1:50.000), supported by proportional histograms.

The quantitative assessment of the erosion phenomenon enables the Region to have an effective planning capacity and, in particular, also to launch the procedures required by the EU Directive 60/2007 “Flood Risk” which covers not only rivers but also coastal stretches.

For the selection of a univocal and transferable methodology for the representation of coastal dynamics, the analysis of different examples in the European context was necessary.

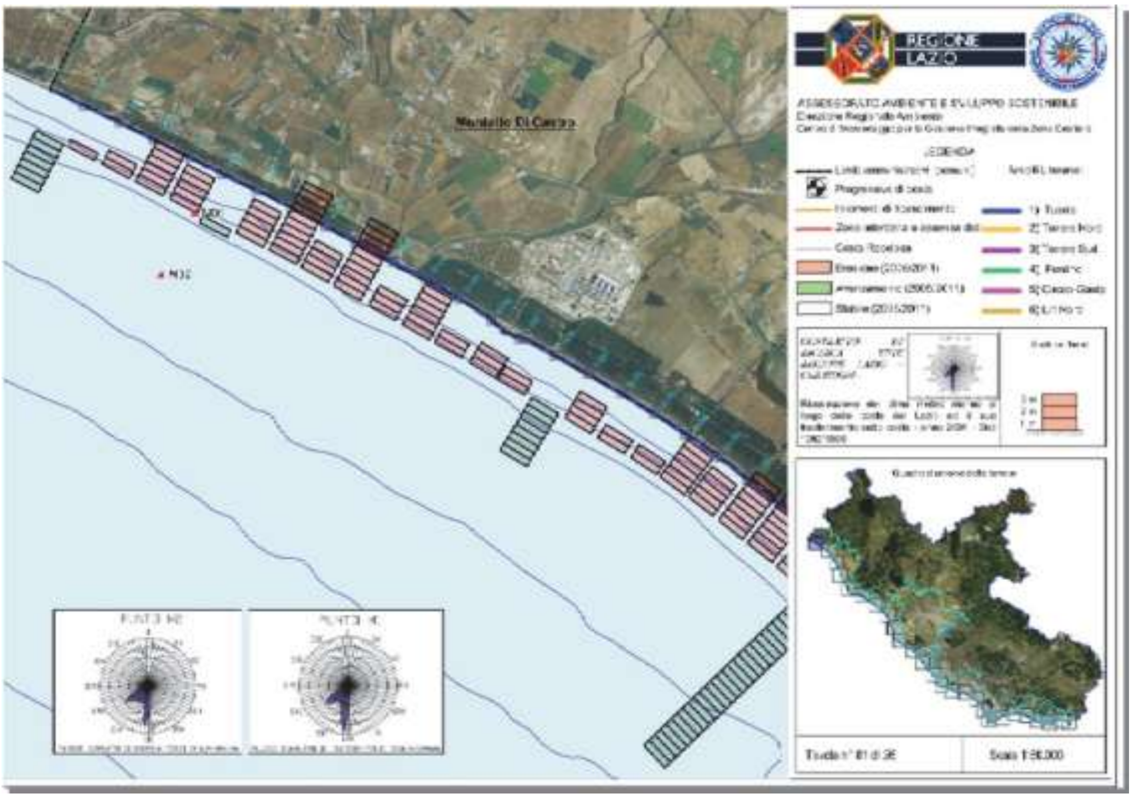
Lazio Region, coordinator in MAREMED of the thematic “Coastal Adaptation to Climate Change”, carried out some tests of the methodology on its regional coastal zone, with a series of graphical representations which are mostly focused on the qualitative assessment of dynamics. The “Coastline Map” (Kustlijnkaart-2011)” of the Dutch government, developed by the national Rijkswaterstaat, was selected as the reference example. This decision is justified by a series of reasons, including the undisputed expertise of this institution which has been dealing with coastal defence for 60 years. The specific technical reasons of this decision are the following:



- The adoption of a representation at 1:50.000 scale. Since the Dutch coasts (open water side) stretch for about 400 km, the analogy with the Lazio region coasts (314.5 Km) from the point of view of extension, made it possible to adopt the same scale and to measure the elements represented in a similar way.
- Representation of each single survey carried out at intervals of 500 m (the basic surveys are

carried out every 50m). The Dutch Map shows coastal dynamics at an interval of 250m. In this first version of the Atlas, we decided to double the interval for a graphical representation reason: the coast along the Lazio region is much more irregular and this causes problems for representation at shorter intervals. Moreover , the surveys of the Rijkswaterstaat are carried out with sections every 250m, whereas the surveys along the Lazio region coast were carried out by photographical survey (2005) and by planimetric linear GPS survey (2011); thus the density of the survey is higher, although accurate. Even if the average of the 500m stretch takes into account the actual situation of the stretch – tested at intervals of 50m -, we decided to average out the data on longer stretches, in order to compensate any peaks.

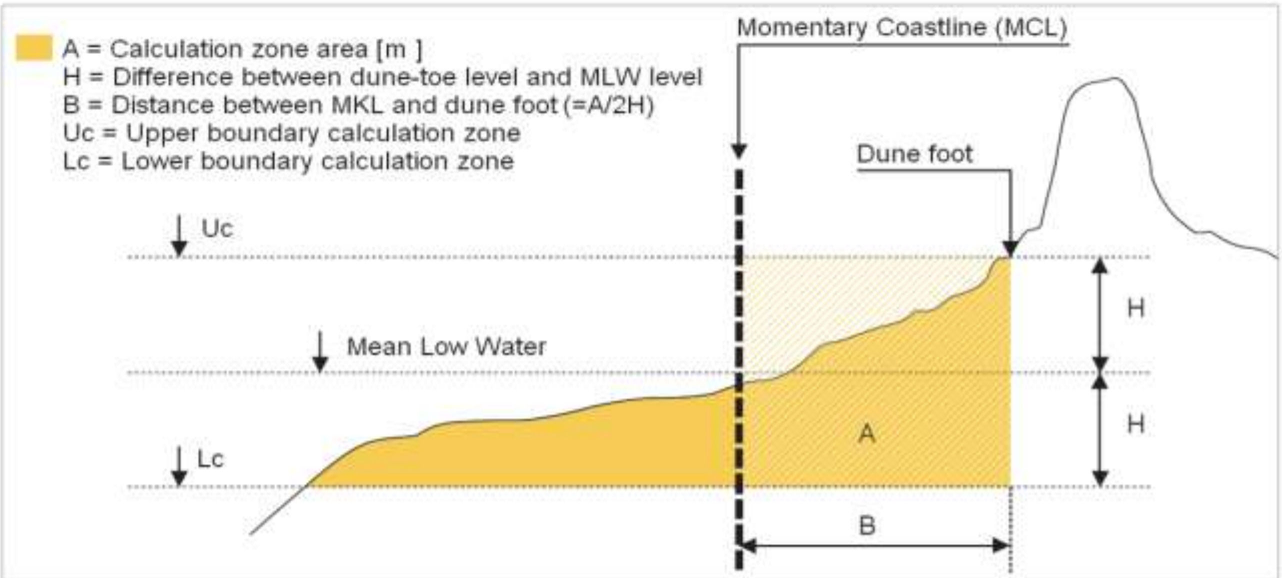
• Representation of local dynamics with histograms proportional to the dynamics encountered. The Kustlijnkaart adopts a continuous metrical scale of the forward or backward evolution, proportional to the values surveyed (averaged out at intervals of 250 m). In the Atlas, we decided to discretise the scale with modules of 1m (averaged out at intervals of 500) to make histograms easier to read, and also to highlight the fact the shorter discretisations would not have any numerical validity. However, as already said in the introduction, we decided to choose a quantitative representation and we definitively discarded the qualitative representation since it is not sufficient to be used effectively. In this first version of the Atlas, we illustrated the actual average shifting (in metres) of the shoreline surveyed over 6 years – between 2005 and 2011. In the next version of the Atlas, we expect to represent this trend in terms of m/year in order to make the representation more homogenous and to facilitate the comparison between different observation periods.



An important difference between the Kustlijnkaart and the Atlas is the coastal morphology surveying system: the Kustlijnkaart is the result of 3D morphological (topographical and bathymetrical) surveys. They were represented as sections at intervals of 250m, thus making it possible to determine a fictitious line

(Momentary CoastLine). This is intended as the seaside distance (B) from a significant morphological element (bottom of the dune) including the sand volume between the height of the bottom of the dune (H) and the bathymetric line–H. By convention, H= 3m over sea level. This system for the determination of the coastline is very significant because it is independent from the periodical or accidental planimetric oscillations of the shoreline (winter profile - summer profile, tides, barometric lines, etc.) and the shoreline is directed referred to the volume of the emerged and submerged beach comprised between the range +H/-H. We could not apply the approach in that the two coastlines plotted for the Atlas derive from planimetric surveys and, in particular, from the QUICKBIRD satellite image (see Annex 1) and planimetric surveys carried out on the spot using a GPS. The difference between the two coastlines for the evaluation of the variation, was calculated with a procedure developed by the Regional Monitoring Centre, which considers the diachronic lines.

Another element which could not be derived from the Kusterlijnkaart is the evaluation of the ratio between the coastline (MCL) and the baseline. The latter is defined as an ideal line on the coastal stretch beyond which critical problems can occur (danger for the infrastructures, the beach is not sufficient for the expected utilisations, etc.). Thus, the objective is to not let the coastline set back beyond the baseline landward.



This comparison is shown in the Kusterlijnkaart using red histograms (full red = setting back behind the baseline, striped ride = the coastline is moving forward but the momentary coastline MCL is still behind the baseline) and represents a new and important evaluation element very similar to what is defined as "risk". Indeed, the graphical representation of the "danger" (dimension of the erosion histograms) does not necessarily correspond to a risk for the exposed assets as the momentary coastline (MCL) could still be distant from the baseline or the assets of interest, which are still safe.

All the red histograms show the existence of a "risk" (even in case of a moving forward) since the baseline is on the seaside compared to the MCL line and therefore the assets are exposed. This graphical representation helps to highlight the priority intervention areas at a glance.

Particularly important for the intervention policies, the baseline of the coasts along the Lazio region has not been traced yet, since it requires a complex concerted action due to the objective complexity of the Lazio region compared to the Dutch coast.

COFLERMap

Coastal Flood/Erosion Risk Map model

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July, 2012

4. COFLERMap: Coastal Flood/Erosion Risk Map model

4.1 Understanding risks and hazards

On 18th January 2006, the European Commission proposed a guideline "regarding flood evaluation and management" which was approved in September 2007 and came into effect in November 2007. This directive aims to improve flood risk management across Europe. It helps Member States by equipping them with a scheduled procedure to assess the risk of flooding and implement coherent plans to reduce the impact of floods on human health, the environment and economic activity (Flood Risk Management Plan). It concerns floods "*temporary covering by water of land not normally covered by water*" and encompasses specifically "*floods from the sea in coastal areas*". The risk management methodology suggested by the directive can be divided into 3 stages :

1. The preliminary evaluation of flood risks, which namely includes a description of the hazards occurred in the past or estimated potential hazards and issues for human health, the environment and economic activity in the concerned basin.

2. The **cartography** of flood zones and the susceptible **damages** caused by the floods. These maps have to take into account 3 scenarios:
   - floods with a low probability, or extreme event scenarios;
   - floods with a medium probability (likely return period *:?* 100 years);
   - floods with a high probability, where appropriate.

   The **cartography** will show:
   - the flood extent;
   - water depths or water level, as appropriate;
   - where appropriate, the flow velocity or the relevant water flow.

   The **damages** will be shown according to 3 indicators:
   - the number of inhabitants potentially affected,
   - the potential economic damages in the area, and
   - the potential damages caused to the environment.

3. The carrying out of flood risk management plans, on the level of the hydrographic district. These plans must introduce a global strategy for risk reduction, based on prevention, protection and "organization in critical situations".

The Flood Directive – which has already been implemented in every partner country - provides official elements that must be followed and helps the correct and univocal interpretation of terms and definitions.

Since most current coastal hazard and risk atlases analyzed during the diagnostic phase of MAREMED (see chapters above), are not fully compliant with the Flood Directive, the following work focuses on a suitable model for the coastal hazard/risk mapping representation according to the Flood Directive.

4.2 Introduction to the model

The concept of the model was developed during the MED MAREMED Project (2010-ongoing) by the Lazio Region and it has been shared for dissemination and discussion during the MED COASTANCE project technical meetings.

Thanks to the experiences developed during COASTANCE and MAREMED projects, MED Programme, 15 Mediterranean coastal administrations had the opportunity to discuss this Risk Model conceptual framework.

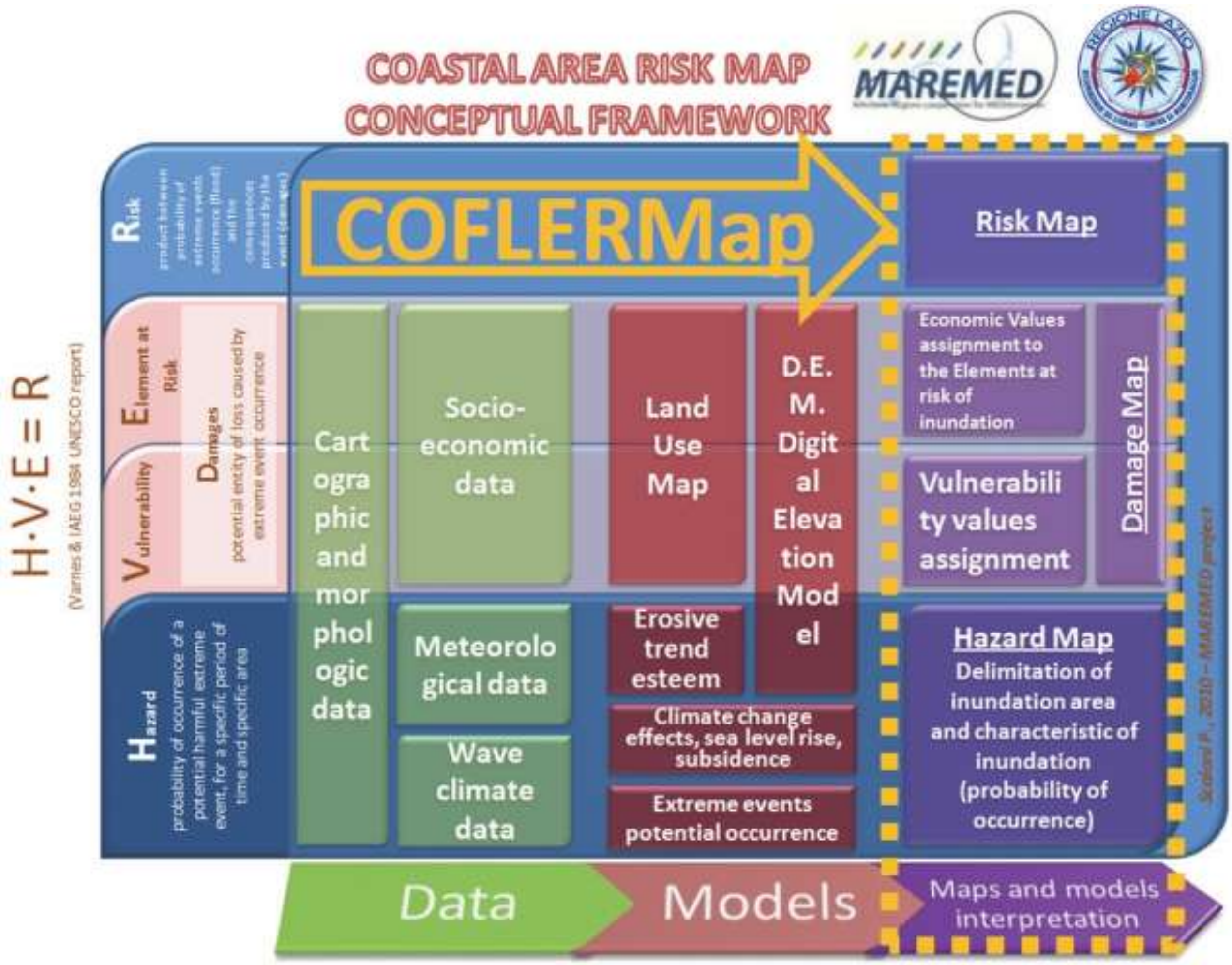


Figure 3.1 - COFLERMap conceptual framework

The model does not concern data collection, hydrological modelling and hazard assessment. Subsequently, only general considerations on these aspects will be developed, so as just to understand the state of the art and what is necessary to feed COFLERMap.

The model concerns risk mapping i.e. the methodologies to cross basic territorial data (hazard, exposed values, morphology) among them, in order to achieve a geographic and quantitative distribution of risk, compliant with Flood Directive requests.

The reliability of this model was also tested through some valuable direct comparisons carried out during the MAREMED activities and specifically through:

1. the VNK Project (or in English "Flood Risks and Safety in the Netherlands - Floris") elaborated by the Rijkswaterstaat[1] (National Agency of the Dutch Ministry of Infrastructure and the Environment): the VNK project is one of the most advanced plans for flood effects forecasting and management. In the Annexe of this Book a synthesis of the VNK project, written by the ARCADIS company, is provided. Two valuable visits near Rijkswaterstaat in Utrecht and ARCADIS in Amsterdam were made in order to learn about VNK project and ARCADIS members attended MAREMED conferences to explain their work (as consultant of the Rijkswaterstaat for VNK).
2. the Flood Risk Management Strategy in the US by the Army Corps of Engineers[2]. Through a MoU between Lazio Region and USACE signed during COASTANCE project, an intensive exchange was launched on the matter of ICZM, and USACE members attended COASTANCE and MAREMED conferences to explain their work.

Besides, significant feedbacks were also collected through exchanges with other European projects like THESEUS[3] and MICORE[4] (7FP).

Finally a useful comparison was made with the "*Handbook on good practices for flood mapping in Europe*"[5] issued by the European exchange circle on flood mapping (EXIMAP).

[1] http://english.verkeerenwaterstaat.nl/English/
[2] https://swwrp.usace.army.mil/
[3] http://www.theseusproject.eu/
[4] https://www.micore.eu/
[5] http://www.ypeka.gr/LinkClick.aspx?fileticket=Ccsy%2F6hAbEk%3D&tabid=252&language=el-GR

4.3 Objectives

The main objective of this model is to provide a geo-quantitative Risk Map model to Administrations in charge of coastal defence and management.

Two specific objectives are considered:

a) to meet the Flood risk directive (2007/60/EC) requirements:

b) to meet the Mediterranean coastal Administrations needs:

4.4 Model Definitions

Risk

The conceptual framework was developed on the basis of the Varnes UNESCO formula, where Risk is defined by the product of Hazard and Damage.

$$R = H\cdot(V\cdot E) = H\cdot D$$

(Varnes & IAEG 1984 UNESCO report)

Flood Risk means the combination of the probability of a flood event and the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event (EU flood directive 2007/60/EC art.2).

Hazard

Hazard is the annual exceedance probability of occurrence of a potential harmful event (the inverse is called return period)

The Hazard is then a dimensional value (1/T where T= return period), always less than one, considering the real cases taken into consideration. Its value depends on the statistical/probabilistic analysis of local climate condition and is referred to different return periods ***Tr*** as requested by the Directive 2007/60 (frequent and rare events).

A flood event with a return period equal to 100 years means that the yearly probability of occurrence or exceeding of this event (characterised for example by a water level) is equal to 1/100=0.01.

Its value is associated to a specific flood event that can be analysed throughout a dynamic or static model. If you know the the basic parameters (meteorological and/or wave historical data) and the use of different models, it is possible to calculate the ***seaward*** characteristic of the expected storm for a specific return period ***Tr***.

The storm can be characterised as a dynamic phenomenon where e.g. the maximum sea level (surge+wave+sea level rise+ tide+ etc.) is a time/space function $HSL_{maxr}(t,x,y)$. Usually only the static maximum value $HSL_{maxr}(x,y)$ along the coastline is taken into consideration.

Also the ***landward effects*** of the flood manifest themselves as a dynamic phenomenon where the propagation in terms of speed and water level elevation, is a function of position and time. The propagation dynamic depends not only from the storm dynamic but as well from the “friction capacity” of the flooded lands (vegetation, buildings, obstacles, etc.), the land surface elevation and coastal defences (dikes, barriers, etc.).

The first step for the determination of the landward effect of the storm is the RUN UP, often calculated by empirical formulas (Hunt, CERC, Mase, Nielsen and Hanlow, Ahrens and Seelig, etc.) and on the basis of the significant waves (height, period, direction) and the beach characteristics (slope, grain size, etc.).

If the run up is so high to overtop the impacted beach morphology (natural banks, dunes, dikes, etc.) causing its collapse or degradation, the propagation assumes the characteristics of a flood involving back lands, often overlapping to the effects of the concomitant flood occurring in the landward hydrographical network.

The simulation of this kind of propagation requires at least bidimensional models, a comprehensive knowledge of land morphology and past events, so that they can be calibrated, too. The application of this method to a very wide territory is nearly always too onerous. Often the full dynamic approach is adopted on specific case studies (e.g. very high value zones exposed to very high flood hazards) and then the data obtained can be successfully implemented in a static way (with the due interpretations) to the other zones.

In COFLERMap a static approach will be considered for the coastal hazard assessment.

Damage

Damage is the potential entity of loss caused by the event occurrence (adverse consequences).

Damage ***D*** is a function of external factors like the intensity (or "*magnitude*" in EXIMAP) of the Hazard (speed, submersion depth) and intrinsic factors like the vulnerability (or "*susceptibility*" in EXIMAP) of the exposed asset itself. The total value of the exposed asset is assumed to be equal to ***E***.

Then ***V*** can be defined as the ***Vulnerability*** of the exposed assets (likelihood that a good is damaged by events of a certain intensity) and its expression is function of the intrinsic sensitiveness of the goods (ID) and of the hazard intensity (e.g. submersion) by the *Damage Factor DF*(s) of the flood (***V = ID x DF***)

- USACE calls this parameter "System Performance".
- In the VNK project, ***V*** is called "Variable damage factor" and depends on the typology of the concerned asset and the submersion level.
- In EXIMAP all the parameters figuring in D are called "vulnerability factors" including the value of the asset itself (E), then D is not an adimensional parameter, and another parameter linked to the exposure of the asset (probability of the element at risk to be present while the event occurs; nevertheless this factor can easily be encompassed in the "intrinsic sensitiveness" of the assets).

Notwithstanding the different symbols and details adopted, it is worth noticing that all the references consulted are adopting a similar approach in which the Risk assumes the meaning of a yearly value of the expected damage.

However, specific important considerations must be developed to deal with the numerous aspects associated to the generic term "Damages". They mainly these three typologies:

1. number of inhabitants potentially affected (Casualties, evacuation, etc.)
2. the potential economic damages in the area (Economic damages)
3. the potential damages caused to the Landscape, Nature and Cultural areas (LNC damages).

The experience already acquired in the elaboration of this model, during the COASTANCE technical debates and through contacts with other European projects like THESEUS, suggests to evaluate separately the risk for each type of specific damages.

In fact the risk concerning social aspects and especially casualties, is hard to compare with the risk affecting assets, and they are often to be used for different purposes.

E.g. a zone like a kindergarten or a hospice prone to high speed flood, must be considered at high risk for human health but it could not represent a relevant economic risk in itself.

The "social" risk is a fundamental parameter to establish priorities and early warning system prearrangements.

The "economic" risk is a fundamental parameter to establish whether it is convenient or not to intervene in specific zones exposed to flood and in general for the adaptation policies.

Besides, the risk of LNC damages does not allow an easy economic approach, although several systems have been proposed. In relative terms these systems can be considered an efficient tool to compare environmental assets between themselves. What has not yet been satisfactorily reached is comparable environmental and economic damages. That is why it is still advisable to deal with them separately.

Concerning the economic assessment, different calculation approaches exist. In particular there are two main trends: commercial and reconstruction value. The first one includes the reconstruction value but also encompasses other aspects (like centrality, ancient buildings, quality of stored goods, etc.) some of which are not easy to evaluate.

These aspects can be evaluated in a more detailed analysis but for the purposes of this work, only economic losses due to the reconstruction works of assets damaged by floods will be taken into account. By the way, VNK project assumes this simplified approach.

Anyway the risk assessment based only on reconstruction costs can indirectly help the comparison with the LNC damages, once the latter are classified in a relative way.

In fact, LNC assets can be compared with economic goods on the basis of the "political" interest, balancing the development and safeguard willing according to the sensitiveness of the administrations in charge of the planning decisions.

If you assign the same monetary value of a certain economic asset to a determined LNC asset on the basis of political evaluations, all the LNC assets can be quantified in monetary and absolute terms, thanks their relative assessment.

In COFLERMap only economic costs for assets reconstruction will be taken into account.

4.5 The Conceptual Framework

The expression of the risk utilised by this model is then characterised by the following unit measures:

Flood risk (€/year) = HAZARD (event/year) x DAMAGE (€/event)

This risk model is elaborated for flood risk evaluation on coastal areas when there is an in-depth knowledge of the following data:

- coastal territory (morphological data, erosion trends, subsidence, existing defence work, etc.);
- economic aspects (land uses and their values);
- meteorological and wave climate data (historical characterisation, datasets, forecasting, etc.);

An in-depth description of the quantity and quality of data necessary for the development of the model is provided in BEACHMED-e ObseMedi TOOL "*COASTAL SERVICES - Operative and consultative services for the Coastal Monitoring*"[6]

The Risk Map does not represent *tout court* the Priority Map but only the expected economic damages in terms of €/year/area. These economic consequences will surely influence the priorities but the risk for human health must be considered first following a separate route, as already stressed before.

Thanks to the quantitative and monetized nature of the method, the following step of the model is the Net Benefit analysis of the adaptation measures adopted to reduce the level of risk.

In fact the fully quantified assessment of flood risk allows to make a relatively easy comparison between expected damages and adaptation work costs + residual damages, if any.

When comparing the Net benefit of the different adaptation typologies, decision-makers are allowed to choose the most suitable adaptation work, from the economic point of view.

The cost/benefit analysis will be illustrated in the 2^{nd} book of MAREMED project.

Figure 3.2 - Risk prevention management tools in coastal area

[6] http://www.beachmed.it/Portals/0/Doc/documents/Tools/COASTAL_SERVICES.pdf

4.6 The dataset required

It is very important for each local administration, to collect all the data consistently with European rules and formats, in order to reach a high level of digital data harmonisation between Mediterranean partners.

The Geographic Information System necessary to apply COFLERMap on a specific Assessment Coastal Zone, must include the following main layers:

1. Exposed Assets present on the assessment Coastal Zone and their values E (x,y)
2. Ground Elevation of the Assessment Coastal Zone HG (x,y)
3. Flooding water level HLFmaxr(x,y) and associated yearly probability Pr(x,y).

In addition to the above geographic datasets, COFLERMap also requires two numerical datasets:

4. Intrinsic Damage Factor (ID)
5. Damage Factor (DF)

4.7 Exposed Assets on the Assessment Coastal Zone "E".

The simplest solution to set up this dataset is to adapt the 3rd level Corine Land Cover, easily available from EEA web-site, which encompasses land use nomenclature as well.

Despite its large availability, this layer comes from an elaboration at 1:100.000 scale and its use is strongly recommended to adopt a more detailed map. In fact the 4th level CLC is already available for many Regions.

Concerning the attribution of economic values to the different land uses, they are considered as the Total Reconstruction Cost. Although often hardly comparable, several datasets are available too. The values already adopted by the Lazio Region for regional basins planning, are gathered in the proceedings of "Conferenza ABR Lazio"[7] and were inferred from different sources.

The VNK offers a list of figures (Maximum Damages) updated as of 2004, inferred from the manual of the software HIS-SSM - estimation of economic damage and casualties due to flooding (Deltares). In this case it is considered the Maximum Damage expected for the concerned asset (E x ID, see par 3.10) and not the Total Reconstruction Cost of the asset (E)

Incidentally, this software seems to be made available soon at www.deltares.nl.

The Exposed Assets can be worthily represented in terms of €/m^2 and associated to a grid with the same detail of the other layers.

4.8 Ground Elevation of the Assessment Coastal Zone "HG".

A Digital Elevation Model D.E.M. would be the best solution with a coherent approximation in relation to the scale of the assessment area.

[7] Conferenza ABR Lazio, Castel Gandolfo 1999 - Studies and Publications www.cmgizc.info

E.g. for an application at 1:5.000/1:10.000 scale, at least a DEM 100x100 m is required**.**

4.9 Flooding water level "HLF" and associated yearly probability "P_r".

The Flood Directive requires three specific level of events: high, medium and low probability. No matter how the flooded areas will be drafted (2d models, single profiles, etc.), the determination of the return period is necessary in order to obtain the annual probability of the event and make the outcomes compliant with the Flood Directive.

Then, the assessment coastal zone must take into consideration three different events (frequent, medium , rare) with three associated exceedance probabilities.

Consequently in the assessment area three different water levels that can be reached or exceeded must be taken into account.

Supposing that HLF1 is the water level reached or exceeded with annual probability P1 equal to 0.033 (Tr = 30 years), each point of the assessment area underneath HLF1 will surely be affected by all the events exceeding this water level, i.e. by all the events with lower yearly probability.

The yearly specific probability p of an event with intensity included between the water level HLF1 and the higher value HLF2 (e.g. Tr = 50 years, exceedance probability P2=0.020), is equal to the exceedance probability P1 minus P2, i.e. p = 0.033-0.020 = 0.013.

It is evident that the lesser the difference between HLF1 and HLF2, the lesser the annual specific probability of occurrence of the event with intensity included between HLF1 and HLF2.

E.g. if we want to know the yearly specific probability of the event included between events with return period T30 (exceedance probability P1= 1/30 = 0.033) and T31 (P = 1/31 = 0.032), it corresponds to the difference between exceedance probabilities P1-P2 = 0.033-0.032 = 0.001 while its yearly exceedance probability P is equal to their average (P1+P2)/2 = 0.0325.

The difference between these two terms (yearly exceedance probability and yearly specific probability) is crucial and its implications will be tackled hereinafter.

In order to facilitate the comparison and overlapping of the different layers, the flooding mapping can be done by a grid with the same detail of the other layers.

Every element of the grid will be then characterised by a flood level (m) and its exceedance probability measured in terms of number of events a year (1/year) i.e. the inverse of the return period Tr.

The use of a grid considerably simplifies the management of the model. In fact the use of the vector data does not significantly improve the overall precision of the output and entails many operating difficulties.

4.10 Intrinsic Damage Factor “ID”

The ID is the percentage of the exposed asset value (as Total Reconstruction Cost) effectively amenable to damages by the worst conditions expected in the planning area.

E.g. if the basement and the ground floor of a multi-storey building are the only vulnerable parts to the expected maximum submersion and they represent 13% of the TRC of the whole exposed asset, then ID = 13%.

This parameter must be considered at least for each typology of Exposed Asset.

The ID value depends on the intrinsic sensitiveness of the good in relation to the maximum effect that the event can produce on it.

It does not depend on the variability of the damaging event but only on its maximum effect on it.

The intrinsic sensitiveness of the exposed asset depends on its capacity to harmlessly face events, including aspects like the presence of perishable goods, the presence of the goods in the flooded area in terms of time, etc.

It is quite difficult to find bibliographic data for the ID parameter and often its determination is omitted by directly estimating the Maximum Damage.

In fact considering that the exposed assets are represented by land use maps inferred from 1:10.000 analysis, with minimum areal elements of about 200-300 m^2, it is difficult to distinguish single characteristics like ID.

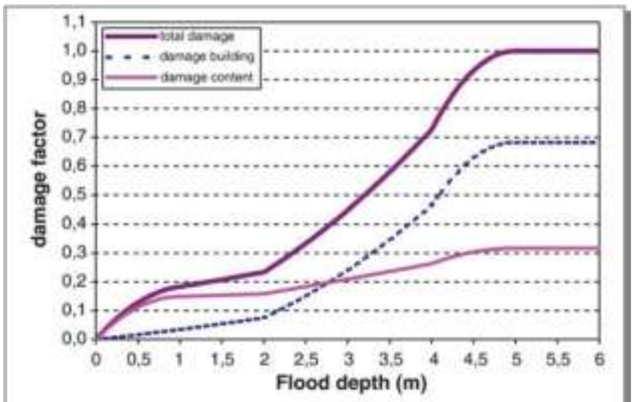
However the explicit expression of this parameter helps the comprehension of each part of the analysis, allows the distinction among the several involved factors and improves the flexibility of the model in relation to the different situations.

4.11 Damage Factor "DF"

The Damage Functions are numerical relations typical of each Exposed Asset, linking the submersion to the consequent percentage of MD reached.

They represent the basic tool for the transformation of the event intensity into the level of damage (when the only parameter considered as intensity is the submersion)

The simplest hypothesis is a linear behaviour i.e. the damage increases proportionally with the submersion. In this case the Damage Factor (DF) is completely defined as follow:



Relation between flood depth and damage factor for houses, distinguishing between damage to building and house content. (*Integrated hydrodynamic and economic modeling of flood damage in the Netherlands S.N. Jonkmana, M. Bočkarjovab,*

Figure 3.3 - Damage Factor curves

$$DF(sr_{x,y}) = \frac{Sr_{x,y}}{Smax}$$

Where

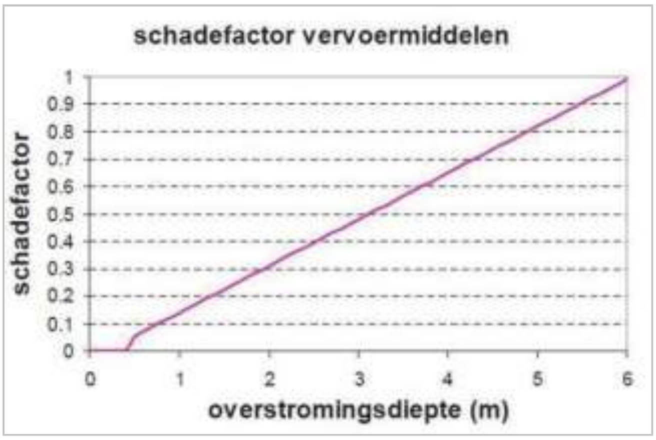
DF= damage factor (adimensional number between 0 and 1)

$Sr_{x,y}$ = submersion (Flood depth) in the point *x,y* for a specific event with return period *t*

Smax = maximum submersion absolute (theoretical assessment of the worst case that can realistically affect the exposed assets)

The compound relation in the above figure shows an estimation of the non-linear damage function of the building and house content.

Different cases can be derived from the bibliography but in general three typologies can be considered as the most representative damages functions:



1. Linear with a threshold: this is the typology of DF chosen by VNK for vehicles (see the figure 3.4). A threshold of about 0.50 m was fixed for the submersion causing the first significant damage

2. Non Linear (convex) with threshold: this is the typology chosen by VNK for high residential buildings (figure 3.5). The damage factor, after an influent submersion of about 0.50 m (threshold), rapidly increases and then tends to the horizontal asymptote of the maximum submersion.

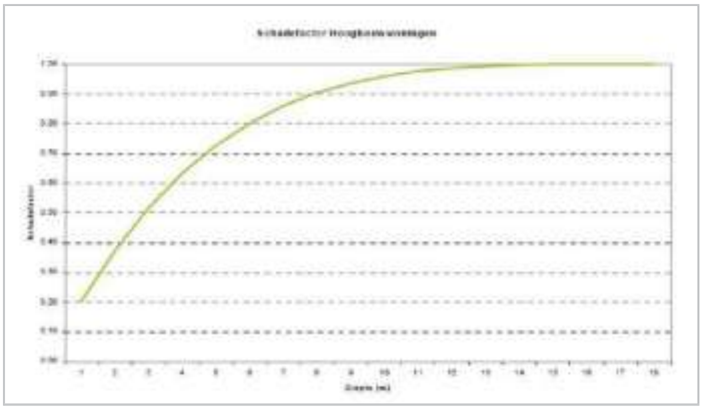


Figure 3.4 (right) - Damage factor linear curve for vehicles

Figure 3.5 (left) - Damage factor convex curve for high residential building

(Source: Ministerie van Verkeer en Waterstaat - Dienst Weg en Waterbouwkunde. HISSchade en Slachtoffer module (2004). See also Annex I to this report.

3. Non linear with inflection point: this typology represents the goods initially indifferent to the submersion, with a rising sensitiveness up to an inflection point after which the DF tends to the horizontal asymptote of the maximum submersionn (figure 3.6).

Using the formula suggested in the proceedings of the “Conferenza ABR Lazio”[8], all these functions can be represented by a parametric relation as follows:

$$DF(Sr_{x,y}) = \frac{Sr_{x,y}^{a}}{(k_2 + (k_1 * Sr_{x,y} + k_0)^a)} - DF_0$$

[8] Conferenza ABR Lazio, Castel Gandolfo 1999 - Studies and Publications www.cmgizc.info

By varying the parameters k_0, k_1, k_2 and a it is possible to simulate the different curbs, imposing as well fixed values of DF at different values of submersion on the basis of experience or other sources. E.g. the curbs in the figure are obtained for a maximum submersion of 3.00 m and the following parameters:

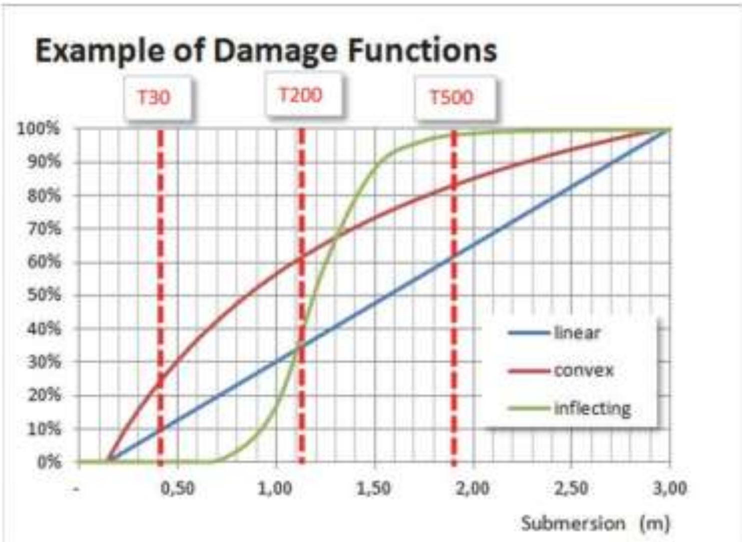


Figure 3.6 - Damage factor curves comparison

	linear	convex	inflected
Smax	3	3	3
do	0,05	0,15	0
ko	2,85	0,75	0,001
k1	0	0,6	1
k2	0	0,05	5
a	1	1	9

The linear curb has a threshold for the first impacting submersion fixed at 0.30 m.

The convex curb has the same threshold at 0.30 m and 50% of the damage is reached for submersion equal to 0.85 m.

The inflected curb has a threshold of 0.7 m and 50% of the damage is reached at 1.20 m.

It is worthily noticing that the risk assessment varies considerably in relation to these different behaviours of the DF for different asset typologies.

E.g. the asset “convex” is significantly jeopardized (about 30%) with an event T_{30} (return period 30 years) while the asset “inflected” is practically unaffected by the same event but it suffers nearly the same damage for T_{200} event.

4.12 Probability, Hazard and Risk

The return periods or exceedance probabilities of effective interest

As mentioned before, in each single part "*i*" of the assessment area at the elevation HG_i, the total risk is a function of the exceedance probability concerning all the events with local water level $HFL_i >= HG_i$.

If the first event which is able to rise this elevation at the point "*i*", has a return period equal for example to *Tr= 45 years*, the point "*i*" will be affected by all the events with higher return period and the yearly exceedance probability of all these events is equal to P_{45} = 1/45 = 0.022.

If the point has elevation HG_i = 0,00 m, the return period can theoretically vary from Tr_{min}= *1 year* (being 1 year the adopted unit) to Tr_{max}=*oo*.

In practice the risk can assume values higher than 0 only where flood is not usually expected. It is useful to make some considerations about the "*maximum event without appreciable damages*" because it can represent a significant parameter for coastal planning: in fact the real planning need starts just from this particular elevation.

The coastline named in ICZM Protocol "**Highest Winter Waterline**[9]" from which a "*zone where construction is not allowed*" should be established (set-back zone), could be worthily assumed as the "no damage line", i.e. the line reached by the very frequent floods (e.g. with return period 5 years -Tr_5).

This definition is rather equivalent to the "**Vegetation Line**[10]" which represents a determinable physical limit. Landward this coastline, the set-back zone[11] should be extended in relation to the flooding areas (at higher return period) and their real/potential damaging capacity.

Under these practical hypothesis, the most convenient assumption for Tr_{min} is then the minimum return period able to engender significant modification to the natural asset of the beach, e.g. to affect the existing vegetation cover, the dune foot, etc..

Postponing further considerations about Tr_{min}, this limit can be assumed as equal to 5 years on first approximation. That means that the yearly exceedance probability of this kind of event is P_5= 0,20 and that

9 PROTOCOL on Integrated Coastal Zone Management in the Mediterranean - Official Journal of the European Union L 34/19 - 4.2.2009

10 "Vegetation Line means the first line of stable natural vegetation, which shall be used as the reference point for measuring oceanfront setbacks. This line represents the boundary between the normal dry-sand beach, which is subject to constant flux due to waves, tides, storms and wind, and the more stable upland areas. It is generally located at or immediately oceanward of the seaward toe of the frontal dune or erosion escarpment. In areas where there is no stable natural vegetation present, this line shall be established by connecting or extending the lines from the nearest adjacent vegetation on either side of the site and by extrapolating (by either on-ground observation or by aerial photographic interpretation) to establish the line." North Carolina Department of environment and natural Resources - "Amendments to Vegetation Line Determination Prior to Beach Nourishment" – October 2001

11 CONSCIENCE EU project "On the use of setback lines for coastal protection in Europe and the Mediterranean: practice, problems and perspectives" - Deliverable D 12 - March 2010

the risk analysis starts from this value (being the events with higher exceedance probability without damaging effects i.e. the flood level HFL_5 cannot reach/disturb any assets) .

Concerning Tr_{max}, the Flood Directive requires to consider "*floods with a low probability, or extreme event scenarios*", having defined previously "*floods with a medium probability*" events with "*likely return period :? 100 years*".

Being the risk a function of the probability and the value of the damageable prone assets, it is suitable to consider the events with very low probability only when these ones are able to flood areas surrounding very high-value assets (in relation to their extension and/ or their specific value). In fact only in these cases the product of a very low probability for a very high value of the damaged assets can turn the risk into a significant value.

In VNK project, considering the extension and the value of the Dutch low lands prone to flood hazard, very low probability events are considered (Tr_{max}= 2,500 – 10,000 years; $P_{10.000}$=0.0001).

The Italian implementation of the Flood Directive requires flood hazard maps covering the geographical areas "*which could be flooded according to the following scenarios*":

Tr_{high} = 30 years; exceedance probability P_{high} = 0.033

Tr_{med} = 200 years; exceedance probability P_{med} = 0.005

Tr_{low} = 500 years; exceedance probability P_{low} = 0.002

Let us have a look at the map springing from this set of scenarios.

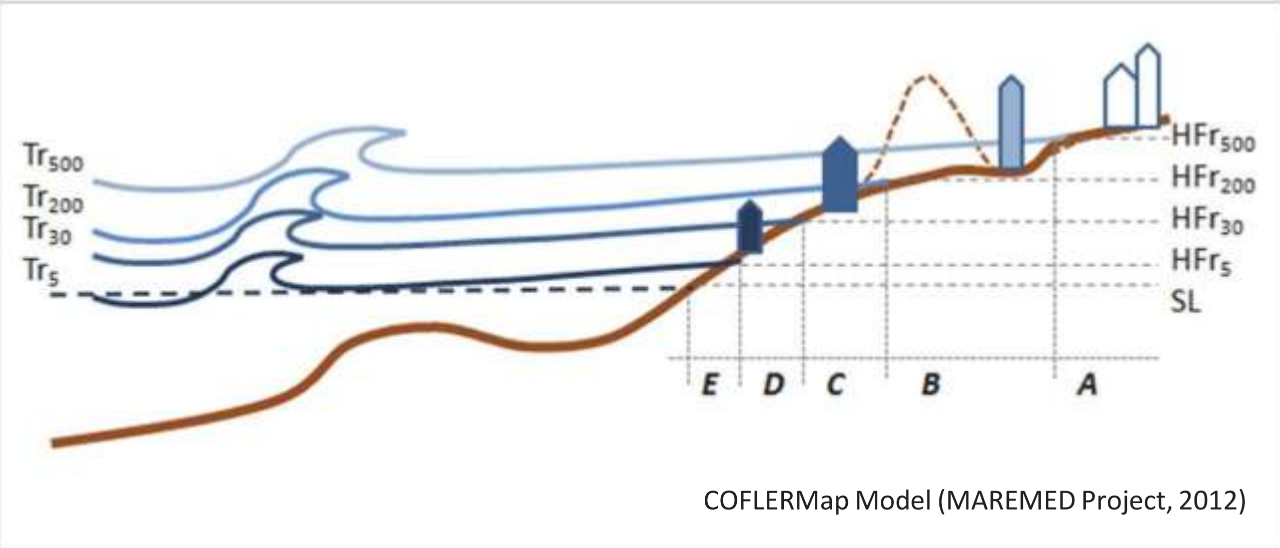


Figure 3.7 - COFLERMap Model - Scheme of the adopted scenarios

Five zones can be distinguished.

ZONE A: since the implementations suggests to assume a return period equal to Tr_{500} = 500 years as the lowest probability event, all the zones at higher elevation than HFr_{500} are safe from flood hazard. This is not physically true because there is always a residual yearly exceedance probability of 0.2% associated to the occurrence of this event. This yearly exceedance probability could not be so little if compared with the expected life of the exposed assets. The probability that at least one of these limit events can occur during the expected life of the exposed structure (e.g. 50 years), is as follows:

$$p_{\frac{50}{500}} = 1 - (1 - \frac{1}{Tr_{500}})^{50} = 9{,}5\%$$

So, if you strictly follow the Italian implementation of the flood directive, you neglect 10% of occurrence probabilities of events having an intensity higher than Tr_{500}, that can affect the assets present in the zones A every 50 years.

Nevertheless also in this case, these zones will be flooded by very low submersions (being at HG>$HFLr_{500}$). Finally the decision of taking a limit event must be taken as the planning activity requires it for the risk assessment. According to Italian regulation, Tr= 500 years.

ZONE B: this zone is subject to flood with return periods from Tr_{200} to Tr_{500}, with correspondent flood levels $HFLr_{200}$ and $HFLr_{500}$. In the figure a dashed profile shows the case of a dune. In this case the possibility of a breach in the dune should be analyzed by a separate assessment; if it occurs, the flood in this zone will take place. Being the event Tr_{500} the maximum considered event, the yearly probability of being flooded (partially or completely) is given by the difference from the two exceedance yearly probabilities:

$$p_{200-500} = P_{200} - P_{500} = 0.005 - 0.002 = 0.003$$

ZONE C: this zone is subject to flood with return periods from Tr_{30} to Tr_{500}, with correspondent flood levels $HFLr_{30}$ and $HFLr_{500}$. Being the event Tr_{500} the maximum considered event, the yearly probability of being flooded (partially or completely) is given by the difference from the two exceedance yearly probabilities:

$$P_{30-500} = P_{30} - P_{500} = 0.033 - 0.002 = 0.031$$

ZONE D: this zone is subject to flood with return periods from Tr_5 to Tr_{500}, with correspondent flood levels $HFLr_5$ and $HFLr_{500}$. Being the event Tr_{500} the maximum considered event, the yearly probability of being flooded (partially or completely) is given by the difference from the two exceedance yearly probabilities:

$$P_{5-500} = P_5 - P_{500} = 0.2 - 0.002 = 0.198$$

ZONE E: this is the non-damage zone and it is subject to all the floods up to return period Tr_{500}. The two levels are included between the standard Mean Sea Level and $HFLr_{500}$. Being the event Tr_{500} the maximum considered event, the yearly probability of being flooded (partially or completely) is given by the difference from the two exceedance yearly probabilities:

$$P_{1-500} = P_1 - P_{500} = 1 - 0.002 = 0.998$$

Flood levels (Hazard) and Probability

The intensity of the event in relation to its occurrence probability can be determined through standard statistical analysis.

By the application of curbs like Gumbel, the exceeded values of the wave in deep see Hso can be calculated for every return period.

As mentioned before, In Italy the implementation of the Flood directive recommends three return periods: 30, 200 and 500 years.

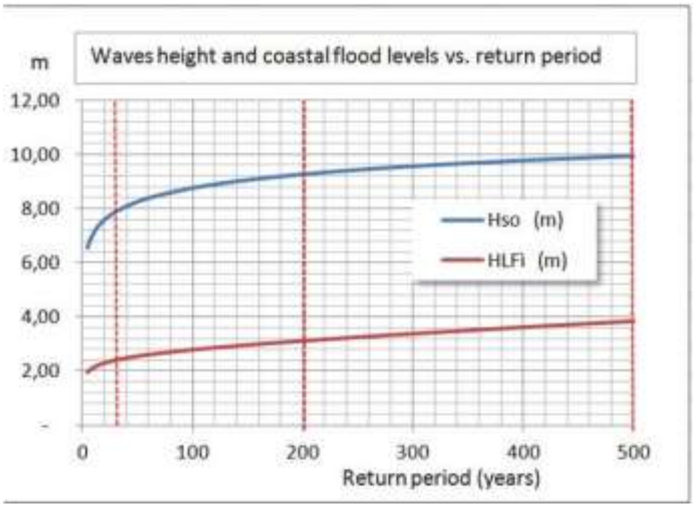


Figure 3.8 - the hazard levels

Tr (years)	Hso (m)	p	HLFì (m)
5	6,55	20,00%	1,97
10	7,06	10,00%	2,14
20	7,57	5,00%	2,31
30	7,86	3,33%	2,41
40	8,07	2,50%	2,49
50	8,24	2,00%	2,56
60	8,37	1,67%	2,62
70	8,48	1,43%	2,67
80	8,58	1,25%	2,71
90	8,67	1,11%	2,76
100	8,74	1,00%	2,80
200	9,25	0,50%	3,13
250	9,41	0,40%	3,26
300	9,55	0,33%	3,39
350	9,66	0,29%	3,51
400	9,76	0,25%	3,63
450	9,84	0,22%	3,74
500	9,92	0,20%	3,85

In the nearby picture, exceeded Hso versus return period is represented. The water level of flooding in the generic point i of the assessment coastal area, could be represented by HLFi where run up and storm surge were considered.

The curb is almost flat, HLFi varying from 2.00 m to nearly 4.00 m. This situation is rather frequent in Tyrrhenian sea where storm surge is not so important and hardly overcomes 0.30-0.35 m.

By the way, from the picture it is evident that the water level at 2.00 m corresponds to an event exceeded with return period equal to 5 years.

This water level occurs very frequently and then it can be assumed as the threshold of no appreciable damage.

This is a realistic assumption for the littoral areas where the storm banks ensure an adequate and proportional defence.

However this water level can become seriously damaging for inland low areas that can be reached by floods after a breach into the dune line (fragile zones). For these cases, specific considerations must be made.

The total risk

As mentioned above, two flood levels HFL (HFL' and HFL''), two submersion values (Sr"-Sr') and finally two Damage Factors (DF"-DF') at each event included between two return periods (*Tr'* and *Tr''*) correspond to two exceedance probabilities (P′′ – P′). Each ΔDF is due a specific probability “p”, reckonable by the difference between the exceedance probabilities of the two events including it.

$$\Delta DF = (DF'' - DF') = f(p) = f(P'' - P') = f\Delta P$$

or in differential notation

$$dDF=f(dP)$$

Knowing that the risk is a function of the damage function $DF_{i,t}$, the relation between the risk of each single part “i” of the assessment area (e.g. a cell of the grid) and for a determined event with specific probability of occurrence “p” included into an infinitesimal interval between two exceedance probability *dP*, can be expressed as follows:

$$dR_{i,T} = E_i * A_i * ID_i * DF_{i,p} dP$$

Being $DF_{i,p}$ the only function of p, the expression of the total risk for all the events with exceedance probability greater than P_m ($T_r = T_{max}$) is the following:

$$R_{i,Pm} = E_i * A_i * ID_i * \int_{P=Po}^{P=P_m} DF_{i,p}\, dP$$

where

$R_{i,Pm}$ = risk (€/year) for events with minimum exceedance probability P_m i.e. maximum return period T_M

E_i = Exposed asset gross value – Total reconstruction cost (€/m^2)

A_i = surface of the element “i” (m^2)

ID_i = Intrinsic Damage Factor associated to the element “i” = max percentage of E_i that can be damaged

$DF_{i,p}$ = Damage factor = percentage of (E_i x ID_i) damaged in relation to the effective submersion for each event with return period included into the infinitesimal difference *dT* i.e. with specific yearly probability p included into the infinitesimal exceedance probabilities delta *dP*.

P_0 = Exceedance probability of the first event able to engender damages (for our case the exceedance probability P_5 referred to the return period 5 years)

P_m = Exceedance probability of the maximum event considered (in this case the exceedance probability P_{500} referred to the return period 500 years)

With reference to the Italian implementation of the Flood Directive, the three levels of risk for each territorial element “i”, can be expressed as follows:

$$R_{i,1/30} = E_i * A_i * ID_i * \int_{P=0,20}^{P=0,033} DF_{i,p}\, dP$$

$$R_{i,1/200} = E_i * A_i * ID_i * \int_{P=0,20}^{P=0,005} DF_{i,p}\, dP$$

$$R_{i,1/500} = E_i * A_i * ID_i * \int_{P=0,20}^{P=0,002} DF_{i,p}\, dP$$

Considering the objective difficulties to manage such a theoretical expression of the Risk, it is worthwhile to represent it in finite terms:

$$R_{i,Pm} = E_i * A_i * ID_i * \sum_{n=0}^{n=N} (DF_{i,n} + DF_{i,n+1})\frac{1}{2} * (P_n - P_{n+1})$$

The number N represents the number of classes in which the whole considered return period can be divided and can vary in relation to the desired accuracy. Anyway a test of the optimal number of classes N should be carried out.

In fact with finite term approach, an average of the Damage Factor must be considered and then . an average between two submersion values.

In the same point "*i*", being HG_i constant, the average of the submersion is equal to:

$$(Sr_{i,n} + Sr_{i,n+1})* 1/2 = [(HFL_{i,n} - HG_i) + (HFL_{i,n+1} - HG_i)]*1/2 = (HFL_{i,n} + HFL_{i,n+1})*1/2 - HG_i$$

Therefore, under the same morphological conditions (HG_i), at each step of the summatory an average of the flood heights must be considered. In order to have similar and not so important �$HFL_{i,n}$ between one step and the next one, an example of the return periods classes could be the following one (with reference to 0):

N	Tr (years)	Hso (m)	P	HLF*ì* (m)	�HLF*ì* (m)
0	5	6.55	20.00%	1.97	
1	12	7.19	8.33%	2.18	0.20
2	**30**	**7.86**	**3.33%**	**2.41**	**0.23**
3	66	8.44	1.52%	2.65	0.24
4	125	8.91	0.80%	2.89	0.24
5	**200**	**9.25**	**0.50%**	**3.13**	**0.23**
6	290	9.52	0.34%	3.36	0.24
7	390	9.74	0.26%	3.60	0.24
8	**500**	**9.92**	**0.20%**	**3.85**	**0.25**

In this case �HLF$_i$ is comprised between 0.20 and 0.25 m, which is a good compromise considering the achievable approximation on the morphology and the other aspects of the elaboration. In the next paragraph some attempts with different N will be performed in order to assess the different degrees of approximation.

Specific risk vs. exceedance probability

It is useful to introduce a simpler parameter called **Specific Risk = $r_{i,r}$**

$$r_{i,r} = \frac{R_{i,T}}{E_i \ x \ A_i \ x \ ID_i} = \sum_{n=0}^{n=N} (DF_{i,n} + DF_{i,n+1}) \frac{1}{2} * (P_n - P_{n+1})$$

i.e. the unitary risk for each € of value of the damageable asset (1/y€). In this formulation the specific risk better shows its "double" nature related to the probability and the damage factor.

Taking into account the non linearity of these two variables, the pattern of $r_{i,r}$ is not banal.

In order to understand the behaviour of the parameter $r_{i,r}$ and the attention to be paid to reckon the most reliable economic value of the Risk, some other considerations will be made on the relation between the different parameters involved.

Using the exceeding flood water levels at different return periods and the elevation HG*i* of the point *i*, it is possible to determine the submersion in every point *i* in relation to the exceeding probabilities.

By the submersion it is possible to calculate the damage factor in relation to the exceeding probability of the event, according to the different behaviours of the existing assets in case of floods (linear, convex, inflected).

In the following examples, one point *"i"* of the assessment area has been considered with elevation HG*i* = 2.1 m.

By using the function:

$$r_{i,r} = \sum_{n=0}^{n=N} (DF_{i,n} + DF_{i,n+1}) \frac{1}{2} * (P_n - P_{n+1})$$

the specific risk can be calculated for different return periods (i.e. for different levels of flooding) varying N.

For example, in this case, if you use 2, 5 and 8 for N, you can obtain the risk respectively for 30, 200 and 500 return periods. The specific risk is obviously higher at higher return period but nonetheless it is interesting to compare the behaviour of the specific risk with different damage functions.

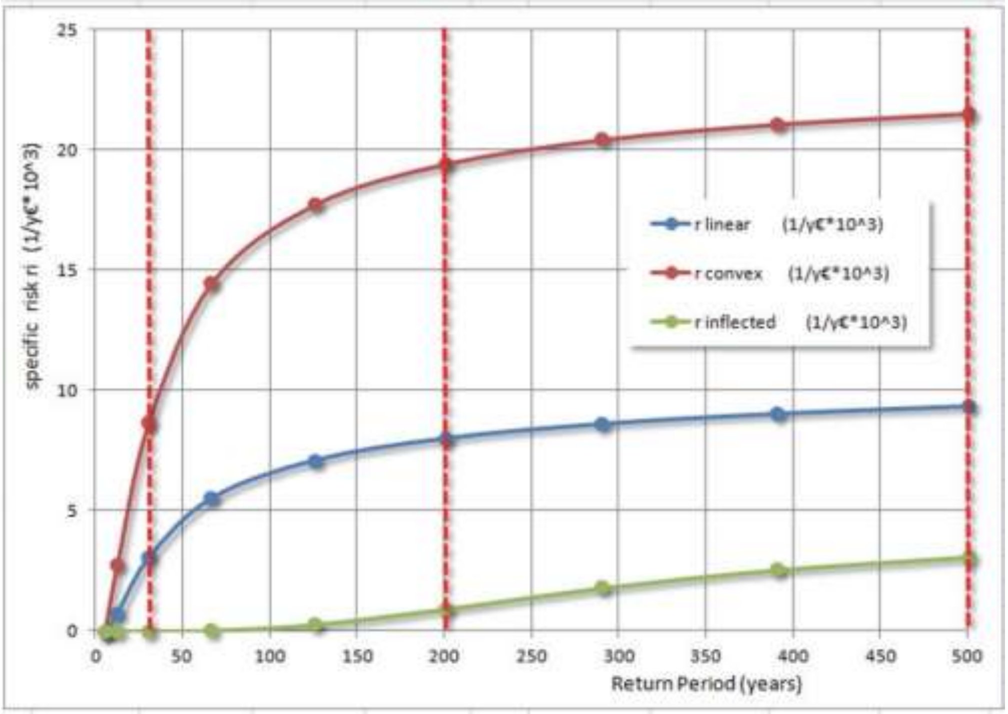
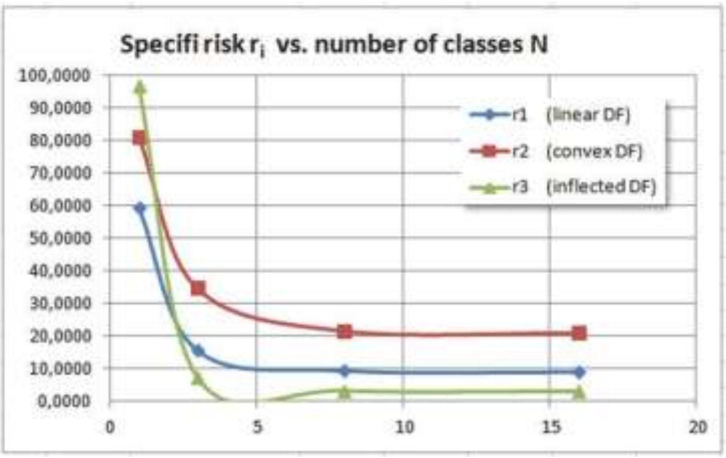


Figure 3.9 - specific risk curves comparison per different typologies of exposed assets

From the above picture a series of considerations can be made:

- In the same point, with the same flood levels and independently from the asset value, the specific risk can change considerably in relation to the damage function characteristic of the exposed asset.
- Although all the examined damage functions reach the value 1 at higher flood level, the resulting pattern of the specific risk is completely different for the three functions. That comes from the circumstance that the risk is an integral (summatory) and the contribution to its global value derives from the product of a series of DF for the �P and this latter decreases very quickly for higher return period. So the "first" part of the summatory (with higher �P) gives a strong contribution to the global risk that cannot be compensated by the products of the "last" part of the summatory (with lower �P and higher DF);
- In relative terms, the specific risk of the assets with convex and linear DF is practically similar at 200 and 500 years of return period, while the specific risk of the assets with inflecting DF may vary considerably between 200 and 500 years return period.



Concluding this list of observations, an attempt to test the achievable approximation with different number of classes of return periods (or �P) was made.

The specific risk at T_r= 500 was calculated using respectively 16, 8, 3 and 1 �P. The final values are showed in the picture.

Figure 3.10 - specific risk curves comparison per different number of classes N

It is evident the importance of an adequate number of steps in order to “stabilize” the final result.

In the case under examination, it is clear that N=8 classes of �P bring very near to the result obtained with N=16 and, considering the heaviness of the calculation, it is obvious that the choice N=8 is then much more suitable.

4.13 Mapping process

On the grounds of the aforementioned 3 geographical and 2 numerical datasets, the application of the model COFLERMap can be summarized in 4 steps:

Step 1. In order to draw up the Maximum Damage Map (MD-Map), the values of the Exposed Assets must be multiplied by the correspondent ID. If the Maximum Damages are already available for the Exposed Assets interested by the elaboration, this step can be omitted. This Map is a theoretical representation of the maximum damage as if all the considered exposed assets (independently from their elevation) were struck uniformly by the maximum event.

Step 2. By calculating the Submersion Map (SUBMap = $HLFmaxr_{x,y} - HG_{x,y}$), the intensity of the flood in terms of its real capacity of submerging the exposed goods is determined in every point of the Assessment Coastal Area.

Step 3. By using Damage Functions applied to the overlapping of the Submersion Map (for each adopted return period T*r*) with the MD-Map, the Total Damage Map (TD-Map) is obtained. This map represents the geographical distribution of the global damages in case of the T*r* event occurring.

Step 4. Each event considered is referred to a specific probability. Then the real risk of damage for an event corresponds to the integral of the varying damages occurring up to the considered event in relation to the corresponding variation of the exceeding probabilities. In simple terms, the summatory of the products of the average damage occurring between two events and the relative �P (difference between the correspondent exceedance probabilities), leads to the Risk Maps as requested by the Flood Directive.

It is worth noticing that all the mentioned maps correspond to specific values defined for each point of the Assessment Coastal Zone.

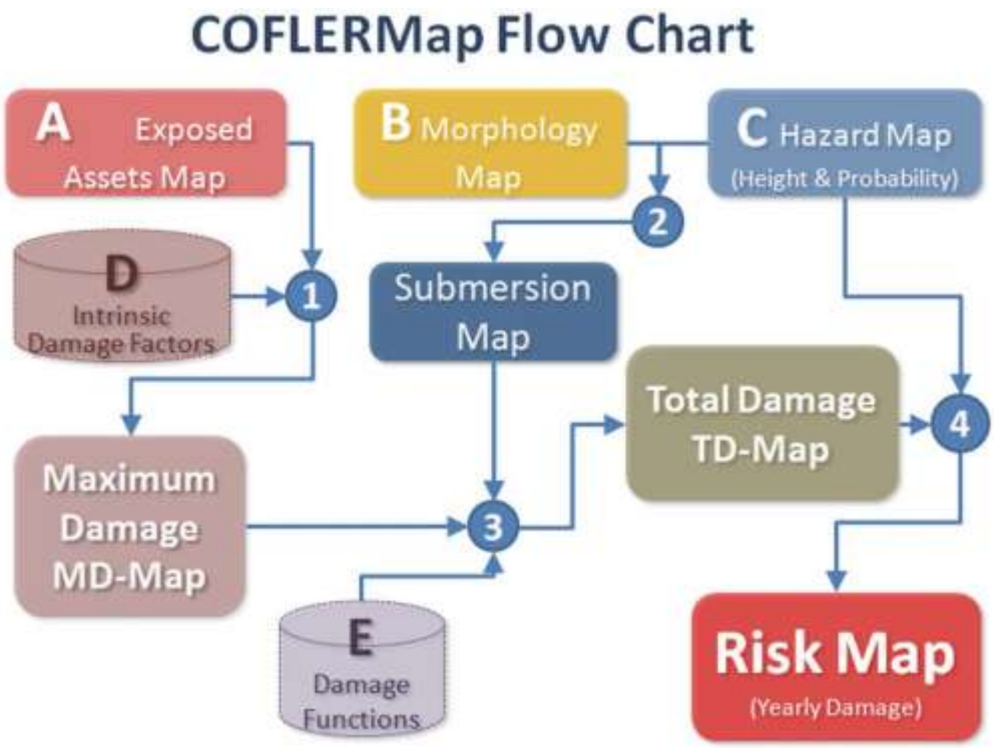


Figure 3.11 - COFLERMap model flowchart

4.14 Conclusions

As specified above, the model COFLERMap does not concern data collection, hydrological modelling or hazard assessment in the risk assessment process.

Only general considerations on these aspects were made, in order to understand the state of the art and what is necessary to feed COFLERMap.

The model specifically concerns the risk mapping i.e. the methodologies to cross the basic territorial data (hazard, exposed values, morphology.) in order to achieve a geographic and quantitative distribution of the risk, compliant with the Flood Directive requests.

The Geographical Information System necessary to apply COFLERMap on a specific Assessment Coastal Zone, must include the following main layers:

1. Exposed Assets present on the assessment Coastal Zone and their economic values E (x,y)
2. Ground Elevation of the Assessment Coastal Zone HG (x,y)
3. Flooding water level HLFmaxr(x,y) and associated yearly probability Pr(x,y).

In addition to the above geographical datasets, COFLERMap also requires two numerical datasets:

4. Intrinsic Damage Factor (ID)
5. Damage Factor (d)

The risk for each single part "i" of the assessment area (e.g. a cell of a grid) and for a determined event with return period "Tr" or exceedance probability P_m, was expressed as follows:

$$R_{i,Pm} = E_i * A_i * ID_i * \int_{P=Po}^{P=P_m} DF_{i,p}\, dP$$

where

$R_{i,Pm}$ = risk (€/year) for events with minimum exceedance probability P_m i.e. maximum return period T_M

E_i = Exposed asset gross value – Total reconstruction cost (€/m^2)

A_i = surface of the element "i" (m^2)

ID_i = Intrinsic Damage Factor associated to the element "i" = max percentage of E_i that can be damaged

$DF_{i,p}$ = Damage factor = percentage of (E_i x ID_i) damaged in relation to the effective submersion for each event with return period included into the infinitesimal difference *dT* i.e. with specific yearly probability p included into the infinitesimal exceedance probabilities delta *dP*.

P_0 = Exceedance probability of the first event able to engender damages (for our case the exceedance probability P_5 referred to the return period 5 years)

P_m = Exceedance probability of the maximum event considered (in this case the exceedance probability P_{500} referred to the return period 500 years)

Considering the objective difficulties to manage such a theoretical expression of the Risk, it is worthwhile to represent it in finite terms:

$$R_{i,Pm} = E_i * A_i * ID_i * \sum_{n=0}^{n=N} (DF_{i,n} + DF_{i,n+1})\frac{1}{2} * (P_n - P_{n+1})$$

The number N represents the number of classes in which the whole considered return period can be divided and it can vary in relation to the desired accuracy. A test was made and it seems that N=8 could be the optimal number of class to consider.

Analysing these variables, an intrinsic complexity of the overlapping procedure comes out and some practical expedients must be individuated.

In the next book of MAREMED (Book no 2) an application of the model will be carried out, with some practical examples of risk assessment for a pilot area and cost/benefit analysis for adaptation work.

References:

7th FP MICORE - http://www.micoreproject.eu

7th FP THESEUS - http://www.theseusproject.eu

ABR Lazio Conference, Castel Gandolfo 1999 - http://www.cmgizc.info

CONSCIENCE EU project “On the use of setback lines for coastal protection in Europe and the Mediterranean: practice, problems and perspectives” - Deliverable D 12 - March 2010

EU Flood Directive 2007/60/EC - http://eur-lex.europa.eu

EXIMAP "Handbook on good practices for flood mapping in Europe"

INTERREG IIIC BEACHMED-e Regional Framework Operation - http://www.beachmed.eu

Italian Decree february 23rd 2010, n. 49 "Directive 2007/60/CE application on flood risk evaluation and management" published on Gazzetta Ufficiale April 2nd 2010, n. 77.

Jonkmana, S.N., M. Bockarjova - Integrated hydrdynamic and economic modeling of flood damage in the Netherlands.

MED COASTANCE Project - http://www.coastance.eu

MED MAREMED Project - http://www.maremed.eu

Ministerie van Verkeer en Waterstaat - Dienst Weg en Waterbouwkunde. HISSchade en Slachtoffer module (2004).

PROTOCOL on Integrated Coastal Zone Management in the Mediterranean - Official Journal of the European Union L 34/19 - 4.2.2009

Varnes & IAEG (1984), UNESCO report

VNK Project (Flood Risk and Safety in the Netherlands) - http://english.verkeerenwaterstaat.nl/English

White paper on Adapting to climate change http://www.medregions.com/pub/doc_travail/gt/66_en.pdf

ANNEX 1: Synthesis of Questionnaire's answers

(integral version of the answers are available on www.maremed.eu)

SECTION 1: State of the art: inventory of the cooperation projects on adaptation to climate change

Question N°	1	2
Partner	**Have you participated in former European programs on adaptation to climate change in coastal areas?**	**Could you describe the main Results, Experiences and Best Practices that you identified in these projects?**
Creta	www.coastance.org, www.beachmed.eu, and also REGIOCLIMA	In Beachmed-e the long term evolution of the erosion of the coastline of the a pilot site (Georgoupoli) was taken into consideration for the local urban and rural planning. In the Coanstance project (in progress), component 4, for another pilot site (Keratokampos) methodologies and techniques are proposed for the protection of the coast from erosion mainly by beach nourishment and "soft" beach protection measures. The main results of the Coastance project is the identification of the main elements of Intergated Coastal Zone Management (considerations on climate change included) that have to be introduced into the planning procedures. For the component 5, of the Coastance project, guidelines are prepared for the Strategic Environmental Assessment including ICZM issues. The Decentralized Administration of Crete and the Energy Agency participate in the project Regional Cooperation towards adaptation to climate change – REGIOCLIMA , funded under the European Program INTERREG IVC. The objective of the project is to raise awareness and assist local societies and local authorities in adapting to the new climate conditions, by both minimizing the risk of damage and exploiting the new opportunities arising from a changing climate. More specifically, the project will focus on how the climate change influence the local societies and if there is a possibility to transform the disadvantages of climate change to advantages. 8 organizations from 8 European countries (covering geographically the area of the European Union as a whole) participate in the project. 5 Regional Authorities (Decentralized Administration of Crete, Region of Veneto, Region of Valencia, Region of Bratislava –Slovakia-, Region of Aubagne -France-), an academic Marine Institute (Tartu-Estonia), the Regional Agency for Entrepreneurship & Innovation (Varna-Bulgaria) & Larnaca District Development Agency (Cyprus). The Energy Agency is the coordinator of the project for the Decentralized Administration of Crete. The project started in October 2008 and will be concluded by September 2011.
Lazio	www.beachmed.eu www.coastance.eu	BEACHKEEPER Web-Cam image registration and restitution system with automatic identification of coastline GNM Grainsize Nourishment Model SAND-MAP Map of sand quarries along Mediterranean platform SAND PROTOCOL Protocol for searching Sea bottom sand quarries methodologies ENV2 & TURB1 Environmental protocol for dredging and nourishment activities. Turbidity effects during dredging and nourishment activities and standardised method for turbidity/sedimentation rate measurement. ICZM ATLAS GIS tool for Integrated Coastal Zone Management BEACH NOURISHMENT Technical instrument for the dissemination of beach nourishment works DUNE CHARACTERIZATION Manual for the Characterization and management of coastal Dunes

		"BOLOGNA CHARTER" A document of understanding between local Administrations for the promotion of EURIOMCODE (EURopean Interregional Observatory for the Mediterranean COastal DEfence) SiCoast Database of coastal infrastructures COASTAL SERVICES Operative and technical services for coastal monitoring LAW-COAST Proposal for an integration of coordinated text for the European Parliament directive's proposal for the theme "ground" and a modification of 2004/35/CE directive RISK MAP Model - A model for the Risk maps elaboration on coastal area
Emilia-Romagna	Beachmed-e (Interreg III C Sud): http://www.beachmed.eu PlanCoast (Interreg III B CADSES): www.plancoast.eu COASTANCE (MED): www.coastance.eu Cadsealand Micore: www.micore.eu	Cadsealand: analysis of the storminess in the period 1950 – 2000; definition of the STORM parameters for North Adriatic; main coastal thematic mapping (land use; geomorphology) and shoreline change analysis (based on DSAS) Beachmed-e: identification and characterisation of a new off-shore deposit for beach nourishment, installation of a wave detection buoy for marine climate monitoring 3 miles off-shore from regional coast, good practices for consolidation of restored/ reconstructed coastal dunes, through vegetation planting (that drove after to the" Bevano Protocol"), signature of a political document "European regions charter for littoral protection and for the promotion of an European interregional Observatory for Mediterranean coast protection (Bologna Charter)". PlanCoast: manual and practices for coastal area planning and integrate marine spatial planning, set up and tested within the Ferrara Province spatial planning process. Definition of coastal risk indicators for: long and short term flooding; erosion; salt water intrusion. Vulnerability analysis and maps of Ferrara coastal zone. COASTANCE: (ongoing) development of a regional action plan against coastal erosion and submersion risk for the adaptation to climate change effects, development of a costal information and managerial system based on 118 sedimentary cells, development of best practices for beach sediments management and of a program for the sustainable exploitation of sediments deposits for beach nourishment purposes. Micore: re-analysis of storminess extended to 2010; sea-storm thresholds definition; development of a prototype of early warning system usind the x-beach model specifically implemented for Emilia-Romagna coast; Catalogue of historical sea-storms (1946-2010)
Toscana	EUROSION (www.eurosion.org); BEACHMED and BEACHMED-e (www.beachmed.eu); CONSCIENCE (www.conscience-eu.net); RES MAR (www.resmar.eu); PERLA (www.progettoperla.eu)	Restoring the sediment balance and providing space for coastal processes; "Favourable sediment status" in order to promote coastal Resilience; Coastal sediment cell: a coastal compartment that contains a complete cycle of sedimentation including sources, transport paths, and sinks; Coastal and Offshore Sediment Management Plans.
FEPORTS	Beachmed: Strategic management of beach protection for sustainable development of Mediterranean coastal zones http://www.beachmed.it/ Rinamed: Drafting and execution of a common strategy between local players in the Western Mediterranean Arch regions in terms of	Beachmed: The results were the identification of measures to mitigate coastal erosion, acceptance of recommendations for land planning in the regions, improved management of coastal domains and the provision of innovative territorial technologies. Master plans and technical reports were also be drawn up for subsequent implementation. Moreover, the project also drew up guidelines and recommendations so that the results of the RFO could be included in policies and regulations in the participating regions. Rinamed: • Drafting of an educational package o A role-play game o A hypertext on CDROM o A travelling exhibition and documentation thereof o Complementary publications • Development of an inter-disciplinary training programme focussing on the different

	information and awareness of the population before natural risks http://www.rinamed.net/	sectors • International exchange meetings and assessment of common practices among the players in the European Mediterranean • Undertaking of awareness actions aimed at different citizens' groups and associations • Creation of internal and external communication mechanisms • Creation of a common space on the internet: Website • International forum for communication agents • Drafting of assessment tools and fine tuning of a continuous assessment programme
Murcia	No	
PACA	No	
Liguria	No	
Marche	LIFESALT http://www.lifesalt.it/en.html	Application of a regional risk assessment methodology based on GIS for a sustainable use of groundwater considering climate change events – Application on Life+ SALT project.
Cypro	No	
Corse	Resmar (Ligurie Sardaigne Toscane Corse)	
yes percentage	63%	

SECTION 2: State of the art: inventory of the atlases and databases regarding coastal risks: erosion, submersion, flood

Question N°	3	4	5	6	7	8	9
Partner	Have you already acquired information or been informed on floods and submersions which already occurred in the past, and which have significant adverse impact on coastal zones?	Have you already defined a methodology to identify priority areas of risks (erosion, submersion, flood)?	Have you already produced risk maps on coastal areas?	Did your risk maps refer to the EU flood directive (2007/60/EC) requirements?	Have you produced atlases and/or databases regarding coastal area management?	Have you adopted a specific guideline to produce these tools? / Should be shared and adopted by the MAREMED partnership?	Could you list some general surveys concerning erosion and submersion events carried out in your Region over the past five years?
Creta	no	no	no	Till the end of 2011 , the Greek General Secretariat for Water(Ministry of Environment, Energy and Climate Change) will present the preliminary risk maps	no	no	
Lazio	Yes. A publication on Coastal monitoring was made by ICZM monitoring Centre and is available on www.cmgizc.info	yes	no	no	ICZM Monitoring center of Lazio Region has published a WEB G.I.S. tool on marine and coastal area ecosystem management. This tool is available on www.cmgizc.info	no	Lidar campaign 2009/2010 80 km of coast in the north of Lazio; Shoreline evolution in the Pontino area after nourishment works.

Emilia-Romagna	Reports, maps, images, sea storm reports. The Catalogue of historical sea-storms (1946-2010) contains information and maps about damages and impacted localities	The methodology is to be shared among regions and implemented to fullfill 2007/60/EC directive. Nowadays the sharing process is ongoing through technical meetings with regions of the same Hydrographic District. It is a statistical modelling method based on the calculation on water rising and ingression considering the worse scenario: run set up + surge + tide (for 1, 10, 100 return time events). Such results will be integrated with cartographic information acquired during other projects such as: •Catalogue of historical sea-storms •Run-up computation along cross shore beach profiles	no	no	Coast and Marine Information System including several databases among which: •Coastal defence database •Nourishment database •Offshore sand deposits •Coastal- Hazard maps Most of them are accessible at the address http://geo.regione.emilia-romagna.it/geocatalogo/ http://geo.regione.emilia-romagna.it/costa/viewer.htm?Title=Servizio%20Geologico%20Sismico%20e%20dei%20Suoli Within the COASTANCE project we set up a subdivision of the regional coast in 118 littoral cells and classified them, for management purposes, by sedimentary balance, interventions realised, physical characteristics and dynamics. The system, named SICELL, will become a web tool available for technical regional offices and local Administrations. Its description and general maps can be accessed at the following link: http://www.ermesambiente.it/difesasuolo/	For the Coast and Marine Information System Eurosion guidelines has been followed; for the metadata and annex 1 -2 from Inspire. yes, It could be sgared	LiDAR 2010 carried out after the sea storm of march 2010 SAR Interpherometry 2002-2009 data analysis for subsidence detection Regional network for the monitoring of sea-storm impact based on GPS survey on the dry beach. Operative since 2010.

Toscana	GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL FEATURES OF THE SHORELINE:The Geomorphological map: the adopted method involves performing the following operational stages:Exploratory stage and acquisition of material made available by the Public Administrations.Remote sensing using photointerpretation before and during direct surveys on the ground.Direct survey on the ground using GPS tools and Regional Design Paper mapping on a 1:10.000 scale.The comparison between the results of the geomorphological survey and the data obtained from the interpretation of the batimetric surveys carried out during the first stages of the study.Shoreline evolution maps from 1938 to 2005.	yes	Mapping HAZARDOUS AND INVARIANCE Areas:Hazardous areas means a portion of territory affected by extreme meteo-marine weather, and refer to a return period of 50 years.For the definition of hazardous areas the following data was used:• the survey of the shoreline (2005);• the results of the modelling calculation of the effects induced by the wave with a 50-year return period, considering:- The maximum set-up value, namely the rise in sea level caused by the wave compared to the average sea level;- The maximum run-up value, namely the highest elevation in relation to the set-up value, reached by the water as it rises up the beach.The flooding of the beach being surveyed and, consequently, delimiting the hazardous areas, was assessed on the basis of the coastline and the height of the overflow of the meteo-marine weather, with reference to current conditions and trends	no	C. BARTOLINI, L.E. CIPRIANI, E. PRANZINI, and M. SARGENTINI, 1989. The shoreline of coastal Tuscany between 1938 and 1985. In: Tuscan coasts - Studies on erosion, winds, and wave motion. The Region of Tuscany - Regional Council, 16 Tables.Study and research for the implementation of the profile of the Tuscan coast in the Regional Plan for Integrated Coastal Management for the hydrogeological provision - Geomorphological map of the coastal belt on a 1:5,000 scale (2005). Atlas of Italian beaches. C.N.R., S.EL.CA., Florence.	Technical specifications to assign feasibility studies at the level of physiographic units for the implementation of the profile of the Tuscan coast in the Regional Plan for Integrated Coastal Management for the hydrogeological provision.Could you list some general surveys concerning erosion and submersion events carried out in your Region over the past five years?Study of the sedimentary supply in main rivers; Geomorphologic (shoreline and emerged and submerged	Study of the sedimentary supply in main rivers; Geomorphologic (shoreline and emerged and submerged beach profiles) and sedimentological (grain size and petrography) features of the coast; Drafting the Geomorphologic Map of the coastal belt on a 1: 5000 scale; Identification of hazardous and invariance areas; Inventory of marine works designed to defend the coast and coastal settlements.

	(provided by the model).Invariance area means the planimetric delimitation of the following urban invariances: urban areas, network infrastructures and areas of environmental and natural interest. The activities that were carried out consisted in the production of GIS files, by updating and standardizing the data provided by the regional SIT and the acquisition and digitization of municipal planning instruments (mapping out the PRGs).The risk from rising sea levels on the coast of northern Tuscany was also assessed (Coastal Studies No 6 - 2003)		beach profiles) and sedimentological (grain size and petrography) features of the coast; Drafting the Geomorphologic Map of the coastal belt on a 1: 5000 scale; Identification of hazardous and invariance areas; Inventory of marine works designed to defend the coast and coastal settlements.

FEPORTS	Information documenting events in the distant past is available. For more recent events there are satellite images, weather reports from the Instituto Nacional de Meteorología (National Weather Institute), information from the press, studies carried out by universities, etc. An example of the maritime storm studies affecting the coast is available through the following link: http://age.ieg.csic.es/boletin/40/14-TEMPORALES.pdf Very significant is the stormy weather that hit the Mediterranean coast in November 2001, producing six deaths and serious damage to frontline beach and coastal infrastructures, and for which a large quantity of scientific and graphic information and press reports are available.	PATRICOVA is based on a methodology designed for priority identification of floodable areas. With regard to erosion, methodologies such as the proposal by the Instituto de Ecología Litoral (Coastal Ecology Institute) in the project "Sistema de monitorización de la erosión costera y sus efectos en las comunidades marinas de la Red Natura 2000" are used.	In the case of flooding, the most significant initiative is being coordinated by the Ministry for the Environment, Rural and Marine Areas, through the so-called "National Cartography of Floodable Areas System". In this cartography a new delimitation of the Public Hydraulic Domain has been carried out. In order to do so, the following steps were followed: • Compilation of previous studies: o Civil Defence Plans o Reservoir operation rules o Etc. • Establishment of the Hydraulic Public Domain through the following criteria: o Hydro-geological o Geomorphologic o Environmental • Establishment of a preferential flow channel, which, if necessary, could be established as a policing zone • Definition of Avenues associated with different return periods, in natural or	In July 2010 the Council of Ministers approved a Royal Decree for assessment and management of flooding risks, which signifies transposition of Directive 2007/60/CE	The studies of the floodable areas in the Valencian Community have been carried out by: • PATRICOVA: Plan de Acción Territorial (Territorial Action Plan), at a sectorial level in reference to prevention of flood risks in the Valencian Community, which uses a risk management tool http://cma.gva.es/web/indice.aspx?nodo=733&idioma=C • Acuamed: Acuamed is the main instrument of the Ministry of the Environment and Rural and Marine Areas for the development of the "A.G.U.A." Programme in the Mediterranean basins. Hence, the state company Aguas de las	In the Valencian Community, directives such as PATRICOVA are interesting for further study. On the other hand, within the scope of the Sistema Nacional de Cartografía de Zonas Inundables (National Cartography of Floodable Zones System), the Ministry for the Environment and Rural and Marine Areas have commissioned CEDEX (Centro de Estudios y Experimentación de Obras Públicas) [Centre of Studies and Experimentation of Public Works], IGME (Instituto Geológico y Minero de España) [Geology and	• PATRICOVA • Maps of natural risks in territorial and urban development planning (ICOG) 2008 • Sea storms and territorial regulation in the province of Alicante (Alicante University) 2005

	altered systems	Cuencas Mediterráneas S.A. has the objective of contracting, constructing, purchasing and exploiting all manner of hydraulic works. Actions of general interest are currently being carried out in the hydrographical basins of the rivers Segura, Júcar, Ebro and the Andalusian Mediterranean Basin and the Inland Basins of Catalonia. The A.G.U.A. Programme action in the Mediterranean basins entrusted to the company seek three main objectives: to increase water resources, to improve the management of water and to	Mining Institute of Spain] INDUROT (Instituto de Recursos Naturales y Ordenación del Territorio de la Universidad de Oviedo) [Institute of Natural Resources and Land Planning of the Territory at Oviedo University], with the development of technical recommendation s in a Methodological Guide discussing the basic aspects for the demarcation of Public Hydraulic Domain and floodable areas in accordance with Royal Decree 9/2008 which amended the Public Hydraulic Domain	

					restore the environment. • The Confederación Hidrográfica de del Júcar (Júcar Hydrographical Confederation) • Private companies contracted for construction projects • The Ministry for the Environment More information: http://www.mma.es/portal/secciones/acm/aguas_continent_zonas_asoc/prevencion_inundaciones/cartografia_inundables/estudios.htm Cartographic viewer: http://sig.marm.es/snczi/visor.html?herramienta=DPHZI	Regulations. These technical recommendations are based on different practical examples carried out in different rivers in the Cantabrian, Douro and Júcar basins, and the first drafts will be available to the general public in the near future.	
Murcia	no	no	no	no	SITMURCIA - Sistema de Información Territorial de la Región de Murcia	no	no

PACA	Yes (the national auth.)	yes	The Region financed, with the state and under the coordination of our 3 coastal Provinces, atlases of risks for erosion and flood (from land and sea). The evolution of the coastline was studied with old pictures and maps, models of local currents were calculated, maps of biocenosis were done. A consultation with public authorities was organized for their appropriation of the level of the risk that will appear on the maps. All data is free and available on the regional portal. The problem is that these atlases are not taken into account by the mayors for their planification of urbanism	no	A scientific project permitted us to have atlases of the coastal structures and the evaluation of the artificialisation induced by the ports, coastal dikes... MEDAM project. The results are online; http://sigcol.unice.fr/website/MEDAM/site_medam/index.php They can be taken freely on the regional portal	yes, We think that we need to know how the other regions did their atlases and to built a common guideline to test it at the basin scale	For the necessity of some management plans, a survey was organized in the Alpes-Maritime and in the Var Province.
Liguria	Historical maps and photos	yes	Definition of run-up level for 1 year and 50 year return period	yes	http://www.ambienteinliguria.it/eco3/ep/CD_PTAMC/cartografiaC08.html	yes	Bathymetric, sedimentological and biological surveys
Marche	Rain gauge data, damages reports, water level data (fluvial), surveys to map the areas	yes	Historical and geomorphological criteria	no	http://www.autoritabacino.marche.it/pai/cartopai2.asp	yes	Between 8-10 sea storm with damages results.

Cypro	no	no	no	no	no	no	Some general surveys concerning erosion and submersion events in Cyprus carried out over the past years are as followed: Department of Public WorksLarnaca District:a. Oroklini – Larnaca regionb. Pervolia – Kiti – Zygi region Paphos Districta. Geroskypou bayb. Polis ChrysochousNicosia district:a. Kato Pyrgos – Pegeia regionNote: The Land and Survey Department is the appropriate department which deals with the coastline evolution.
Corse	Il s'agit d'études portant sur l'historique des inondations et submersions, notamment par la presse. Ces informations remontent jusqu'au 15° siècle.	no Ce sont les services compétents de l'Etat, à l'aide des outils fournis par l'OEC, qui définissent leur méthodologie pour identifier les zones prioritaires à risque et élaborent par la suite les moyens de prévention, de protection et d'intervention adaptés.	On peut distinguer deux types de cartographies des risques sur la zone côtière insulaire. La première traite de l'érosion et la seconde des tempêtes.	Corine Land Cover et facies primaire et secondaire pour la mer	no	no	Non, il y a un suivi global des cas d'érosion et de submersion mais pas d'étude concernant des cas spécifiques
yes percentage	73%	63%	54%	36%	73%	54%	

SECTION 3: Cartographic and morphological data

Question N°	10	11	12	13
Partner	Have you already acquired morphological data describing your coastal zone?	What kind of tools do you use for coastal monitoring?	Have you developed common cartographies together with your neighbor region?	Have you collected information evaluating the subsidence phenomenon along your coast?
Creta	Sand grain size available for Keratokampos and other sites from existing coastal engineering studies.	Aerophoto	no	no
Lazio	Shoreline acquisition; Equilibrium beach section acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments; Sand Dune acquisition	Webcam Airphoto Topobathimetric measurement Satellite images Lidar	no	Yes, on the coastal area of Fondi (Pontino littoral)
Emilia-Romagna	Shoreline acquisition; Equilibrium beach section acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments; Sand Dune acquisition	Webcam Topobathimetric measurement Satellite images Lidar SAR interpherometry	no	yes
Toscana	Shoreline acquisition; Equilibrium beach section acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments; Sand Dune acquisition; Morphology, texture and chemistry of continental shelf sand and gravel reservoirs	Webcam Topobathimetric measurement Satellite images Lidar Beach sediment grain size and colour measurements	yes	yes

FEPORTS	Shoreline acquisition; Equilibrium beach section acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments; Sand Dune acquisition	Webcam Topobathimetric measurement Satellite images	Cartography being developed at a national level shows uniformity and continuity between neighbouring regions.	yes
Murcia	no	satellite image	no	no
PACA	Shoreline acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments	Aerophoto; Lidar	yes	yes
Liguria	Shoreline acquisition Equilibrium beach section acquisition Erosion trend Sand grain size Chemical and Physical characteristics of sediments	Topobathimetric measurement; Aerophoto	no	no
Marche	Shoreline acquisition Erosion trend	Webcam	no	?
Cypro	Shoreline acquisition Erosion trend Sand grain size Physical characteristics of sediments	Topobathimetric measurement Satellite images	no	no

Corse	Shoreline acquisition; Equilibrium beach section acquisition; Erosion trend; Sand grain size; Chemical and Physical characteristics of sediments. LIMA qui permet de cartographier les fonds sous marins de 0 à 100 mètres	Topobathimetric measurement Lidar Airphoto	Oui dans le cadre du Projet de Parc Marin International des Bouches de Bonifacio. (Corse Sardaigne) + programme GERER qui traite de la problématique d'érosion des plages	no
yes percentage	91%	100%	36%	46%

SECTION 4: Meteorological and wave climate data, climate change effects

Question N°	14	15	16	17	18
Partner	Have you collected information on high tide level in your region?	Have you collected information evaluating sea level evolution of your Region in the medium/long term (100÷200/500 years)?	Have you collected information evaluating offshore meteorological characteristics (wind speed, wind direction, atmospheric pressure, water and air temperature, ...) along your coasts?	Have you collected information evaluating offshore (about -100 m) wave characteristics (Wave height H, Wave period T and main direction) along your coasts?	Have you collected information evaluating nearshore (about -20 m) wave characteristics (Wave height H, Wave period T and main direction) along your coasts?
Crete	yes	no	> 20 years	> 20 years	> 20 years
Lazio	yes	no	> 20 years	> 20 years	5÷20 years
Emilia-Romagna	yes	no	> 20 years	> 20 years	< 5 years
Toscana	yes	yes	5÷20 years	< 5 years	< 5 years
FEPORTS	yes	yes	< 5 years	< 5 years	< 5 years
Murcia	no	no	no	no	no
PACA	no	no	no	yes	no
Liguria	yes	no	no	> 20 years	no
Marche	no	no	5÷20 years	no	no
Cypro	yes	no	5÷20 years	5÷20 years	5÷20 years
Corse	yes	no	5÷20 years	5÷20 years	5÷20 years
yes percentage	73%	18%	73%	82%	64%

SECTION 5: Social economic data, exposed values

Question N°	19	20
Partner	Have you already developed land use maps for your coastal area?	Have you already assigned economic values to your coastal area?
Creta	"Regional Plan of Urban and rural development and sustainable development: Region of Crete" (nEpI<EpEIaK6 I:xtolo XwpoTaÇIKoû I:xEolacr�oû Kal AEI<6paç Avé TuÇ�ç: nEpI<tpEIa Kp�T�ç) Ministry of Environment and Climate Change 2003. (www.ypeka.gr) It is a context that gives directions/guidelines for making land use maps through theOpen Cities Urban and Rural Plan (I:xtola XwpIK�ç Kal OIKIcrTIK�ç Opyévwcr�ç AvoIxTWv n6 Ewv I:.X.O.O.A.n.) Some municipalities in Crete have completed or they are preparing these plans.	The economic values of real estate are assigned from the Ministry of Economics for all Greece. It concerns all the areas and they are used for taxes.
Lazio	Yes, land use map are available on web GIS tool www.cmgizc.info	Taking account information about resident population size, typology recreation activities, typology of tourism, direct and indirect incoming, the objective is to determine a euro/m2 of beach value assigned to each typology of land use. See also www.beachmed.eu.
Emilia-Romagna	Please see the Land Use web GIS at the following: http://archiviocartografico.regione.emilia-romagna.it/bookshopfe/mappeonline.html A specific land use classification of 1,5 km coastal strip is available on the http://geo.regione.emilia-romagna.it/geocatalogo/ for the years 1945 – 1982 – 1998 and 2005	The economic value of the coastal area has been estimated considering the GDP of the main sectors of the coastal economy: tourism industry, touristic and commercial harbours, fishery, aquaculture. Thus defined, the coastal system GDP is estimated to contribute up to 7% of total regional GDP. Further evaluations on real estate, infrastructures, industrial settlements, natural heritage are not structured.

Toscana	http://web.rete.toscana.it/sgr/webgis/consulta/viewer.jsp	no
FEPORTS	SIOSE: Sistema de Información de Ocupación del Suelo en España (Land Occupation Information System in Spain): http://terrasit.gva.es/es/ver?servicio=siose	no
Murcia	Corine. " Cambios 1990-2000 Murcia IGN (Instituto Geográfico Nacional)	no
PACA	Not specifically for the coastal area but for all our territory	no
Liguria	no	no
Marche	http://www.autoritabacino.marche.it/costa/costa.asp	no
Cypro	http://www.moi.gov.cy/moi/tph/tph.nsf/index_gr/index_gr?OpenDocument	For the valuation of the economic benefits use is made of the differences in the productivity of the housing and agricultural sectors attributed to the coastal environment. This is a particular application of the more widely used economic appraisal technique of considering 'with' and 'without' situations.
Corse	Corine Land Cover	no
yes percentage	91%	36%

SECTION 6: Future scenarios

Question N°	21	22	23	24
Partner	Are there any key studies containing future scenarios for your area with a focus on:	Could you list some interventions in your Region concerning adaptation measures to climate change in coastal areas, realised over the past 10 years?	Could you identify problems that hinder the development of risk maps in coastal zones (budget; technical competences; technical tools; lack of data or lack of shared data...)?	What would you suggest to the European Regional Development Fund (ERDF) for the next financial program (2014-2020)?
Creta	Changes in population size Population dynamics Economic evolution Land use changes Spatial planning		The budget issue is the most important. The Coastance project showed that the necessary data, technical competences and technical tools are available in the Greek market.	The development of a G.I.S. database including: • Coastal works all around the Region of Krete, • land uses and existing structures in coastal areas, • coastal land values • protected coastal habitats • coastline evolution based on analysis of successive satellite images A regional Coastal study to determine: • Sedimentary cells • Erosion and accretion rates based on historical orthophotomaps • Coastal dynamics • Main trends of sediment transport • Main rivers sediment yield • Main areas under erosion and submersion risk • Coastal flood risk maps • Available off-shore sand deposits appropriate for sand nourishment

Lazio	no	Nourishment defense work of Tarquinia (Nourishment protected by groynes, year 2004) Nourishment defense work of Terracina (only Nourishment, year 2006) Nourishment defense work of Fondi (Nourishment protected by groynes year 2006) Nourishment defense work of Formia (only Nourishment, year 2007) Nourishment defense work of Minturno (Nourishment protected by groynes year 2007)	Administrative and Organisational	The creation of an Interregional Obseratory for Mediterranean coastal monitoring, as introduced and sustained by Bologna Charter. The suggested formula could be the creation of a network among regional observatories able to cover data acquisition, collection, elaboration at the Med basin scale.
Emilia-Romagna	Climate Change Changes in population size Population dynamics Economic evolution Land use changes Spatial planning	Years 2002 and 2007 beach nourishment interventions with off-shore deposits sediments (1,7 Million of cubic meters along 10 km of critical coastal stretches) in order to widen and elevate the beach quota. "Da Vinci Gates" in Cesenatico harbour, completed in year 2005, in order to block marine ingression by events with water level up to 2,20 m, on medium sea level, accompanied by the realisation of artificial dunes "Giardini al mare" along inland promenade, with the same quota (+2,20 m), southward to the harbour, and a "managed retreat" intervention by the municipal Master Plan/ realignment of buildings in the area northward to the harbour.	---	To foresee a budget line for next financial period on erosion monitoring systems in the Mediterranean and a pilot action programme to finance demonstrations of best practices for adaptation of coastal zones to climate change. To re- launch the EUROSION Initiative, with a particular focus on the Med basin and giving the Regions a strong role in its definition and development. To foster the creation of an Interregional Observatory for the coast of the Med basin (as introduced within the" Bologna Charter" 2007), a network among regional observatories able to cover data acquisition, collection, elaboration at the Med basin scale. To foresee a budget for multidisciplinary analysis projects focused on the impact of shoreline retreat on coastal system (morphology, ecology, hydrology, ecc.) Promoting new interventions based on environmental engineering applicable at regional scale (dune recostruction; backshore restoration...

Toscana	Climate Change	Program of priority operations to reclaim and rebalance the littoral zone and the training activities under the integrated coastal management plan (Regional Council Resolution n. 47/2003).	Budget and lack of appropriate technical tools	The Development of Forecasting Models that are able to evaluate the morphologic response of the coastal plains to the rise in sea level (migration/changes in the beach-dune system).
FEPORTS	Climate change Changes in population size Population dynamics Economic evolution Land use changes Spatial planning	• Application of Agendas 21 • Beach regeneration • Control of CO2 emissions • Air quality improvement plans • Flood risk plan	Fortunately the risk maps have been carried out gradually and very intensely by different bodies (private companies, universities, regional government, central government, etc.) so that the requirements set by the European Commission for 2013 will be met. The major problems that have been encountered are mainly organisational and administrative.	Bearing in mind that progress in the subject of Integrated Coastal Management or Adaptation to Climatic Change evolves very slowly and implementation in regions such as the Valencian Community where action is mainly due to short term political and economic interests, the enforcement of the Barcelona Convention needs to be promoted, and, where necessary, regulatory frameworks based on Directives or Regulations established. Similarly, the promotion of inter-regional agreements or agreements between states and regions for the uniform, harmonised implementation of the CZIM premises and the goals to be attained for a suitable adaptation to climatic change is required. Perhaps, through European project finance programmes, projects could be put forward aimed at establishing a clear, well-defined and differentiating CZIM policy in and between coastal regions.
Murcia	Spatial Planning	no	Technical competences and Budget.	Monitoring Program of Mediterranean Coast

PACA	NO	A lot of means to fight the lost of surface of the beaches and to protect the human constructions are developed by the local authorities since 20 years. The municipalities have the role to manage their coastal line and they do a lot of small actions, principally of beach nourishment, without a global vision at the hydrosedimentary scale. The region try to give some tools to the local actors like atlases of risks, share of experiences and data, technical and financial help, bathymetric lidar data. Different experiences of geotextile's submarine dikes are done with good and bad results and it would be really interesting to share the results and experiences on these methods which are a reversible way of protection of our coasts against the waves.	The budget is a true problem because we must coordinate numerous sources of budget to arrive to constitute these atlases and it's not a recurrent process. It seems necessary to implement trainings of public managers to the use of the GIS and the data management. For technical competences on the thematic of erosion and technical tools it seems ok, but it's true that we need common guidelines for the creation of data and for doing the atlases.	We would suggest - that the regional ERDF envelops can be used to create data and atlases shared among the Mediterranean regions, especially between neighbor regions - that the methods used to protect the coastal zone, if they respect the orientations of the white book on adaptation to climate change must be financed by ERDF funds.
Liguria	no	no	Budget	Provide suitable financial resources to develop for all coastal areas risk mapping (erosion, submersion, flood)

Marche	no	Beach nourishment, hard defence structures.	Organizational regional structure and lack of human resources on that aspect	- To completely implement the EU Flood risk directive 2007/60/EC and its flood risk management plans (speaking from a regional point of view the directive appears as a good instrument but the real implementation structures from the National Government has to be done) - always dedicate a budget line to inform, to teach operative staff (es. Municipalities directly involved in civil protection on flood risk). - ameliorate prevention on urbanized coastal areas.
Cypro	Climate change	no		From the 2nd semester of 2011 Department of Environment has started to structure the National Plan on Adaptation to Climate Change.
Corse		Commune de Calvi : un épis et deux brise-lame + un engraissement de 55 000 m 3 de sable Ile Rousse : restauration d'un quai Ajaccio : Etude de réhabilitation et de protection de la Plage de Saint François Conseil général de Haute Corse : étude de faisabilité d'un programme de travaux de la plage de l'ospedale étude dans le cadre de la lutte contre l'érosion du littoral en Costa Verde. Réhabilitation de la plage de Cagnano Communauté d'Agglomération du Pays Ajaccien : renforcement de la digue de la station d'épuration des sanguinaires	La cartographie des risques nécessite une échelle fine. A partir de là, un budget doit être alloué afin d'acquérir les moyens techniques suffisants pour répondre à ce besoin. D'ici deux à trois ans on peut estimer que les cartes de risques dans la zone côtière de la région Corse seront achevées.	Une prise en compte des prescriptions qui sont faites dans les Plan de Prévention des Risques. Il y a une connaissance des zones sensibles et tant au niveau économique qu'écologique il serait souhaitable d'acquérir les moyens pour intervenir sur la réduction de ces risques et de leurs impacts.

ANNEX 2: Dissemination Dutch coastal protection

Analysis of the project safety of the Netherlands on Map (Veiligheid Nederland in Kaart - VNK) about the Methods adopted for hazard, exposed values and Vulnerability evaluation for flood risk assessment on Coastal areas

in cooperation with: ICZM Monitoring Centre of Lazio Region

DISSEMINATION DUTCH COASTAL PROTECTION

"ANALYSIS OF THE PROJECT SAFETY OF THE NETHERLANDS ON MAP (VEILIGHEID NEDERLAND IN KAART - VNK) ABOUT THE METHODS ADOPTED FOR HAZARD, EXPOSED VALUES AND VULNERABILITY EVALUATION FOR FLOOD RISK ASSESSMENT ON COASTAL AREAS"

REGIONE LAZIO (ITALY) - DIREZIONE REGIONALE AMBIENTE - CENTRO DI MONITORAGGIO G.I.Z.C

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Summary

The VNK project is multi-year project of the Dutch Government aimed at developing and validating a new methodology to assess the safety of the defences protecting the Netherlands from storm surge and river flooding. VNK is the acronym of *Veiligheid Nederland in Kaart* (Safety of the Netherlands on Map). In English translations the same project is presented as FLORIS (FLOod RISks and Safety in the Netherlands).

VNK is a result of the need for a renewed approach to safety stimulated by the exceptional high waters of the River Rhine in the 90's. It has been developed in two tranches known as VNK 1 (2001-2005) and VNK 2 (under way since 2008). Several national and supranational, legislative and governmental advances in the field of flood protection came into force in the meantime, including the EU directive on the assessment and management of flood risks of 2007.

At present, the coastal and riverine defences in the Netherlands are designed, assessed and maintained to withstand water levels and (where applicable) wave fields with assigned return periods, ranging between 250 and 10,000 years depending on location. Alternatively, the VNK methodology proposes to evaluate the safety levels through the *risk* associated to the consequences of a water-defence failure. A flood is firstly treated probabilistically as a combined result of a natural severe event and of a water-defence failure potentially occurring for a number of mechanisms. Secondly, the consequences are evaluated in terms of life losses and of direct and indirect damage to assets and infrastructures. Finally, the risk of flooding in a given area gives the amount of money that has to be set aside in an indefinitely long period to compensate for the damage possibly caused by all probable floods. A uniform methodology applied to the entire national territory also provides a reliable mapping of the vulnerability of the country.

The VNK project only aims at demonstrating the feasibility of an innovative approach and does not set normative levels for the risk that the water defences will have to withstand at some point in the future. The VNK results are expected to provide the basis for political and public debate on how to cope with flood risks, possibly adopting different safety standards. In the meantime, however, several other programs, briefly mentioned in this review, will benefit widely from the results of VNK; among those Water Safety for 21st Century (WV21, *Waterveiligheid 21e eeuw*), the normative toolkit for dike design and assessment (TOI, *Toets- en Ontwerpinstrumentarium*) and the Delta Committee program.

CHAPTER

1 The Netherlands

This chapter provides the reader with some basic information on geography, administration and water management in the Netherlands. The purpose is to highlight the relevance of flood protection for the Netherlands and to outline the context in which the VNK project is embedded.

1.1 ESSENTIAL GEOGRAPHY

Extension

The Netherlands is approximately 41,500 km^2 wide and nearly 20% percent is covered by inland waters. The Netherlands is thus about 7 times smaller than Italy and 4.5 times larger than Cyprus. The widest distance from east to west is 195 kilometres, while the widest one from north to south is about 310 kilometres. The total land border length is 1,027 kilometres. The Netherlands borders with Germany to the east and Belgium to the south. A satellite view of the country is given in Figure 1.

Sea

The coastline with the North Sea, on the western and northern sides, has a total length of 451 kilometres. The North Sea is a semidiurnal tidal sea (two highs and two lows per day) with amplitudes and phases that vary considerably along the Dutch coast. The average high water at different locations ranges from 58 to 205 cm above the chart datum (see Section 1.1.3), while the average low water ranges between -63 and -181 cm (Rijkswaterstaat, 2009), with the greatest values being reached within the estuaries.

Rivers

The Netherlands is the delta region of three of the largest rivers in Europe: the Rhine (from Switzerland and Germany, average discharge: 2,200 m^3/s), the Meuse and the Scheldt (both from France and Belgium, average discharges 230 and 110 m^3/s respectively).

The course of River Rhine branches off several times inside the Dutch territory. It enters the country at Lobith and, soon after the border, splits in two distributaries. The main branch with an average discharge of 1,500 m^3/s is called Waal and merges with Meuse before flowing into the North Sea in the so-called Southern Delta region (Section 1.1.4). The second branch is called the Pannerdensch Channel and with an average discharge of 700 m^3/s; it further splits into the Nederrijn/Lek river, which flows out at Rotterdam (average discharge: 475 m^3/s), and the IJssel that flows north towards the Lake IJssel (average discharge: 230 m^3/s).

1.1.1 TERRITORIAL ADMINISTRATION

State

The capital of the Kingdom of the Netherlands is Amsterdam. The government, diplomatic centres and international institutions are based in The Hague. On 1 August 2010 the Netherlands counted 16.609.145 inhabitants[1].

Provinces

The Dutch State is divided in twelve Provinces, shown in Figure 2 and listed in Table1.1 from north to south.

Municipalities

The Provinces are further divided in 430 municipalities which are in charge of the local regulations, taxation and administration. The four largest cities of the Netherlands (Amsterdam, Rotterdam, Utrecht, The Hague) are merged in the so-called *Randstad*, where fifty percent of the Gross National Product is created[2]. The Randstad spans over the provinces of North Holland, South Holland, Utrecht and Flevoland. 'G-4' is a term in use to indicate the Randstad together with the harbour of Rotterdam and the airport of Schiphol [3].

Water management

The territorial administration of water management is discussed specifically in Section 1.2.

Table1.1

The Dutch provinces.

Province	Area[4] [km^2]	Number of inhabitants[5] [2009]	Average income per inhabitant[6] [€, 2008]
Groningen	2885	576,631	22,389
Friesland	5672	646,293	22,840
Drenthe	2626	490,849	23,567
Overijssel	3370	1,130,025	23,653
Flevoland	2253	387,538	23,620
Gelderland	5146	1,998,367	24,806
Utrecht	1432	1,220,093	27,801
North Holland	4090	2,667,321	27,262
South Holland	3479	3,503,877	26,298
Zeeland	2756	381,350	23,888
North Brabant	5560	2,443,354	25,369
Limburg	2279	1,122,801	23,723
The Netherlands	**41,548**	**16,568,499**	**24,600**

1.1.2 REFERENCE SYSTEMS

Vertical

The Dutch chart datum for altitudes is called NAP (*Normaal Amsterdams Peil*, Amsterdam Normal Level). In general, the difference between the mean sea level (MSL) and the NAP is

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1 www.cbs.nl

2 http://www.europa- nu.nl/id/vhubm2le7ire/west_nederland_randstad

3 http://www.grotevier.nl/

4 http://www.plaats.nl/provincie-drenthe/alles-over/ oppervlakte/

5 http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=37230NED&D1=17&D2=5-16&D3=101&HDR=T&STB=G1, G2& VW=T

6 http://www.cbs.nl/nl-NL/menu/themas/inkomen-bestedingen/publicaties/artikelen/archief/2008/2008-2407-wm.htm

within a few centimetres, although the MSL may depart from the NAP level by up to 24 cm at locations inside estuaries (at Rotterdam) (Rijkswaterstaat, 2009).

Horizontal

The Dutch geographical system uses the National Triangulation System (*Rijksdriehoekstelsel)*, also referred to as *RD-coordinates*. The origin of this system is located in the city of Amersfoort, but it is then translated to Paris in order to give positive coordinates over all the Dutch territory. This coordinate system is used by the several governmental institutes including the Land Registry (*Kadaster*), for GIS referencing, for drawing the official map of the country and for all topographic maps.

1.1.3 ALTIMETRY

The elevations of the ground and sea bottom in the Netherlands are shown in Figure 3. The areas in black are 2.5 m *above* NAP and those in white are 1 m *below* NAP. The lowest ground level is found at – 6.76 m, the highest at 322.7 m.

More than 60% of the country is either below the sea level or below the high-water level of rivers. Six million people (2 million full-time jobs) live in flood-prone areas. In 2007, one third of the GDP was generated in flood-prone areas for an amount of 182 billion euro. The geographical repartition of various economical activities is shown in the chart of Figure 4[7].

Since the regions below sea level have been gained through the progressive land reclamation over the centuries, the territory above sea level is commonly referred to as the 'high ground' (*hoge gronden*) or 'old land' (*oud land*).

1.1.4 OUTLINE OF THE DUTCH COAST

The North Sea coast

The coast is geographically divided in three main parts from north to south:

- The Dutch Wadden Sea (*Waddenzee*). This is the sub-basin of the North Sea enclosed between the mainland and five barrier islands in the north – see Figure 5. The Wadden Sea is listed as a UNESCO World Heritage Site since 2010[8]. The 100 km^2 wide Eems-Dollard estuary forms the eastern part of it at the boundary with Germany.
- The Coast of Holland (*Hollandse Kust*), about 100 km long between the cities of Den Helder in North Holland and Hoek van Holland at the mouth of the Nederrijn/Leek river, in South Holland (recall Section 1.1).
- The Southern Delta (*Zuidelijke delta*) comprising of the southern stretch of South Holland and the province of Zeeland – see Figure 6. This area comprises of the left bank of the port of Rotterdam (*Maasvlakte*) and of the access to the harbour of Antwerp in Belgium through the mouth of the western Scheldt River.

Hydraulic structures

A number of hydraulic structures are also present in the coast.

- In the Wadden Sea:

[7] http://www.cbs.nl/en-GB/menu/themas/macro-economie/publicaties/artikelen/archief/2009/2009-2935-wm.htm

[8] http://whc.unesco.org/en/list/1314

  - o Lauwersoog, a 13-km long closure dam with sluice (a tidal area of about 100 km^2 was closed off from the sea in 1969) .
  - o Afsluitdijk, 32 km-long closure dam connecting Friesland and North Holland, with sluices and navigational locks (closed in 1932) – see Figure 7.
- In the Coast of Holland:
  - o The harbour moles and sluice gates of the port of Amsterdam (IJmuiden).
  - o The (smaller) harbour moles and sluice of the city of The Hague (Scheveningen).
- In the Southern Delta:
  - o Maeslantkering and Hartelkering, as storm-surge barriers.
  - o Closure dams with sluices in the mouths of the former estuaries Grevelingen and Haringvliet.
  - o Storm surge barrier (total length ca 8 km) in the Oosterschelde, including a large number of separation dams with sluices inside the former estuaries.

The hydraulic structures in the Southern Delta are collectively referred to as the Delta Works (*Deltawerken*)[9].

Lake IJssel

Another prominent feature is the Lake IJssel (*IJsselmeer*) – see Figure 7 – resulting from the closure of the connection between the former Southern See (*Zuider Zee*) and the Wadden Sea. Lake IJssel receives the waters of River IJssel and Vecht, which are further discharged into the Wadden Sea through the sluices in the *Afsluitdijk*.
The water level is regulated with slightly lower levels in winter period (to be able to accommodate high river runoffs) than in summer period (when an extra volume of fresh water is needed to overcome possible dry periods).

A second major dike was built in the south-western Lake IJssel between 1963 and 1976 to connect the provinces of Noord-Holland and Flevoland: this is the 26-km long *Houtribdijk*. It divides two water bodies: the greater Lake IJssel and the *Markermeer* in the southwest.

1.2 WATER MANAGEMENT AND COASTAL PROTECTION

The Big Flood of 1953

The key event at the origin of the current Dutch flood-protection policy is the catastrophic flood of 1 February 1953 affecting Belgium, The Netherlands and the United Kingdom. In the Netherlands, in particular, the breaching of the sea dikes due to an exceptionally severe storm caused 1,836 victims and the inundation of 136,500 hectares of land (Gerritsen, 2005 -- the interested reader is referred to that entire special issue of the Philosophical Transactions of the Royal Society A).

Delta Committee 1953

Soon after the 'big flood' of 1953, a panel of 14 experts (the so-called *Deltacommissie*) was appointed to advise the Ministry of Transport on how to provide adequate flood protection for the future. In the final report finalised in 1960 and 1961, based on engineering and socio-economic considerations, they conceived the so-called Delta Programme (*Deltaplan*) for flood defences. A risk-based approach is already conceptually formulated therein, but not yet prioritised for implementation. In particular, they

[9] http://www.deltawerken.com/English/10.html?setlanguage=en

- Identified extreme high waters, and thus overflow and wave overtopping, as the greatest threat for the coastal water defences;
- Proposed to (re)design the primary water defences so as to withstand severe flood-giving events with assigned return times (see also Safety Levels in Section 1.3);
- Promoted the realisation of the Delta Works to protect the Netherlands from storm surges.

Delta Committee 2007

A second Delta Committee (also known as Sustainable Coastal Development Committee or as Veerman Committee) was appointed in 2007-2008 [10]. Its task was to advise the government over the consequences for the Dutch coast of sea-level rise, greater variations in river discharge, and social and climatological developments; and over the strategies for sustainable development and long-term added value for the entire country. The final report (*Samen werken met water*, Working together with water) is also available in English (see References in Section 1.4).

National Water Plan 2009-2015

The governmental National Water Plan (NWP, *Nationale Waterplan*[11]) of 2009 followed on the work of the Delta Committee 2007. The NWP sets the water-management guidelines to follow in the years 2009-2015 in order to guarantee future safety, liveability and wealth. The NWP consists of individual water framework directives[12] for the four areas of influence of the Dutch rivers (Eems, Maas, Rhine delta, Scheldt) – see Figure 8.

Further initiatives

Further initiatives following the works of the second Delta Committee include the institution of a Delta Commissary, of the (second) Delta Programme and of specific funding schemes. These are not discussed in this report[13].

1.2.1 LEGAL FRAMEWORK

The Water Act 2009

The so-called *Waterwet*[14] (Water Act) of 2009 is the current law providing the legal framework for the management of surface- and ground-waters with an integrated approach, with consideration for climate change, water policy and spatial planning.
This recent law unifies eight pre-existing water-related laws, including the *Wet op de waterkeringen* (Flood Defense Act) of 1996 which specifically dealt with flood protection.
The Water Act is considerate of the EU Framework Directive Water (2000/60/EC).

The Water Decree 2009

The so-called *Waterbesluit*[15] (Water Decree) of 2009 completes the Water Act with several other prescriptions. Among others, it lists the waters and water defences under the direct management of the State and delimits the river basins. In particular, it states that the

[10] http://www.deltacommissie.com/ (also in English)

[11] http://www.rijksoverheid.nl/onderwerpen/water-en-gebruikers/vraag-en-ant woord/wat-is-het-nationaal-waterplan.html (in Dutch)

[12] http://www.helpdeskwater.nl/onderwerpen/wetgeving-beleid/kaderrichtlijn-water/uitvoering/nationaal/item_27248/ (in Dutch)

[13] http://www.deltacommissaris.nl/english/

[14] http://www.waterwet.nl (in Dutch)

[15] http://wetten.overheid.nl/BWBR0026872/geldigheidsdatum_26-01-2011#Hoofdstuk4_5 (in Dutch)

National Water Plan (section 1.2) must include a flood-risk management plan in compliance with the European Directive on Floods (2007/60/EC).

It should however be noted that the Water Act and the Water Decree are not the unique pieces of legislation dealing with specific water-related issues. This topic is not covered in this report.

The Water Act formally recognises three institutions having water-management responsibility:
- the State for the national waters (Section 1.2.2),
- Provinces (Section 1.2.3)
- the Waterboards (Section 1.2.3) for the remaining waters and for wastewater treatment (*Ministry of Transport, Public Works and Water Management, 2008)*.

1.2.2 NATIONAL GOVERNMENT

The Ministry

The Dutch government administrates the issues concerning water through the Ministry of Infrastructures and Environment (*Ministerie van Infrastructuur en Milieu*) recently instituted in October 2010.

This Ministry takes over the competencies of the former Ministry of Transport, Public Works and Water Management (*Ministerie van Verkeer en Waterstaat – MVW* or *VenW*)[16].

General Directorates and Agencies

The organisation chart of the Ministry of Infrastructure and Environment in the current cabinet is shown in Figure 9, which still refers the previous MVW. In particular, the Ministry counts three General Directorates (*DG*'s) responsible for the policy-making specifically on
- Mobility (*Mobiliteit*)
- Aviation & Maritime Affairs (*Luchtvaart en Maritieme Zaken*)
- Water

and three agencies
- *Rijkswaterstaat (RWS*), for Public Works and Water Management
- Inspection of Transport and Water Domain (*Inspectie VenW*)
- The Royal Dutch Meteorological Institute (KNMI)

Both the DG-Water and RWS are involved in the organization of VNK (see Chapter 2).

Rijkswaterstaat

The *Rijkswaterstaat* (RWS)[17] is the ministerial agency in charge of the execution of public works concerning transport and water, including flood protection (9,000 employees over 240 offices). It aims at providing the Dutch citizens with "dry feet, sufficient clean water, smooth and fast transport on roads and waterways, reliable and useful information".

Rijkswaterstaat consists of an executive board and a general board, which set the strategy for the period of appointment, manage the contacts with the other Ministry departments and report to the Minister on budgeting. Also, with reference to Figure 9, within RWS there are five offices with nationwide competencies, namely
- RWS Traffic and Shipping

16 http://english.verkeerenwaterstaat.nl/english/

17 http://www.rijkswaterstaat.nl/

- RWS Water (also known as *Waterdienst* and, previously, as *DWW*)
- RWS Infrastructure
- RWS Data ICT
- RWS Corporate

as well as several offices focussed on regions, for example

- RWS North Holland
- RWS Ijssel Lake
- RWS South Holland
- RWS North Sea.

Also, large nationwide programmes can be controlled by *ad hoc* offices, for example: RWS *Ruimte voor de Rivier*[18], a multi-year flood-mitigation programme, stimulated by the floods and alerts of 1993 and 1995, and aiming at the enlargement of restricted river floodplains (2.3 billion € over the period 1995-2015).
The administration of the VNK project is discussed in detail in Chapter 2.

1.2.3 LOCAL WATER MANAGEMENT

Waterboards

Beside the state administration (Section 1.1.1), the Netherlands is also divided in 27 Water Boards (*waterschappen*) that are responsible for water management, wastewater treatment and disposal, water supply for civil, industrial and agricultural purposes, and flood protection[19]. These are shown in Figure 10.

Each *Waterschap* controls a territory that does not necessarily overlap with Provinces and Municipalities. Residents pay taxes to the respective water board in return for their services. The Water Boards also get funding from the national Government to implement approved works, as specified next.

Provinces

While the State decides the level of safety applied to the primary defences, the Waterboards have to carry out the necessary maintenance works, determine their safety at regular intervals and report to the Provinces for assessment. The Provinces report their assessment to the government who grants the funding for the dike improvements.

Note that Provinces and Municipalities are not directly responsible for water management, although they have a voice for decisions having impact on their competencies. Provinces have a controlling role over the Waterboards (read further) and also define the safety levels of regional dikes and areas outside the dike.

1.3 COASTAL PROTECTION

The coastline

Formally, the Dutch sandy coast is defined by the Base Coastline (*basis kustlijn, BKL*), which defines the position of the coastline based on a volumetric approach. Roughly speaking it contains the minimal amount of sand necessary to protect the inland areas (considering the volume of the dunes behind).

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[18] http://www.ruimtevoorderivier.nl/meta-navigatie/english.aspx

[19] http://www.waterschappen.nl/wat-doet -een-waterschap.html

Every year the coastal profiles are measured at regularly-spaced locations alongshore (ca 200 m distance) and the actual volume of sand is used to calculate the position of the so-called momentary coastline (*momentane kustlijn, MKL*). When the MKL is farther inland than the base coastline, beach nourishments are effected to restore the minimum amount of sand required for safety.

Classification of water defences

The Dutch water defences are categorized into

- Primary: A primary *line of defence* is formed by dikes, dunes or hydraulic structures that protect the dry land from the marine and river water directly. Primary defences are listed in the Water Act and they are managed by Rijkswatersaat and the Water Boards. Their total length is about 3600 km
- Secondary: A secondary dike is a water defence not listed by the Water Act that protects regional areas from secondary streams, canals and small lakes. Their total length amounts to a about 11,000 km
- Tertiary: Tertiary dikes are water defences protecting from water that has no contact with open waters. These water defences protect only against very small lakes and streams.

The Water Act does not contain further specific instructions regarding the primary defences (MVW, 2008), since it serves mainly as a framework law for the development of further water-related legislation.

The Dutch water defences are legally divided in different parts. The core area (*kernzone*), similar for dike and dunes, is the heart of the defence and every action on the water defence must be approved by the dike administrator (most often the Water Boards). For example, new buildings on the dune areas should be guaranteed not to enhance erosion and not to reduce the safety level at that particular cross-section.

Typology of water defences

The primary coastal protection in the coast of Holland is mainly provided by dunes and, for limited stretches of North Holland, by dikes (the *Hondsbossche en Pettemer* sea defences).
The Delta Works protect the low-lying regions of South Holland and Zeeland.
The coast of the Wadden Sea is protected by dikes, often in combination with salt marshes.

The dike rings

The Water Act designates the 53 areas enclosed by primary defences (dike ring, *dijkring*) that form the backbone of the Dutch flood-defence system -- see Figure 11. There are also a few water defences that connect two or more dike rings to each other, like the *Afsluitdijk*.
The Water Act also designates additional 42 dike rings along the river Meuse in the southern country are called *Maaskades* that are handled separately, since they are not subject to the remote effect of tidal excursions.

Safety levels

The Water Act also tabulates the safety levels assigned to the dike rings in the Netherlands, shown in Figure 12. These safety levels are expressed by the return frequency of the water level that the flood defence needs to withstand.

In coastal areas, the safety levels take exceedance frequencies of 1 in 10,000 years (South and North Holland; in red) and 1 in 4,000 years (elsewhere; in orange). These values were first set by the first Delta Committee based on econometric analysis (Jonkman et al, 2008). It is noted that a 1/10,000 years frequency does not mean a flood probability of once per 10,000 years. The idea is that the flood defence is strong enough to withstand, with a safety margin, a storm surge with a frequency of occurrence of 10^{-4} per year. In practice and based on probabilistic procedures, the probability of a real flood will be around once per 100,000 years (for those areas designed for a 10^{-4} attack).

In the river dike rings, the exceedance design frequencies are 1 in 2000 years (downstream stretches of the Rhine; in yellow) and 1 in 1,250 years (elsewhere; in green). The dike rings along the Meuse River are designed with a 1-in-250 year flood return period. These values are set based on consideration of predictability, water depth expectations, expected damage, and fresh-salt water balance.

The remaining territory of the Netherlands is regarded as non flood-prone area (*hoge gronden*).

Hydraulic Boundary Conditions

The exceedance statistics of either the river discharge at the national border or of the water levels and waves are used to determine statutory water levels at each locations.
These statutory exceedance values are determined with specific hydraulic models for each stretch of primary defence having uniform characteristics. (The crest of the dike, for example, must be at least half a meter higher than the water level with the statutory exceedance level.) This knowledge is collectively known as the Hydraulic Boundary Conditions (*Hydraulische Randvoorwaarden, HR*) and is assembled based on the state-of-the-art modelling techniques.

The hydraulic boundary conditions are updated every six years (previously every five years) and are approved by the Minister competent for the water domain. Since the institution of these regular revisions in 1996 with the Flood Defence Act, the hydraulic boundary conditions have already been updated in 2001 and 2006, while those for 2011 are in preparation. The next round is planned for 2017. In each new round, new academic and practical insights (such as new field data) about critical conditions and failure mechanisms are used to improve the assessment of the current safety situation.

Safety assessment

In parallel with the regular update of the hydraulic boundary conditions, all primary water defences are tested by the Water Boards to verify whether they still meet the statutory standards. In 2011, for example, the water defences are tested against the criteria set by the Hydraulic Boundary Conditions of 2006. For this purpose, the Ministry for Infrastructures and Environment issues the guidelines to test the primary water defences (*VTV: Voorschrift Toetsen Op Veiligheid van Primaire Waterkeringen,* Instructions for Assessing the Safety of the Primary Defences).

On the one hand, dike safety is tested for failing mechanisms such as overflow and wave overtopping, and stability. Several facets of stability are considered, such as piping, heave, macro-stability of the inner and outer slopes, micro stability, stability of the revetment, deformation of land between dike and water. Some of those are also considered in the VNK methodology (see Chapter 3).
On the other hand, dune safety is tested against erosion caused by the wave attack during storms.

As a result of the assessment, each stretch of water defence can be approved, rejected or given a 'no verdict' flag. A rejected water defence is scheduled for restoration in the framework of the High-Water Protection Program (*Hoogwaterbeschermingsprogramma*) funded by the Government. For example, strengthening works have already been finalized or are currently under way at the sea defences of Hondsbossche and Pettemer, Katwijk, Noordwijk and Scheveningen.

Relation with VNK

The VNK project is not part of the existing regulatory monitoring programmes. However, the calculation of the flooding probabilities in the VNK methodology is closely related to the existing safety assessment, although the information needed to carry out the probability calculations within VNK is more extensive. Moreover, the consequences of any flooding is an important part of VNK in order to be able to compute the flood risk (probability times damage), whereas this plays no role in the standard safety assessments. It can further be expected that the existence of dike stretches with a 'rejected' or 'no verdict' status increases the vulnerability of an entire dike ring.

1.4 SOURCES AND REFERENCES

- Deltacommissie, 1960-61. *Rapport Deltacommissie*. 6 volumes. Staatsdrukkerij- en Uitgeverijbedrijf, Den Haag.
- Deltacommissie, 2009, *Working together with Water, A living land build for its future, Findings of the Deltacommissie 2008*, Hollandia Printing. (Downloadable from www.deltacommissie.com/doc/deltareport_summary.pdf)
- Jonkman SN, Kok M, Vrijling JK. 2008. Flood Risk Assessment in the Netherlands: A Case Study for Dike Ring South Holland. *Risk Analysis*, 28:1357-1373
- Gerritsen H, 2005. What Happened in 1953? The Big Flood in the Netherlands in Retrospect. Phil. Trans. R. Soc. A, 363:1271-1291
- Ministerie van Infrastructuur en Milieu (voorheen: Ministerie van Verkeer en Waterstaat). 2007. *Hydraulisch Randvoorwaardenboek 2006*, ISBN: 978-90-369-5761-8. (In Dutch).
- Ministerie van Infrastructuur en Milieu (voorheen: Ministerie van Verkeer en Waterstaat). 2007. *Voorschrift Toetsen op Veiligheid Primaire Waterkeringen*, ISBN: 978-90-369-5762-5. (In Dutch).
- Ministerie van Infrastructuur en Milieu (voorheen: Ministerie van Verkeer en Waterstaat, directoraat-generaal Water). 2008. *De Waterwet in het kort*. (In Dutch)
- Rijkswaterstaat, 2009. *Getijtafels voor Nederlands* 2010 (Tide Charts for the Netherland), SdU Uitgevers BV, Den Haag ISBN 978-90-12-13111-7

Figure 1

The Netherlands, satellite view.

Source: Google Maps Pro (licensed to Joost Hoekstra, ARCADIS NL)

Figure 2

The Dutch Provinces
and major cities.

Source: own drawing

Figure 3

Altimetry of the Netherlands.

Data source: RWS. Processing: Alkyon HC&R

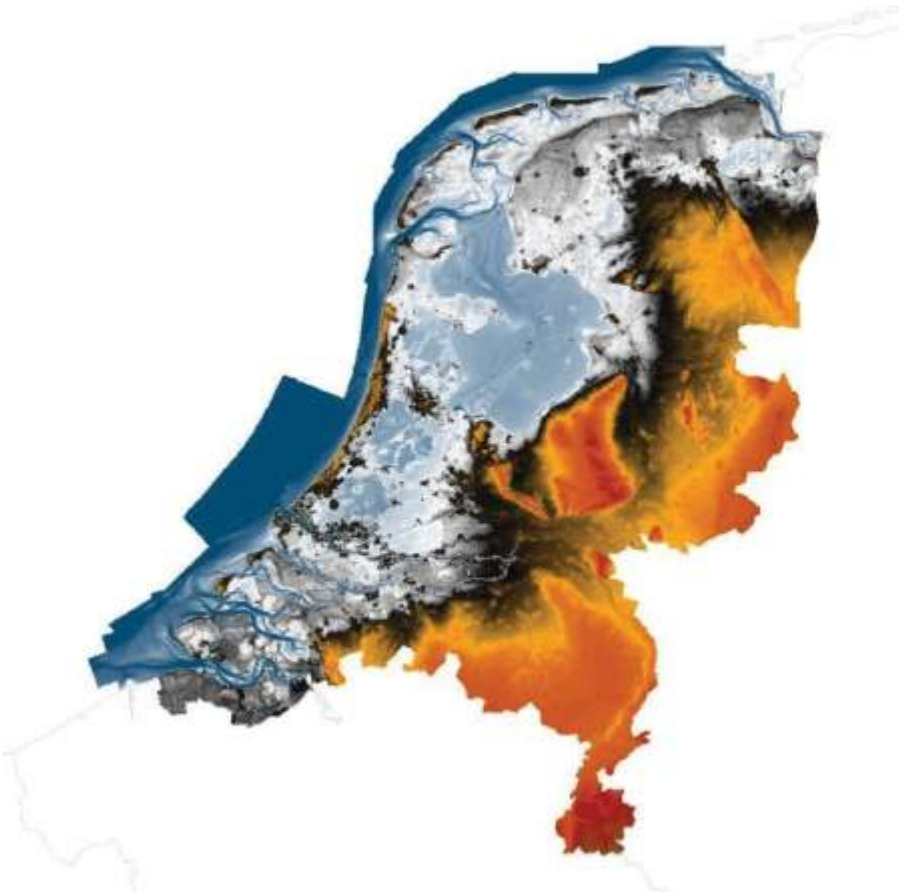


Figure 4

Share employment per sector in flood-prone and non flood-prone areas (in labour years), 2007.

Source: www.cbs.nl; Centraal Bureau de Statistiek, The Hague/Heerlen

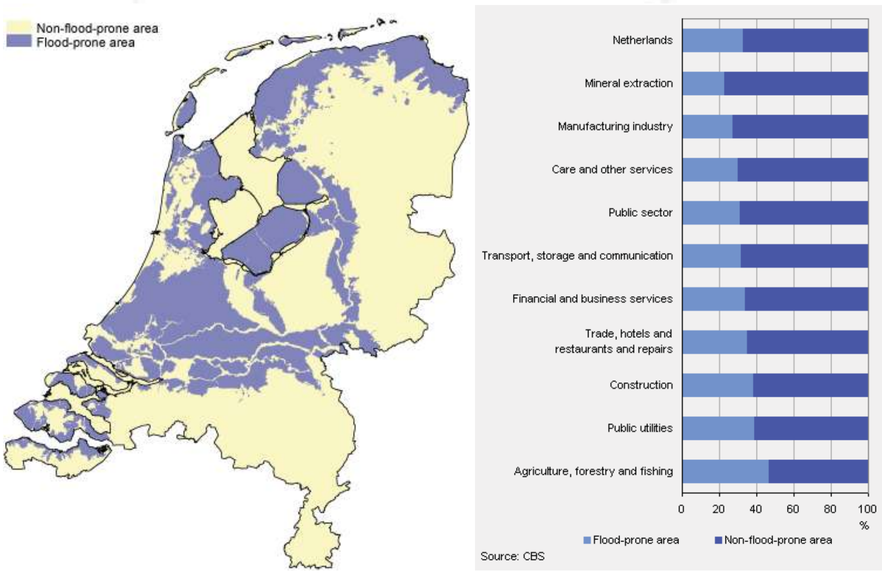


Figure 5

The Wadden Sea.

Source: Google Earth Pro (licensed to Joost Hoekstra, ARCADIS NL)

Figure 6

The Southern Delta.

Source: Google Earth Pro (licensed to Joost Hoekstra, ARCADIS NL)

Figure 7

The Ijssel Lake. The dikes are the Afsluitdijk (north) and Houtribdijk (south).

Source: Google Earth Pro (licensed to Joost Hoekstra, ARCADIS NL)

Figure 8

Districts for the National Water Plan (2009).

Source:
www.helpdeskwater.nl;
Helpdesk Water, Lelystad

Figure 9

Organisation of Ministry of Traffic and Water Management (Infrastructure and Environment since October 2010).

Source:
http://www.rijksoverheid.nl/ministeries/ienm
Ministerie van Infrastructuur en Milieu, The Hague

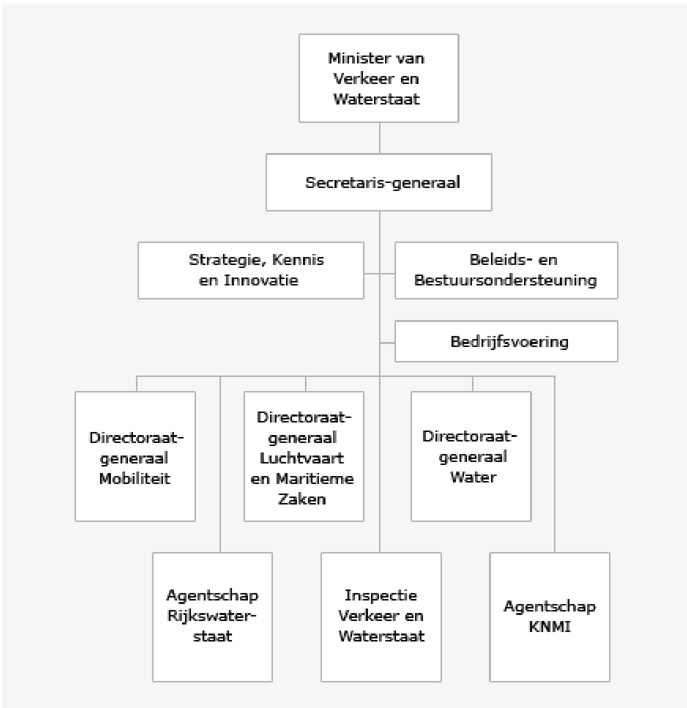


Figure 10

Waterboards.

Source:
http://www.uvw.nl/; Unie van Waterschappen, The Hague

Figure 11

The first 53 dike rings according to the Water Act 2009

Source: www.overheid.nl; Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, The Hague.

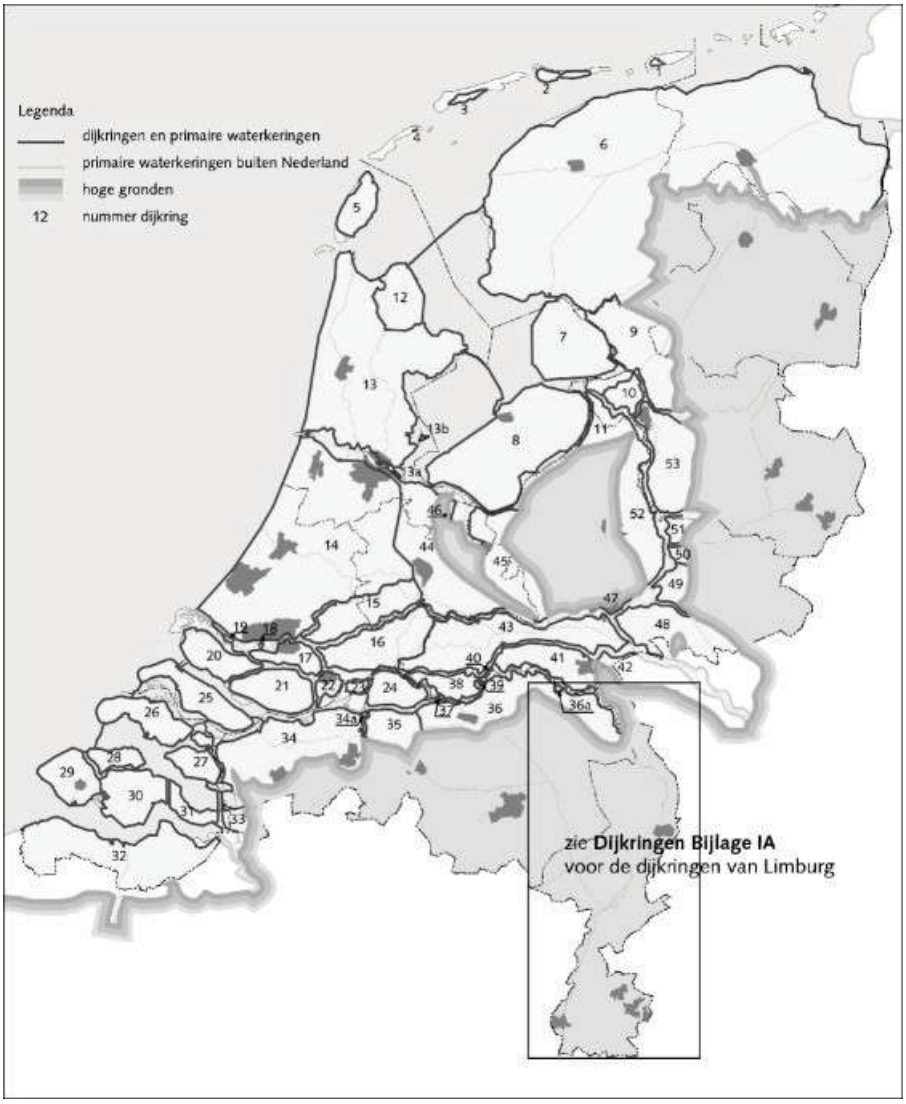
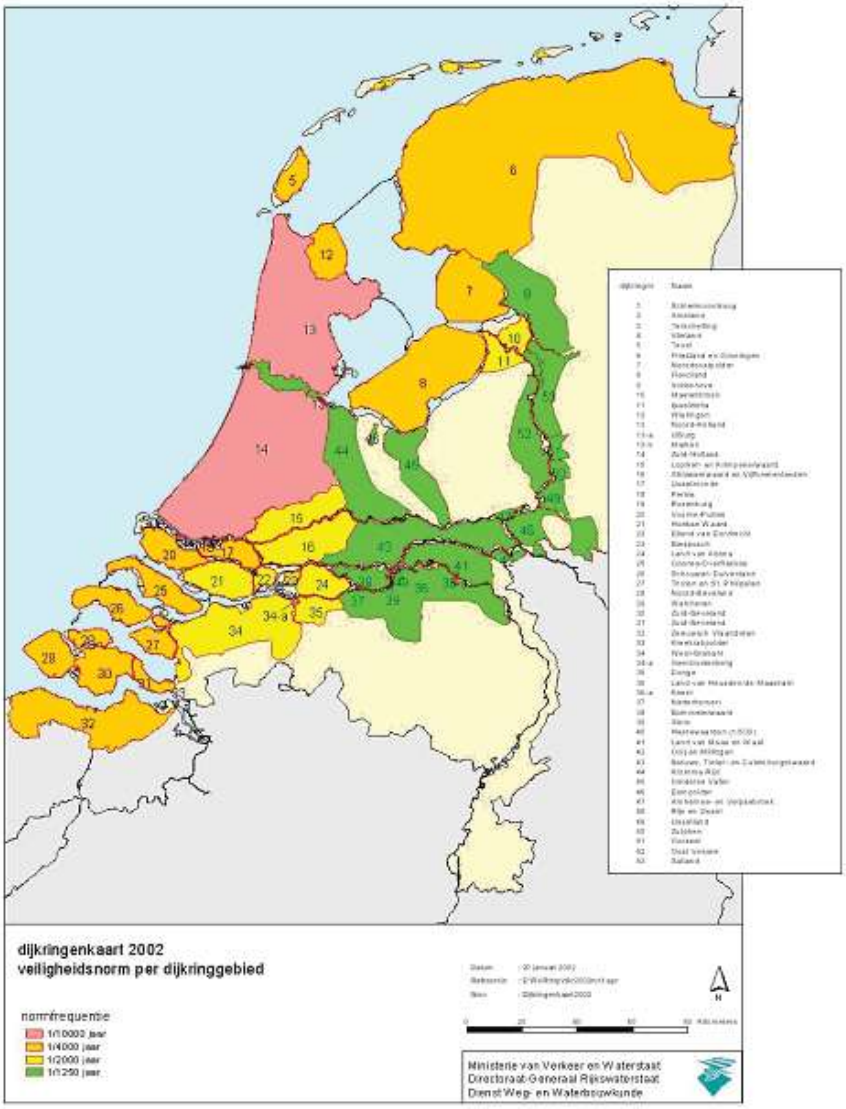


Figure 12

Safety levels for the first 53 dike rings.

Source: http://www.rijksoverheid.nl/ministeries/ienm; Ministerie van Infrastructuur en Milieu, The Hague.



CHAPTER 2 The VNK project

This chapter describes the origin, institution and development of the VNK programme, the focus topic of this document. Methodologies and results are discussed in Chapters 3 and 4.

2.1 PRECEEDING WORK

A Different Approach to Water (2000) (WB21)

During the 1990's the water levels of the Dutch rivers reached both severe highs and extraordinary lows leading to critical situations. For example, the maximum discharges of the Rhine River in of 1993 and 1995 reached the fourth and second values on record since 1900 (in excess of 10,900 m^3/s)[20]. Up to 200,000 people had to be evacuated with severe discruption to the national economy. Fortunately no dikes breached and the damage was minimal.

Long-term concerns from issues such as climate change and increasing population density also revived the rationale of a risk-based approach. These occurrences stimulated the then State Secretary of the Ministry for Traffic and Public Works to establish an Advisory Committee on Water Management Policy in the 21st Century in 1999.

As a result of the committe's recommendations, the Cabinet's memo 'A Different Approach to Water – Water Management Policy in the 21st Century' (*Anders omgaan met water – Waterbeleid in de 21e eeuw*) of 2000 set the political agenda towards an integrated and proactive approach to water management in the Netherlands. The main points of the approach consisted in

- Anticipating the consequences of future trends and designing current water-defence strategies accordingly;
- Allocating more space for flood water (such as widening and lowering flood plains) in addition to traditional technological measures (such as dike heightening and reinforcement);
- Mitigating the downstream aggravation of floods by prioritising the local retention and storage of excess water (flood and precipitation).

While primarily addressing river flood emergencies, the Government's recommendations had a bearing on coastal defences too.

From Exceedance Frequencies to Flood Probability (2000)

In 2000 the Technical Advisory Committee on Water Defence (*TAW*; now Expertise Network Water Defences), an independent panel of experts, supported the shift of paradigm for the flood defences from the *exceedance frequency of high-water levels* to *probability of flood occurrences*. Compared to the statutory method, they considered additional dike-failure

[20] http://live.actuelewaterdata.nl/cgi-bin/measurements/LOBI.Q10?template=afvoeren (in Dutch)

mechanisms (overflow and wave overtopping, sliding, erosion of revetment, and piping) as well as the failure of hydraulic structures and the role of uncertainty.
Pilot calculations were carried out in four test dike rings (the SPRINT project) leading to the conclusions that

- The flooding probability could actually be calculated;
- The new method could be used to identify 'weak spots' in the dike rings (where the combined probability of flooding is higher than the regulatory probability of high water) and to assess the efficacy of the remediation works;
- The role of the uncertainties inherent in natural processes, in the physical and in the statistical models is an important one for the safety assessment.

As a result, the Ministry approved the suggestions to extend these pilot calculations to all dike rings and to aim at improving the safety approach developed by the Delta Committee in the 1960's. This marked the beginning of the VNK project.

2.2 MOTIVATIONS AND AMBITIONS

Goal

The VNK goal, in a formulation of 2001, is "to obtain insight into the probability of flooding in the Netherlands, the consequences of flooding and the uncertainties involved when identifying the probabilities and consequences. Based on this understanding it will be possible to gain an overview of the weak spots in the dike rings and the risk of flooding can be determined" (VNK 1 Project Bureau, 2001).

FLORIS = VNK

In the English translation the project VNK (*Veiligheid Nederland in Kaart*) is also presented as FLORIS (FLOod RISk and Safety in the Netherlands).

Tracks/routes to the goal

The VNK goal is to be achieved through four lines of action ('tracks' or 'routes') (Project Floris, 2003)

- Determining the probabilities of flooding in all 53 ring areas;
- Assessing the safety of the hydraulic structures;
- Determining the consequences of flooding;
- Coping with uncertainties.

Collateral goals

Some collateral benefits of the VNK programme were also identified :

- An update survey of flooding exposure in the Netherlands;
- The identification of the 'weak links' in the dike-ring system, with a first estimate of the costs for improvement (also a criterion for prioritisation);
- Scientific progress in techniques and methods for protection against high water.

Development levels

It was expected from the outset that the final results would have been achieved in steps. Three levels are used to classify the intermediate results expected from VNK with respect to their reliability and usability. These are known as 'development levels' and determined as follows:

- *Level 1*, when the calculated probability of flooding only gives an rough estimate of the actual probability;
- *Level 2*, when the calculations of the probability of flooding and of the flood consequences enable the comparative assessment of dike rings that are similar. For

example, the criteria used to identify weak spots in one dike ring can be used to assess another dike ring where a detailed study has not been carried out yet;

- *Level 3*. The probabilities of flooding and the consequences are determined with an acknowledged margin of error. As a result of the controlled uncertainty, cost-benefit analyses can be carried out, for example to determine the investment that offsets the increase in safety. Also, the flood risk may be compared with other collective risks, such as transport of hazardous material, terrorism, and so forth.

EU Framework Directive Flood

Although the risk-based approach underlies both initiatives, there is no direct link between the VNK and the Flood Directive of the European Union of 2007. This link was formally set by the Water Decree of 2009 (see Section 1.2.1).

Climate change

VNK does not take into account climate-change scenarios.

2.3 ORGANISATION

Project Office VNK

VNK is guided by the Project Office VNK (*Project Bureau VNK*), consisting of experts from the Ministry, Water Boards, Provinces and (hired) engineering consultancies. The Project Office VNK, working within the *Waterdienst* of Rijkswatersaat, is responsible towards the Ministry of Infrastructure and Environment and publishes the individual reports per dike ring. Also, it provides the guidelines that the operating consortia (see later) follow to operate within VNK.

Teamwork

The VNK involves the participation of several figures and parties from the Ministry and the Public Administration (*Bestuurders*), as schematised in Figure 13. These are in detail

- The Secretary of State for the Ministry
- The General Directorate Water (*DG Water*)
- The Agency for Public Works and Water Management *(Rijkswatersaat/Waterdienst)*
- The Water Boards (*Waterschappen*)
- The Union of Water Boards (*Unie van Waterschappen*)
- The Municipalities *(Gemeenten*)
- The Association of Dutch Municipalities (*VNG)*
- The Provinces (*Provincies*)
- The Interprovincial Consultation Board (*IPO*)

In particular, being responsible for the management of the flood defences and for the safety of the dike rings in their area of competency, the Water Boards provided the data on the dikes, dunes and other flood-defence elements. The Provinces contributed by providing information on the consequences of flooding. Also the study results on the failure probability as well as on the risk mapping will be reviewed by the Water Boards and Provinces, so that their experience and opinion can be taken into account in drawing the conclusion.

Knowledge development

New methods needed for the implementation of the VNK methodology were developed by:

- RWS
- Universities and research centres
- Consulting firms.

Work and consortia

The calculations have been mostly carried out by a number of engineering service providers, selected with European tendering procedure. Any staff working on VNK was required to have a BSc or MSc degree in civil engineering, with at least three years of experience.

The appointed consortia deliver their results to the Project Office VNK who reviews them and submits them to the auditing committee for approval (see later). The work is finally published under the collective authorship of Project Office VNK.

The VNK Project Office too is actively involved in additional engineering studies, also in co-operation with engineering companies and research institutes.

Consortia

The workload for VNK (both in its parts VNK 1 and VNK 2 – read later Section 2.4) has been assigned on the basis of the dike rings. The following consortia of engineering companies were appointed for the execution of the project:

- Albicom (19 dike rings) composed by Alkyon Hydraulic Consultancy & Research, Lievense Ingenieursbureau, Ingenieursbureau BCC (nowdays RPS-BCC) and Iv-Infra
- ARCADIS, Royal Haskoning and Fugro (4 dike rings)
- DHV, TAUW and Oranjewoud (23 dike rings)
- Grontmij and Witteveen+Bos (7 dike rings)

During the development of the VNK programme, the company Alkyon Hydraulic Consultancy & Research was taken over by ARCADIS.

Quality control

The Expertise Network Water Defence (formerly Technical Advisory Committee on Water Defences) set up an external audit team for the quality assurance of VNK. Methods and results have been reviewed by the ENW Safety Working Group since September 2004.

Financial resources

The VNK project is funded by the Ministry, the Interprovincial Consultation Board (IPO) and the Union of the Water Boards (UvW). At the time of writing this report, no detailed information on the budgeting was available.

2.4 VNK 1 AND VNK 2

Time plan

The first action plan of VNK was drawn in 2000. The project started in July 2001. In 2002 the calculations of the probability of flooding of the first 6 dike rings, all of them along rivers, had been completed. In theory the calculations for the complete dike system should have been completed in 2004.

However, not all the knowledge to determine the probabilities of flooding was readily available. Firstly, considerable research had to be carried out to reduce the uncertainties in modelling the failing mechanisms (especially piping) so as to bring the computed probability of flooding down to acceptable levels. Secondly, the development and application of the assessment method for the hydraulic structures required special efforts. Thirdly, collecting the new necessary information on the primary defences was time-demanding and, finally, the computational times were longer than expected.

Analysed dike rings

Therefore, the number of dike rings under analysis was restricted to 16 – see Figure 14. The additional 10 rings were selected for their usability as templates since they include urban and rural areas as well as low-lying *polders* and 'old land'. Moreover, they border with all water systems (North Sea, Wadden Sea, the Ijssel Lake, the western Scheldt estuary, and the major rivers).

Achieved development levels

Because of the consistent methodology, the results for those 16 dike-ring areas could be compared with one another at least to some extent. The project results could be brought up to level 1 for 13 dike rings, and up to level 2 for the remaining 3 dike rings – recall Section 2.2.

VNK-1 (2001-2005) VNK-2 (2008-…)

This point in time marked the separation of the VNK project into two phases: VNK 1, containing the state of the play in summer 2005, and VNK 2, which started in 2008 and still under way.

VNK1 is described in more detail in Chapter 3, while the progress of VNK 2 is briefly outlined in Chapter 4.

2.5 WEBSITE

The website of the VNK project is

http://www.helpdeskwater.nl/onderwerpen/waterveiligheid/veiligheid-nederland/

containing an archive of the report production of VNK1 and newsletters and intermediate reports of VNK2. Most of this information is available in Dutch.

2.6 SOURCES AND REFERENCES

- Ministry for Traffic and Public Works, 2000. *Anders omgaan met water – Waterbeleid in de 21e eeuw* [A Different Approach to Water – Water Management Policy in 21st Century]. December 2000. Also available in English from http://www.waterland.net/showdownload.cfm?objecttype=mark.hive.contentobjects.d ownload.pdf&objectid=9802A380-C264-EF55-F34F273A01FEB696
- Project Floris, 2003. *Flooding in the Netherlands – Probabilities and Consequences*. DWW-2003-09 ISBN 90-369-5527-0.
- Technische Adviescommissie voor de Waterkeringen (TAW), 2000. *Van overstrijdingskans naar overstromingkans*. [Towards a new safety approach. A calculation method for probabilities of flooding]

Figure 13

Project chart VNK 1

Source: http://www.helpdeskwater.nl/onderwerpen/waterveiligheid/veiligheid_nederland/vnk1_archief/teksten/4_doel/; Helpdesk Water, Lelystad.

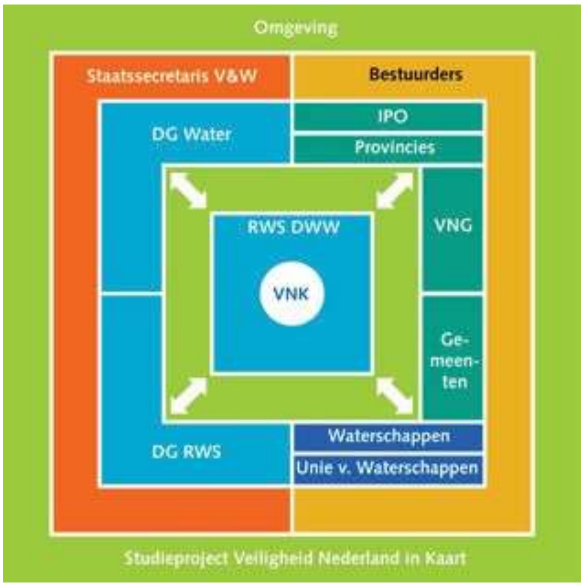
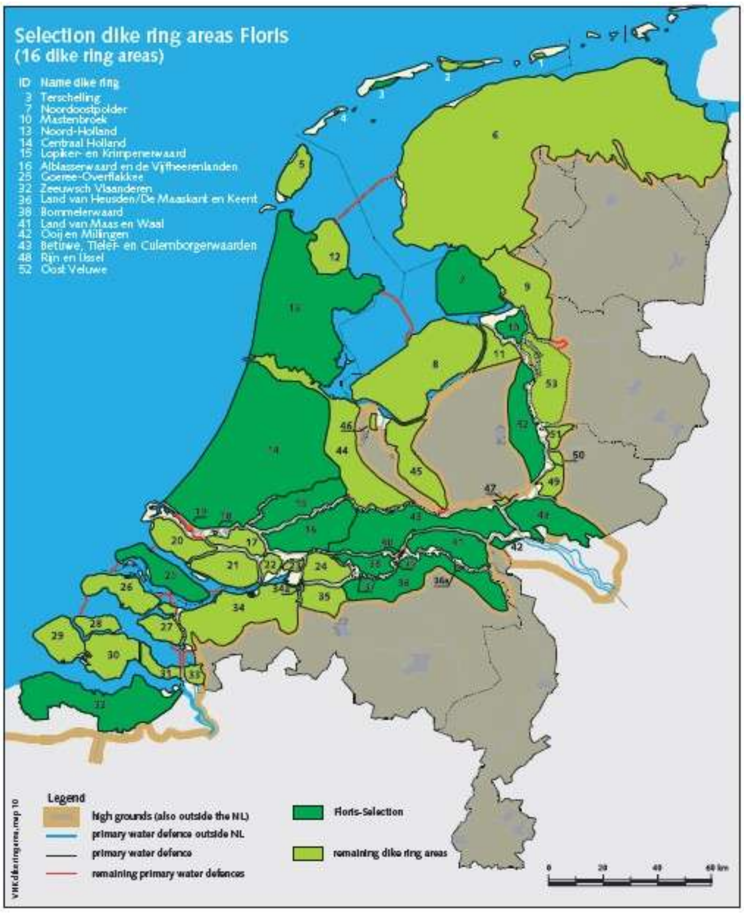


Figure 14

The 16 dike rings studied in VNK 1 (dark green).

Source: VNK report (2005)



CHAPTER 3 VNK 1

This chapter outlines the risk-based methodology under study at VNK, with special emphasis on the results obtained within VNK 1. The risk based-approach combines the probability of occurrence of a flood and the evaluation of its consequences, namely damages and loss of lives (Section 3.1). These two elements are therefore discussed separately.

On the one hand, the probability of occurrence of a flood in a dike ring requires knowledge about the hydraulic loads challenging the water defences, the failure mechanisms that determine the vulnerability of the water defence, and the propagation of the flood within the dike ring. The procedure and tools for evaluation of the flood hazard are described in Section 3.2.

On the other hand, the evaluation of damages and casualties caused by a flood scenario requires, firstly, the evaluation of the loss of value/usability of properties and infrastructures exposed to the flood; and, secondly, the evaluation of the time, routes and means for people to escape the flood. The assessment of the flood consequence is thus discussed in Section 3.3.

3.1 THE RISK-BASED APPROACH

Risk

The VNK projects aims at determining the flooding risk over the national territory with a consistent methodology. The flood risk is quantified by the product of the probability of a flood (measured in event per year) times the consequences of that flood (measured in euro per event). Thus:

flood risk (€/year) = *flood probability* (event/year) x *consequences* (€/event)

The flooding risk can be seen as the amount of money that should be set aside each year to approximately compensate, in the longer term, for the damage of the probable flood.

No cumulated effects

The flood risk is determined per each dike ring, without taking into account that the same flood can affect several dike rings at the same time. In reality, for example, a river flood occurring in an upstream dike ring reduces the flooding probability in the dike rings downstream, since the water levels become lower.

3.2 FLOODING PROBABILITY: MODELLING THE FLOOD HAZARD

Dike sections

Each dike ring is divided into sections with almost uniform material properties and shape. These vary in length between a few hundreds to a few thousand meters. According to the current safety assessment routines (Section 1.3), the probability of failure due to all failing mechanisms is assessed per dike section.

Dike-ring parts

For the purpose of calculating the consequences (Section 3.3), however, a dike ring is split in parts that may include several contiguous dike sections. The flooding caused by a failure at any dike section within the same dike part is assumed to cause comparable equivalent damages and number of casualties within a 20% accuracy.

Different criteria are used to determine the separation of a dike ring into dike parts, such as the presence of hydraulic structures or the change of the water body that the dike ring borders (for example, from lake to river). This expedient is used to reduce the number of scenarios to compute. To this end, the maximum number of dike parts per dike ring has been set to 13.

Cumulated effects between dike *parts* of the same dike ring are taken into account for the riverine defences. So, for example, the occurrence of a failure in an upstream dike part will rule out that another failure can occur in a downstream dike part.

Flood scenarios

A flood scenario for a dike ring is thus determined by the following:

a) the hydraulic load;

b) the failure at one or more dike *parts* at the same time;

c) the propagation of the flood inside the dike ring, which is also a consequence of the nature and layout of the flooded terrain;

d) the breach growth, which determine the flooding discharge and speed depending on the dike material and on the flow speed.

External loads causing failure

The loads exerted by the water bodies on the dike rings are determined by the software *PC-Ring* according to the schematisations that follow, at least closely, the normative Hydraulic Boundary Conditions (Section 1.3). *PC-Ring* takes into account the boundary conditions that are relevant to each dike part (for example: water level, river discharge, wind speed and wave direction and wave height).
The water levels used for the evaluation of flood scenarios are that of the official regulations (thus connected to an assigned return period; recall Section 1.3) plus one lower value and two or three higher values.

Failure probability

PC-Ring has been used to determine the probability of failure for each dike or dune *section* and for the hydraulic structures. *PC-Ring* is developed by TNO-Construction in cooperation with Rijkswaterstaat, the Technical University of Delft and engineering firms (Vrouwenvelder et al, 2003).

Also, *PC-Ring* allows the modelling of multiple breaches. Not only is multiple breaching a realistic occurrence, but also it has a great impact on the evaluation of flood consequences (both in terms of evacuation plans and damage).

Figure 15 and Figure 16 show two screenshots of a dike section as visualised by *PC-Ring*. The profile of the dike section is shown at the right top panel. The left-hand column contains, among other information, the listing of all the sections in the dike ring. The bottom right panel shows the position of the section, with descriptive information. The second screenshot shows more information on coordinates, relative position, name and so forth in numerical format.

Failure mechanisms

The Guide to the Fundamentals of Flood Defence (*Leidraad Grondslagen Waterkeren* of 1998) gives the overview of the 12 different types of failing mechanism for an earthen water defence. Among those, VNK selected four mechanisms related to flooding and for which a minimal knowledge was available, namely:

- *Overflow and wave overtopping*: the water defence collapses because of water flowing over the crest or because of the wave breaking over the dike;
- *Heave and piping*: the sand is washed away from underneath the water defence, once the uppermost layer of clay that seals the dike is lifted because of the increased water pressure;
- *Damage to the revetment and erosion of the dike body*: the revetment is first damaged by wave attack, and the seaward side of the dike core is eroded;
- *Sliding or heaving of the inner slope*: the landward side of the dike becomes unstable due to prolonged water action, until it slides.

These mechanisms are also shown in Figure 17. A dike failure occurs when the action of the external loads exceeds the resistance of the water defence. The formal definition of action and resistance depends on the failing mechanism.
An important distinction is made between failure modes whose probability to occur is uniform over the dike length and those which may occur at several points of the dike independently of one another. An example of the former is overtopping that, given an external water load, is equally probable over the dike-part length, since its height varies mildly in the alongshore direction. An example of the latter is piping, which depends on soil properties that are patchily distributed with considerable uncertainties; for this mechanism the probability of finding a point vulnerable to piping has to increase with the length of the dike (the so-called *length effect*).

For sand dunes, erosion and dune deformation are the only failure mechanisms taken into account.

For hydraulic structures, finally, the failing mechanism are:

- *Overflow and wave overtopping*: the hydraulic structure is assessed based on the comparison of the water level to be retained and of the exceedance frequency curve of the water level outside;
- *Non-closure*: the hydraulic structure fails as a result of the delay of the closure. In particular, VNK borrowed the probability model for ‘non closure’ from the Hydraulic Structures Guideline (*Leidraad Kunstwerken*, 2003).
- *Structural failure*: the assessments for structural failure are based on the inspections of strength and stability of the structure, in relation to the load and water levels to withstand. In this assessment the probability of the following seven conditions are controlled:
  - failure caused by water-pressure differences;
  - collapse of the concrete structure;
  - failure of foundations;
  - instability of the bed protection;
  - collapse due to piping;
  - collapse due to collision of the structure.

These mechanisms are also shown in Figure 18.

Flood propagation

The water depths, velocities, time rate of water-level rise, and arrival times during flood are determined with the hydrodynamic model suite SOBEK developed by Deltares (previously WL | Delft Hydraulics). The solver consists of a two-dimensional flow solver coupled with a one-dimensional flow model used to schematize waterways. Flood propagation and time effects are thus taken into account.

Calibration and validation of flood simulations are difficult merely for lack of data where floods do not occur, or occur rarely, like in the Netherlands. This is an inherent uncertainty that, within VNK, was mitigated with data from old floods (1953) or by *ad hoc* fine-tuning based on expert judgement

Scenario Toolkit

The evaluation of multiple flood scenarios is carried out with the software *Scenario Toolkit*, which can analyse all possible combinations of failures that are used as input of *PC-Ring* for the evaluation of probabilities. The summed probability of all scenarios determines the cumulative probability of flooding of the dike ring.

The pilot computations of VNK 1 have shown that the scenarios caused by the ten most probable failures account for nearly 100% of the probability of failure of the entire dike ring. However, a flood scenario with a marginal probability of occurrence may still cause extensive damage and casualties. In the risk-based approach, therefore, the impact of all possible flood scenarios needs to be considered to identify those of high importance.

Global flood scenarios

Flood scenarios can be modelled in two modes: global and detailed. In *global* flood scenarios it is assumed that the whole dike ring is flooded. This is used as a theoretical worst case situation. Specific criteria to produce this ideal, less realistic condition are set. In particular

- Dike rings are regarded as areas with uniform properties;
- The volume of flooding water is unlimited;
- The water level is set equal to the lowest height of the dike ring, with a lowest water level of one meter;
- For high-ground areas, the water level is set to the highest water level according to applicable Hydraulic Boundary Conditions. Only areas lower than this water level will be flooded.

Note that this mode is not suitable to assess of casualties, since it does not allow for flood propagation and evacuation modelling. Also, a probability of flooding and risk estimate obtained with the global flood scenario belong to the 'development level 1' rank in the scale of assurance presented in Section 2.2.

Detailed flooding scenarios

The combination of the occurrence of a probable failure and of the simulated flood propagation gives one flood scenario, which is suitable for the evaluation of both damage and casualties (Section 3.3).

The probability of flooding for the entire dike ring is the combination of the probabilities of occurrence of the flood scenarios (thus considering the vulnerability of all dike parts to all the failure mechanisms). Details of the statistical algorithms are available in Projectbureau VNK2 (2011).

For example, the dike ring 14 (roughly coinciding with the province of South Holland) is currently protected against a combination of surge and waves having a return frequency of 1/10,000 years. When detailed flood scenarios are analysed with the VNK methodology, the probability of flooding for the entire dike ring is 1/2,500 per year. The two values describe the safety level of the same dike ring: in the first case through the water-level exceedance, in the second case through the probability of flooding.

3.3 DAMAGES AND CASUALTIES: EVALUATING THE CONSEQUENCES

Consequences

The flood consequences are divided in two major contributions:
- The economical damage (a monetary sum);
- The number of casualties (number of victims per year);

and also, in second order, in:
- Damage to landscape, wildlife and cultural heritage;
- Environmental damage.

The loss of landscape, nature and cultural areas is also referred to as the LNC damage. VNK 1 has dedicated limited time and efforts into the assessment of LNC-related values.

3.3.1 DAMAGE

VNK 1 used two methods to determine the damage expressed in euros. One method is referred to as ‘global’ and the other as ‘detailed’.

Damage assessment in four steps

Figure 19 gives an impression of how a damage assessment is carried out with *HIS Damage and Casualties* module (Ministerie van Verkeer en Waterstaat, DWW, 2004 – version 2.1 was used by VNK 1). The items in the list below correspond to the steps in the figure. The procedure consists of the following steps:
- *Assessment of the flood scenario*, based on the ground elevations and water levels (see Section 3.2);
- *Use of the land*, determined through databases collected from different sources, such as the Central Office of Statistics (data of 1999); Dunn & Bradstreet for industry, utilities, transport, communication, etc; WIS-file (*WIS Waterstaatkundig Informatie Systeem*, 1997) for treatment installations; Bridgis (data of 2000) for the different category of residential buildings; Bridgis (data of 2000) for vehicles and casualties; NWB-W file, (*Nationaal Wegen Bestand*, 2002) for the road network and, finally, the National Railways (data of 2008);
- *Damage functions*, given by the product of a maximal damage and a variable damage factor for each land use. The maximum damage is defined by the amount of money needed to replace the damaged good. The damage factor is a function, with values between zero and one, that depends on the flood water depth and on the speed of inundation. The inundation speed and the water depth is assessed by flow simulations.
- *Damage per grid cell*: The damage in each computational cell of the software *HIS-Damage and Casualty* is assessed upon combining the water level (depth), flow velocity and the damage function at the same location.

Global damage-assessment

For this assessment, the water levels are determined with the global flood scenario. The damage in euros is then calculated using *HIS-Damage and Casualties*. Further, the amount of casualties and the loss of landscape, nature and cultural areas are not defined in the global method.

Direct and indirect damage

Three types of damages are considered in the global method (assessments of 2004):

- *Direct material damage*, defined as damage that occurs to objects, capital goods and private property caused by the direct contact of water. Direct material damages are estimated by:
  - The restoration costs for private and rent property; restoration of land and buildings.
  - Restoration costs for production equipments, machinery, process installations and transport infrastructures;
  - Damage on furniture;
  - Damage on the loss of movable goods, such as commodities, raw materials and products (including harvest);
- *Direct damage caused by business interruption;*
- *Indirect damage to business*, caused outside the flooded area by, for example, delayed deliveries and disruption to transportation systems.

Detailed damage-assessment

Within the VNK 1 project the detailed assessment method was used for 3 dike rings only, (namely 7, 14 and 36, with dike ring 14 being the province of South Holland). The software *HIS-Damage and Casualties* is also used here. The detailed damage assessment requires large amounts of information obviously connected to detailed flood scenarios (Section 3.2), namely:

- Schematization of the area:
  - Ground elevations and obstacles locations;
  - Land use;
  - Location of the water streams;
- Definition of the flooded area;
- Hydraulic boundary conditions
  - Water level;
  - Duration of the high water causing the flood.

Maximum damage

The maximum damages are estimated by the averages cost prices in the Netherlands. Maximum damages are listed in the manual of the software *HIS - Damage and Casualty*. Table 2 shows a tabulation with the damage groups, the asset categories (with units) and the damage amount (*schadebedrag*) per unit asset (MWW-DWW, 2004). The unit maximum damage may vary in order of magnitude from a few to ten million euros. The values of maximum damage estimates are the same over the national territory.

Table 2

Damage categories and maximum damage. Source: MVW-DWW, *HIS- Schade en Slachtoffer module* (2004). Abbrevations: b.i. = business interruption; j.p. = job position.

	Damage category and type		Unit	Max damage
Soil usage	Agriculture	direct	m^2	€ 1.50
		indirect	m^2	€ 1.60
	Horticulture	direct	m^2	€ 40
		indirect	m^2	€ 4
	Water surfaces	direct	m^2	€ 49
	Urbanised areas	direct	m^2	€ 0
	Intensively used resorts	direct	m^2	€ 11
	Extensively used resorts	direct	m^2	€ 9
	Airports	direct	m^2	€ 1,198
		b.i.	m^2	€ 36
Infrastructures	National roads	direct	m	€ 1,450
		indirect	m	€ 650
	Motorways	direct	m	€ 980
	Other roads	direct	m	€ 270
	Railways	direct	m	€ 25,150
		indirect	m	€ 86
		b.i.	m	€ 151
Properties	Low-rise housing		item	€ 172,000
	Medium-rise housing		item	€ 172,000
	High housing		item	€ 172,000
	Detached houses		item	€ 241,000
	Farm		item	€ 402,000
	Vehicles		item	€ 1,070
Companies	Mining	direct	j.p.	€ 1,820,000
		indirect	j.p.	€ 116,000
		b.i.	j.p.	€ 84,000
	Factory	direct	j.p.	€ 279,000
		indirect	j.p.	€ 70,000
		b.i.	j.p.	€ 62,000
	Public utility	direct	j.p.	€ 620,000
		indirect	j.p.	€ 163,000
		b.i.	j.p.	€ 112,000
	Construction	direct	j.p.	€ 10,000
		indirect	j.p.	€ 26,000
		b.i.	j.p.	€ 45,000
	Trade and catering	direct	j.p.	€ 20,000
		indirect	j.p.	€ 3,500
		b.i.	j.p.	€ 7,500
	Bank and insurance	direct	j.p.	€ 90,000
		indirect	j.p.	€ 7,000
		b.i.	j.p.	€ 14,000
	Transport and communication	direct	j.p.	€ 75,000
		indirect	j.p.	€ 6,400
		b.i.	j.p.	€ 11,200

	Health care	direct	j.p.	€ 20,000
		indirect	j.p.	€ 6,300
		b.i.	j.p.	€ 3,400
	Government	direct	j.p.	€ 60,000
		indirect	j.p.	€ 2,200
		b.i.	j.p.	€ 9,200
Others	Pumping station		item	€ 747,200
	Waste water treatment		item	€ 10,853,000

Damage-factor functions

Figure 20 and Figure 21 show two examples of damage-factor functions used to determine the effective monetary damage for the damage categories 'high residential buildings' and 'means of transportation' respectively. In both cases only water levels above 0.5 meters cause damage.
In the first case, for example, the damage per unit of exposed asset (m^2) caused by a water depth of 0.5 meters is 20% of the maximum damage tabulated in Table 2. The complete loss of high buildings would occur for (virtually unlikely) water depths of 14 meters (this can be compared for the 4-meter water depth causing complete loss of low buildings). Similarly, Figure 21 shows that all transportation equipments are lost for water depths in excess of 6 meters.

The formulas which are used to assess the damage can be found in the HIS - Damage and Casualty manual (*Ministerie van Verkeer en Waterstaat, DWW, 2004*). An update version of the software has been used for VNK 2 but has not been released to the public.

Expected damage

The expected total damage in a dike ring is calculated as the average of the consequences of the individual flood scenarios, weighted with the probability of occurrence of such scenarios.

3.3.2 CASUALTIES

Casualty assessment

The assessment of casualties in VNK 1 is carried out based on the same flood scenarios used for the damage assessment. Figure 22 schematises the procedure implemented in VNK 1 that is divided into

1. The evacuation analysis;
2. The estimate of the number of casualties (*inschatting aantal slachtoffers*).

Specific modules of the software *HIS - Damage and Casualties* were also developed for the casualty assessment in VNK 1.

Available time

The available time is the time between the detection/forecast of a potentially critical situation and the arrival of the real flood.
Flooding caused by high river discharge or intense rainfall develops slowly and can be forecast with sufficient advance time (in the order of days) to evacuate people and assets exposed to flooding. Conversely, the flood arrival time and logistics both limit the completion of evacuation when a potential cause of flooding is forecast with little advance or, even worse, when it occurs suddenly. In those cases, there may be no time to evacuate the areas near the breach point of the water defences.

Thus the available time strongly depends on the water body that breaches through the water defences system (sea, river, lake). The predictability of a failing mechanism, the awareness of weak links in the dike rings, and the speed of a flooding are also important factors determining how the available time varies within the dike ring.

Figure 23 shows how the flood rapidity influences the possibilities of evacuation.

Required time

The required time is the time necessary to complete an evacuation procedure and is divided in four phases: decision, warning, response and effective departure from the area at risk.

A conceptual schematisation of the evacuation procedure is shown by the time-population percentage chart of Figure 24, also referred to as the evacuation curve. A percentage of the population may not receive the warning (*niet gewaarschuwd*) or may not behave accordingly to a received warning (*niet gereageerd*). All the remaining population can be evacuated if the available time (*beschikbare tijd*) is more than the required time (*benodige tijd*). The fraction of people that, in a given scenario, can be effectively evacuated before the arrival of the flood (*overstroming*) is the output of the casualty-assessment models.

Evacuation analysis

The first step of the evacuation analysis is the assessment of the number of people who are in the area during a flood, of the escape routes and of the arrival time (the left-hand side of Figure 22). The resulting evacuation curve returns the number of people that can leave the flooded area because of a certain failure occurring. The number of people exposed to a flood is thus estimated.

Estimation of casualties

It is assumed that inhabitants who live in high buildings are always safe from floods (recall also Figure 20). Beside those, three geographical zones in a dike ring are identified as shown by scheme of Figure 25:

1. Zone nearby the breach point, where high flow velocities can cause the buildings to collapse and people to be caught by the stream;
2. Intermediate distances, where the rapid increase of water level hinders the evacuation to higher ground and shelters;
3. The rest of the dike ring, where the increase of water level and flow velocity are slower.

Casualty function

A casualty curve estimates the number of casualties as the fraction of the exposed population and as a function of the water depth.
The casualty function is an empirical relationship based on the data from the 1953 flood (Section 1.3) and international literature on floods. A rule of thumb derived from it is that the amount of casualties is between 0.1% and 1% of the exposed people. Figure 26 shows the function used for water levels rising more slowly than 0.5 meters per hour. However, the casualty percentage rises in case of a rapid increase of water level and Figure 27 shows the casualty function adopted when the water level rises faster than 0.5 m/h.

Expected casualties

The expected value of casualties (in a dike ring) is calculated as the average of the numbers of casualties of all individual flood scenarios, weighted with the probability of occurrence of such scenarios.

3.4 EXAMPLES

Noordoostpolder

As a first example, the risk for dike ring 7 (region *Noordoostpolder*) determined with the *global* method is 10 million euros per year. The corresponding damage is 9,000 million euros (there is, of course, only one global scenario).

On the other hand, the risk calculated with the *detailed* method is 2.1 million euros per year. The economical damage ranges between 170 million and 4,000 million euros per event depending on the location of the breach. The casualty risk varies between 0.006 and 1.6 individuals per year, depending on the breach location too.

South Holland

Typical maps obtained as result of the VNK procedure are given in Figures 29 to 35, which refer to dike ring 14 (region South Holland). These data effectively have been produced within VNK 2 (Chapter 4) and reproduced with specific permission of the VNK Project Office. The values associated to the colour shading cannot be disclosed until the final results of VNK 2 are released for public distribution.
Figure 28, Figure 29 and Figure 30, in particular, represent the altimetry, the location of the breaches considered and one of the possible flood scenarios.
The other maps concern the results of the flood risk analysis and namely:

- Figure 31: the Local Risk (PR, *Plaatsgebonden risico*), defined as the annual probability for an individual to die owing to the flood, while excluding preventive evacuation;
- Figure 32: the Local Individual Risk (LIR, *Lokaal individuele risico*), defined as the annual probability for an individual to die in a flood, while considering preventive evacuation or sheltering;
- Figure 33: the estimated territorial density of flood victims per year (expressed in number of victims per hectare per year) due to the all flood scenarios including evacuations;
- Figure 34: the estimate territorial density of economic damage that can be expected per hectare and per year.

Results on casualties are also presented as graphs in the plan having the number of casualties and the probability of occurrence as axes. This is crudely schematized in Figure 35, where a possible use of the VNK results to support decision-making (such as prioritizing preventive and mitigating measures in) is sketched (Projectbureau VNK2, 2011).

3.5 CONCLUSIONS OF VNK 1

During the development of VNK 1 (2001-2005) some limitations to the initial scope became apparent, and namely:

- The determination of probability of flooding was not ready for general application;
- The study could cover only 16 dike rings out of 53, and the complete cross-comparison among was not yet feasible;
- The physical modelling of some failure mechanisms, and notably piping, was still incomplete;
- Non-closure failures for hydraulic structure were caused by insufficient procedure documentation;
- Several new tools to calculate the probability of flooding were developed that applied a uniform methodology across all the dike rings;

- Uncertainty, whether modelled or estimated by expert guesses, could be explicitly included in the calculation of the flooding probability;
- Knowledge transfer and data exchange between the Water Boards, the Provinces and the consulting engineering firms greatly improved;
- Last but not least, the VNK 1 results produce a first mapping of the flood risk in the Netherlands.

The complete list of recommendations and conclusions is available from the FLORIS/VNK report (in English, see Section 3.6).

3.6 REFERENCES

- Ministry of Transport, Public Works and Water Management, 2005. *Flood Risks and Safety in the Netherlands (FLORIS). Floris Study – Full report*. Report DWW-2006-014, ISBN: 90-369-5604-9. English version: (http://www.helpdeskwater.nl/publish/pages/3320/hoofdrapport_vnk_engels.pdf)
- Ministry of Transport, Public Works and Water Management, 2005. *Floris Study (VNK) Interim report*. Report DWW-2006-13, ISBN: 90-369-5609-9.
- Ministerie van Verkeer en Waterstaat, 2001. *Hydraulisch Randvoorwaardenboek 2001*.
- Ministerie van Verkeer en Waterstaat - Dienst Weg en Waterbouwkunde (MVW-DWW), 2004. *HIS – Schade en Slachtoffer Module versie 2.1*. (Huidige versie: 2.4).
- Ministerie van Verkeer en Waterstaat, 2006. *Veiligheid Nederland in Kaart – Inschatting van het aantal slachtoffers ten gevolge van overstroming dijkring 7, 14, 36*.
- Ministerie van Verkeer en Waterstaat, 2006. *Veiligheid Nederland in Kaart – Modellering en analyse van evacuatie, dijkring 7, 14, 36*.
- Projectbureau VNK2, 2011. *De methode van VNK2 nader verklaard*. Document HB 1267988. (http://www.helpdeskwater.nl/publish/pages/27082/de_methode_van_vnk2_nader_verklaard.pdf, in Dutch)
- Technische Adviescommissie voor de Waterkeringen (TAW), 1998. *Leidraad Grondslagen Waterkeren.*
- Technische Adviescommissie voor de Waterkeringen (TAW). *Leidraad Kunstwerken*. Report DWW-2003-059, ISBN: 90-369-5544-0.

Figure 15

Screenshot of *PC-Ring* 5.3.2. (Licensed to the Albicom consortium)

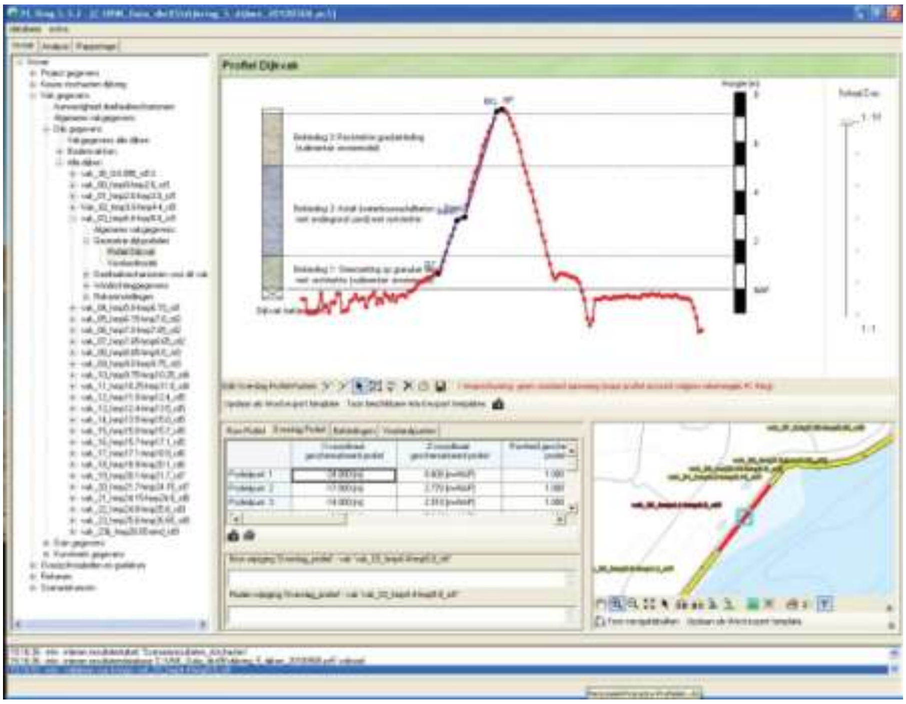


Figure 16

Screenshot of *PC-Ring* 5.3.2 (licensed to the Albicom consortium)

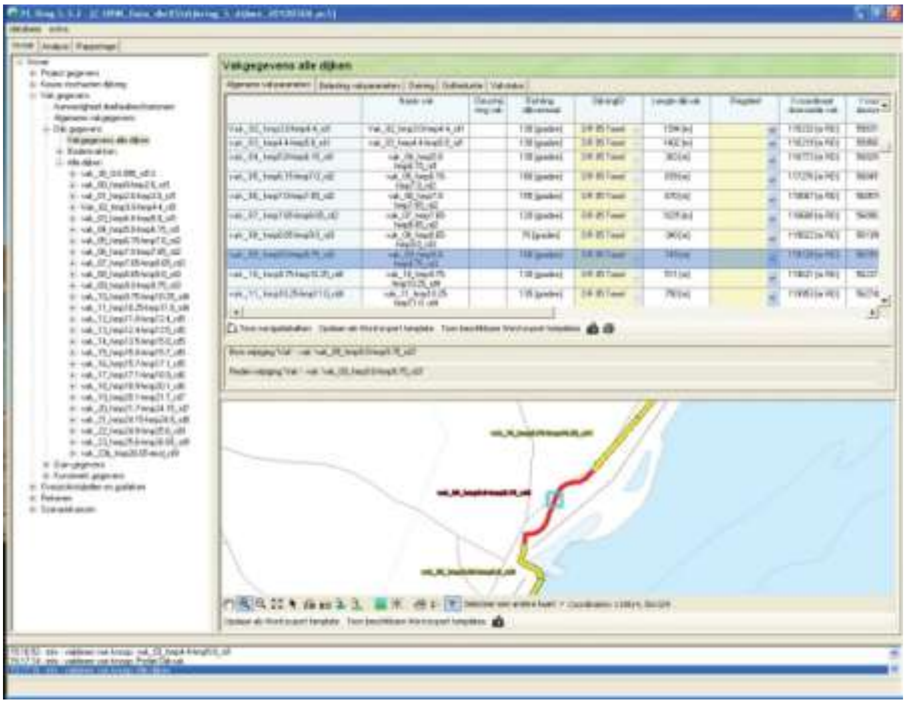


Figure 17

Major failure mechanisms for earthen water defences.

Source: Ministerie van Verkeer en Waterstaat (2003), *Flooding in the Netherlands – probabilities and consequences*

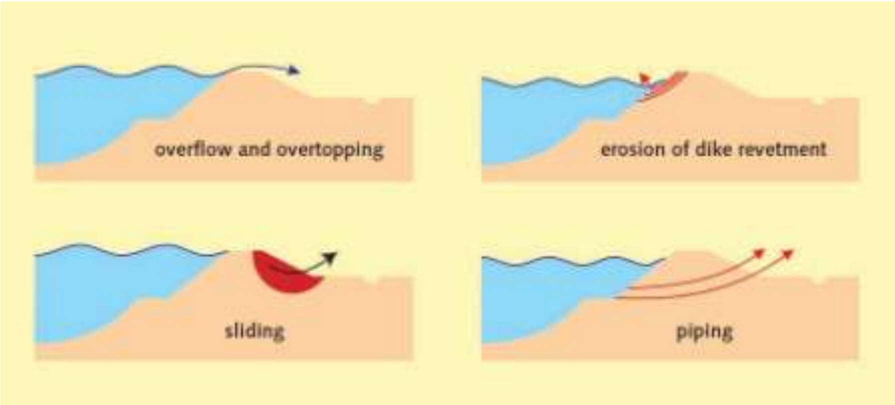


Figure 18

Failure mechanisms for hydraulic structures.

Source: Ministerie van Verkeer en Waterstaat (2005), *FLORIS Study – Full report*.

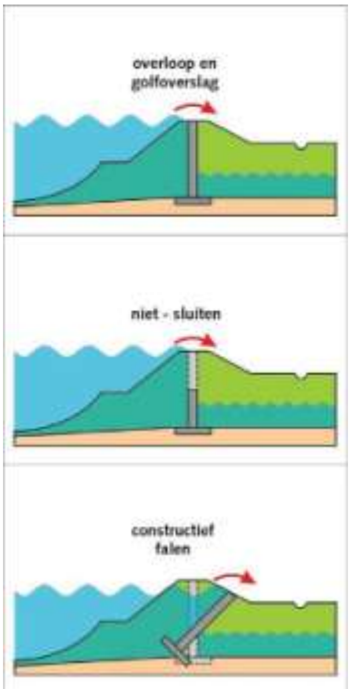


Figure 19

Impression of the global damage method.

Source: Ministerie van Verkeer en Waterstaat - Dienst Weg- en Waterbouwkunde. *VNK Overstromingriskiko dijkring 10 Mastenbroek (2005)*

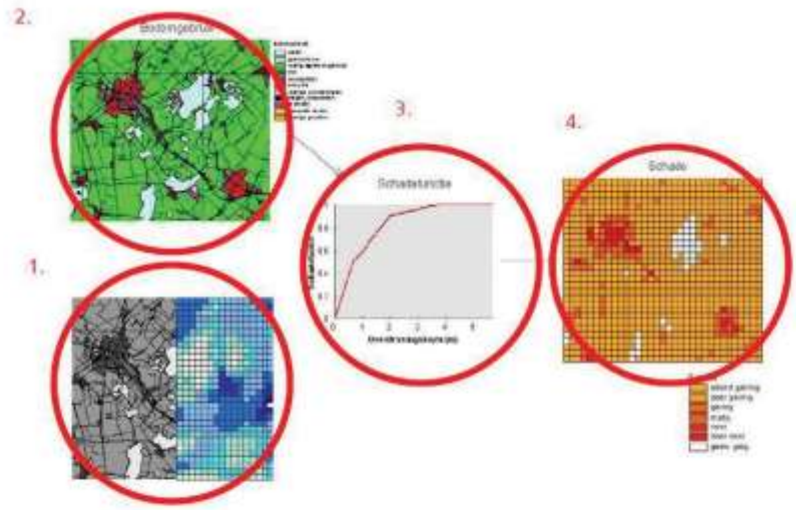


Figure 20

Damage-factor curves for high residential buildings.

Source: Ministerie van Verkeer en Waterstaat - Dienst Weg- en Waterbouwkunde. *HIS-Schade en Slachtoffer module* (2004)

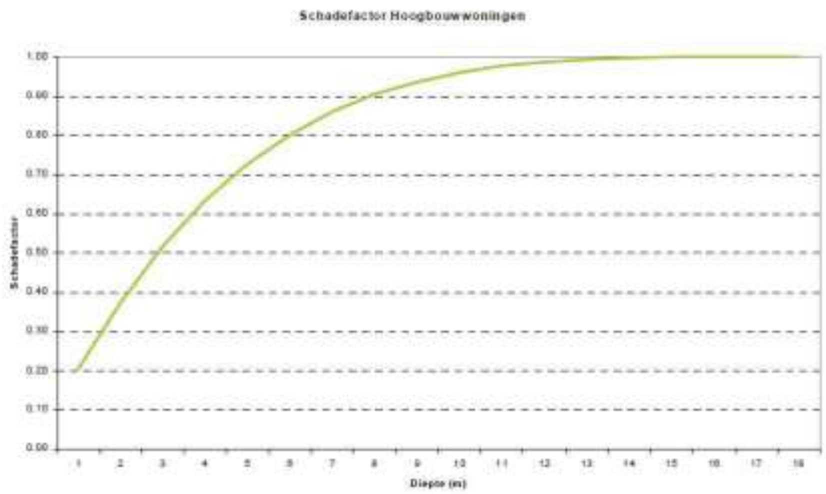


Figure 21

Damage factor curves for vehicles.

Source: see Figure 20

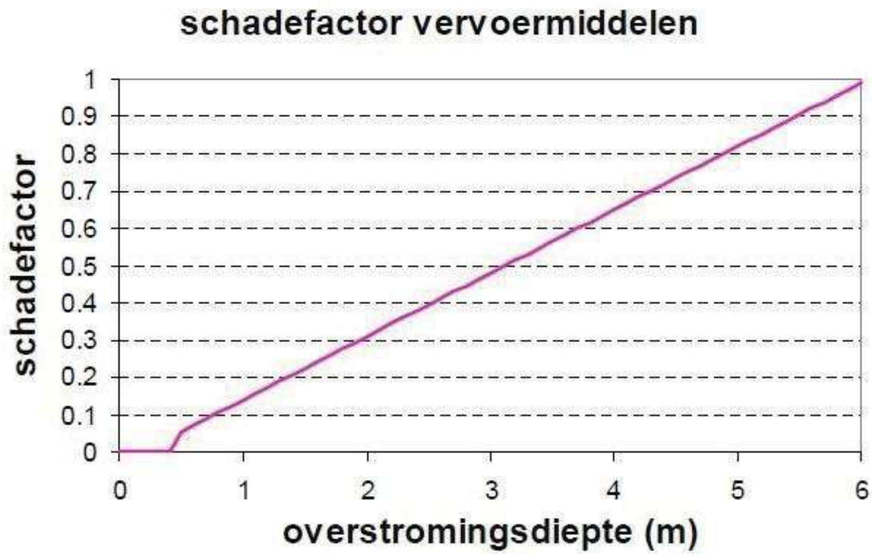


Figure 22

Flow chart for casualty assessment.

Source: Rijkswatersaat - Dienst Weg- en Waterbouwkunde. *VNK Overstromingriskiko dijkring 7 Noordoostpolder (2005).*

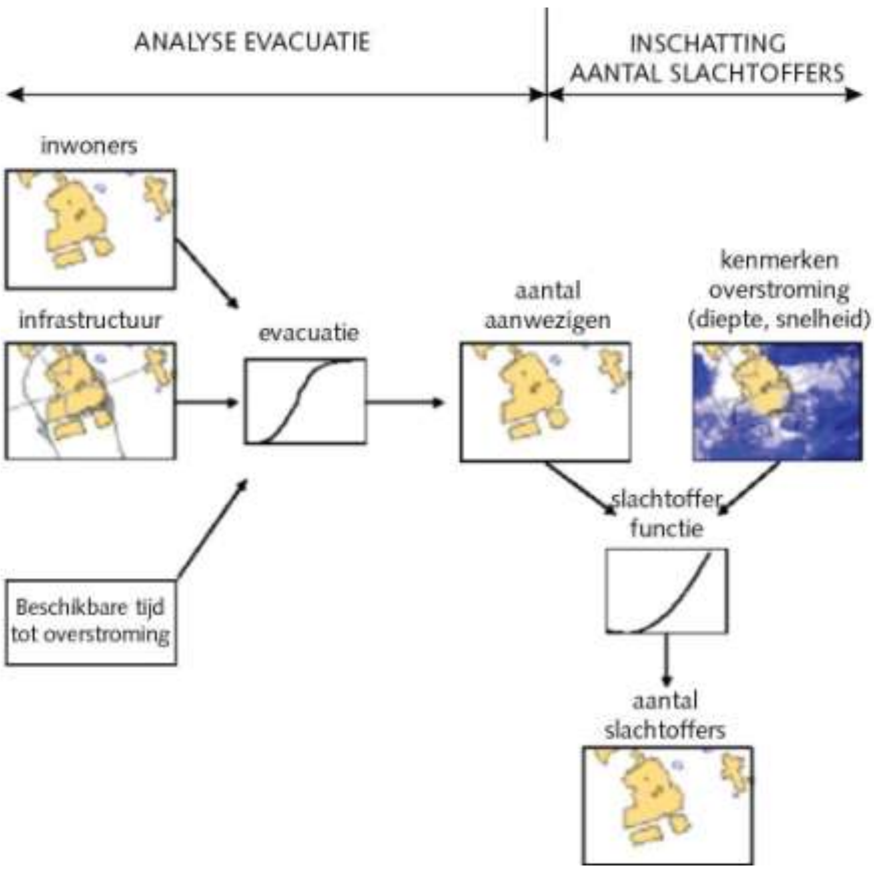


Figure 23

Evacuation modes.

Source: see Figure 22

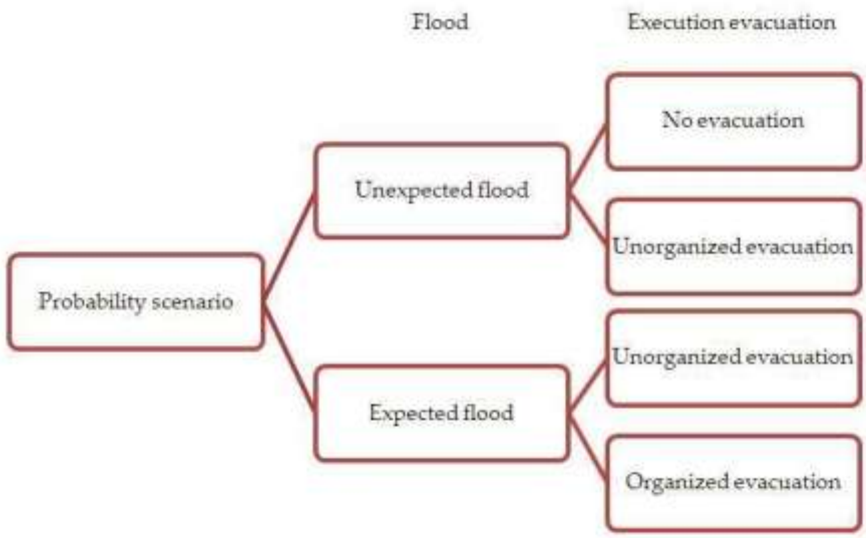


Figure 24

Conceptual chart for the evacuation model.

Source: see Figure 20

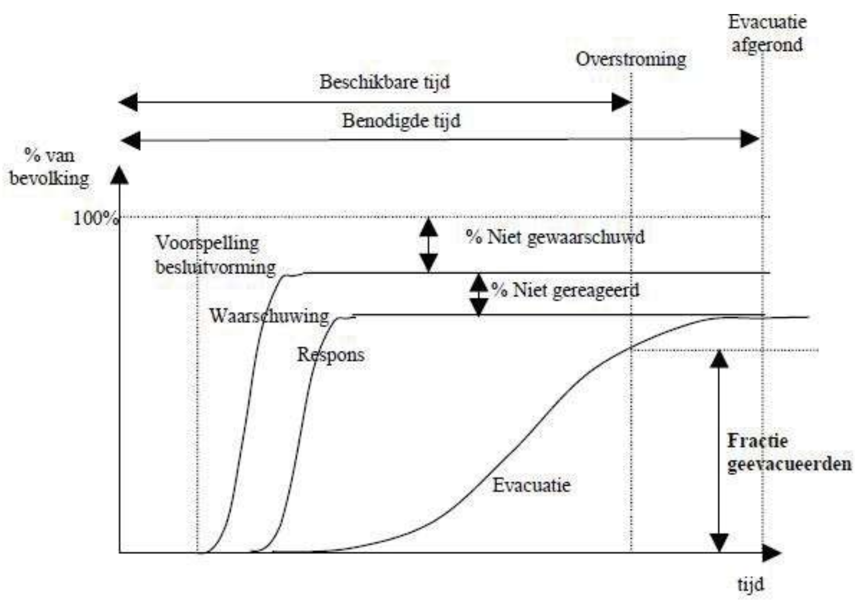


Figure 25

Zoning in a dike ring around the breach point for casualty estimation.

Source: see Figure 20

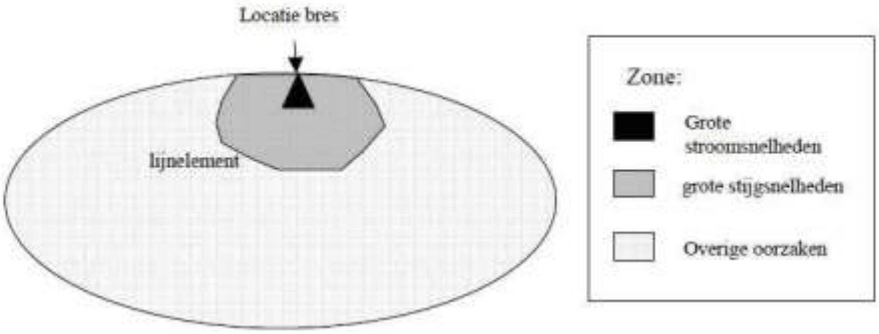


Figure 26

Casualty curve for gradually-raising water levels.

Source: see Figure 20

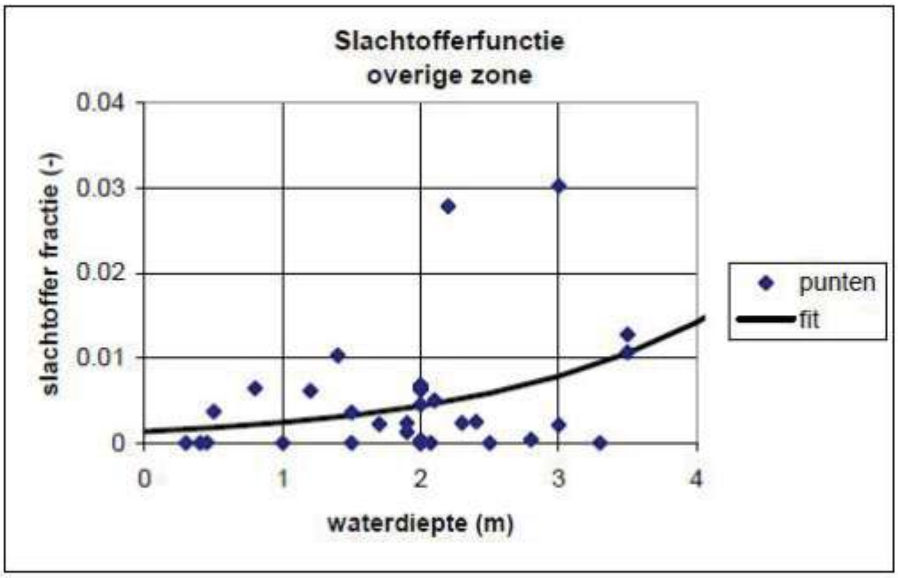


Figure 27

Casualty curve for rapidly-raising water levels.

Source: see Figure 20

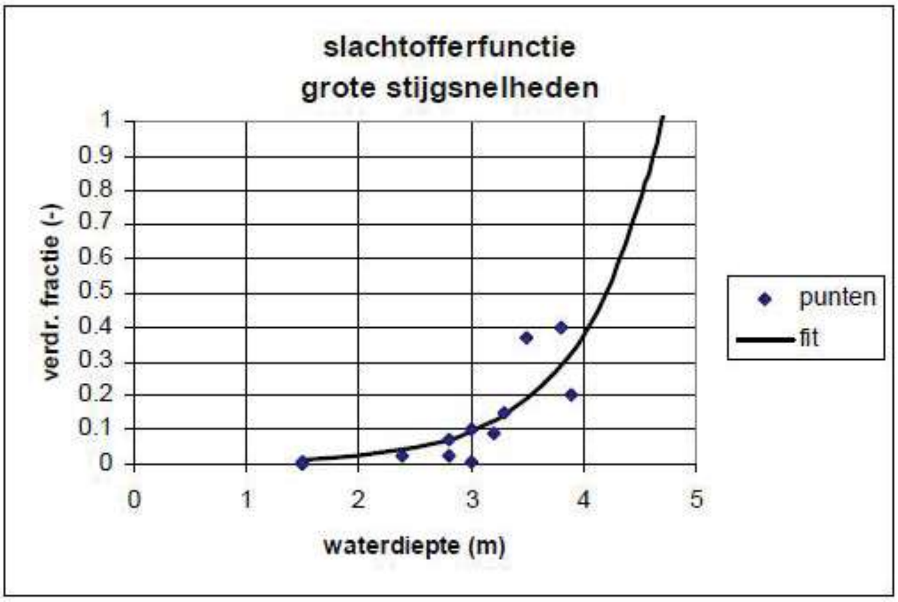


Figure 28

Ground elevation of dike ring 14 (cm w.r.t. chart datum)

Source: Projectbureau VNK2. Reproduced with permission

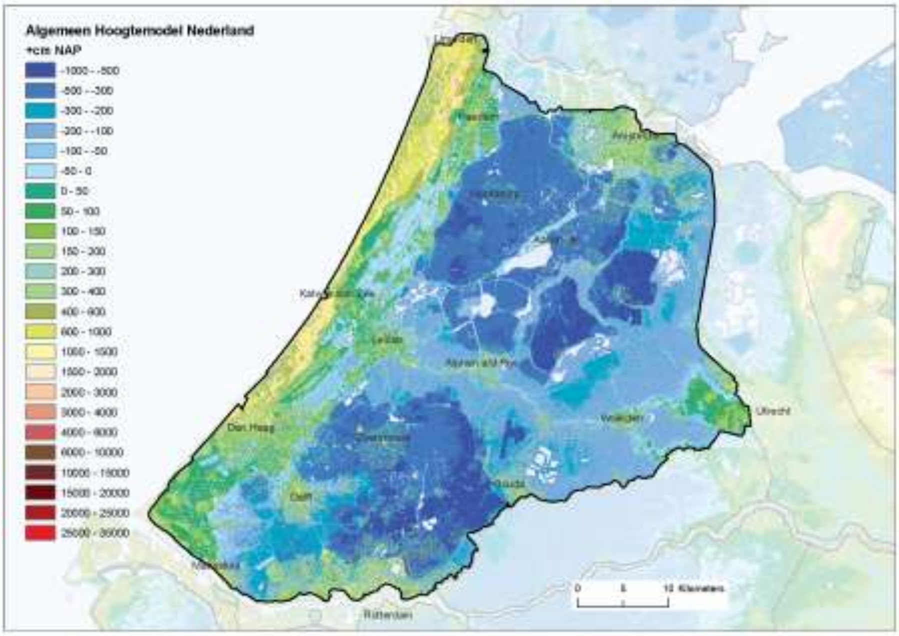


Figure 29

The dike ring, with the dike parts and locations of braches

Source: Projectbureau VNK2. Reproduced with permission

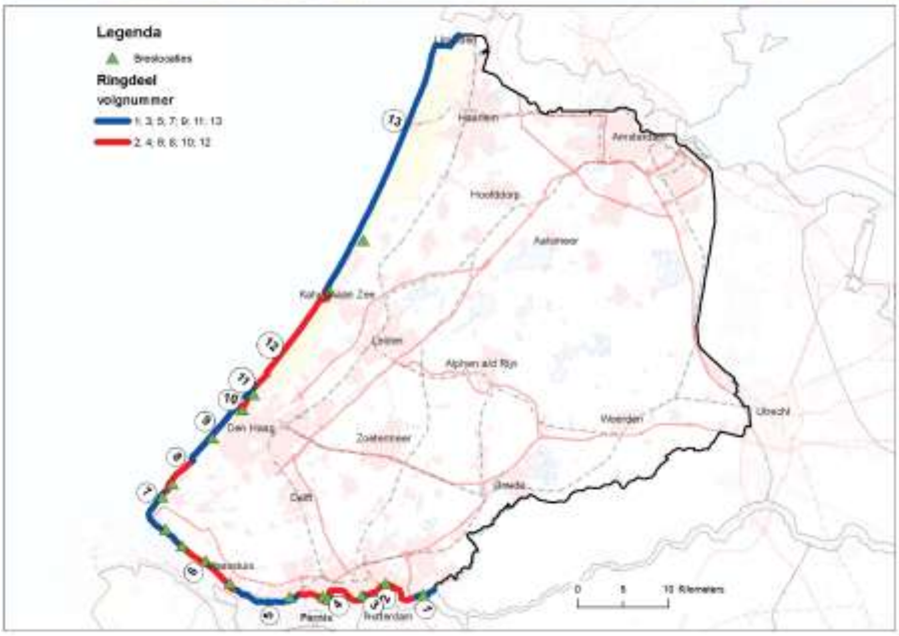


Figure 30

Water depths in one flooding scenario

Source: Projectbureau VNK2. Reproduced with permission

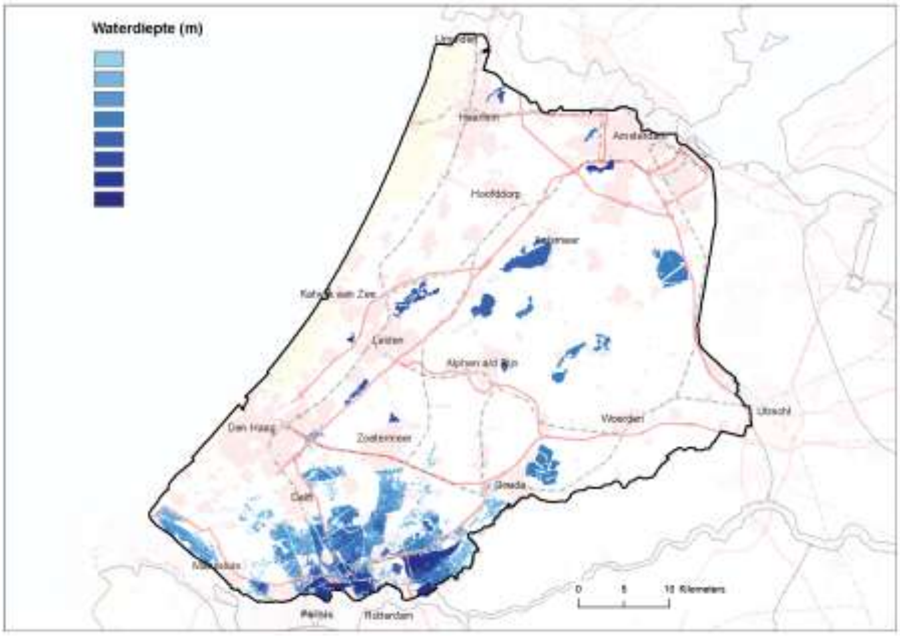


Figure 31

Map of Local Risk (PR) per year

Source: Projectbureau VNK2. Reproduced with permission

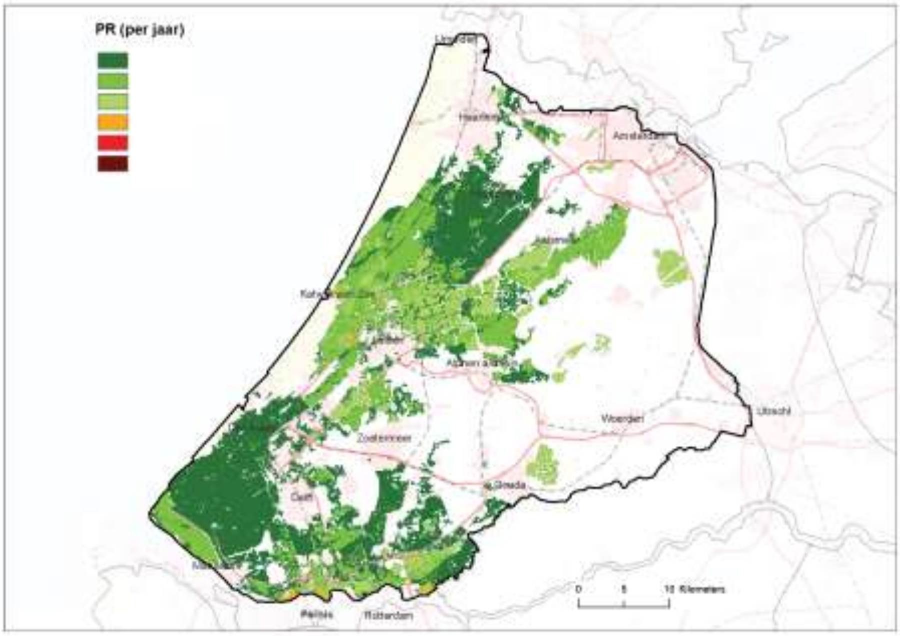


Figure 32

Map of Local Individual Risk per year

Source: Projectbureau VNK2. Reproduced with permission

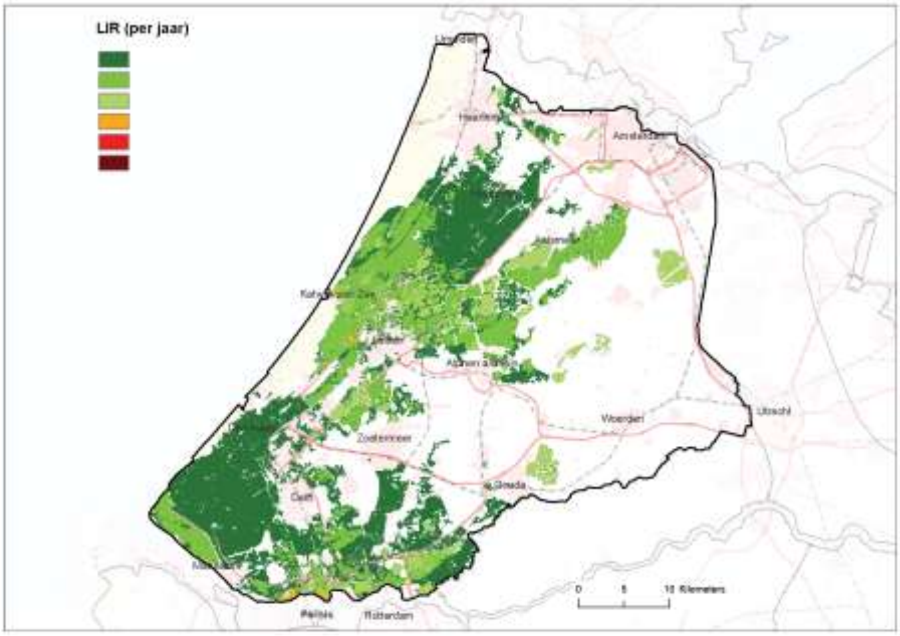


Figure 33

Expected number of victims per hectare per year

Source: Projectbureau VNK2. Reproduced with permission

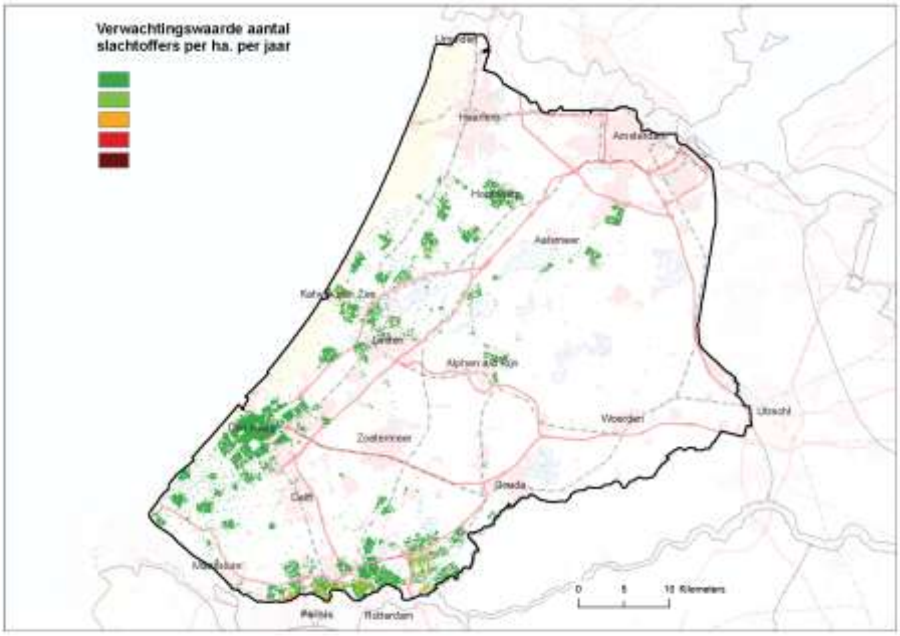


Figure 34

Expected economical damage per hectare in €/year

Source: Projectbureau VNK2. Reproduced with permission

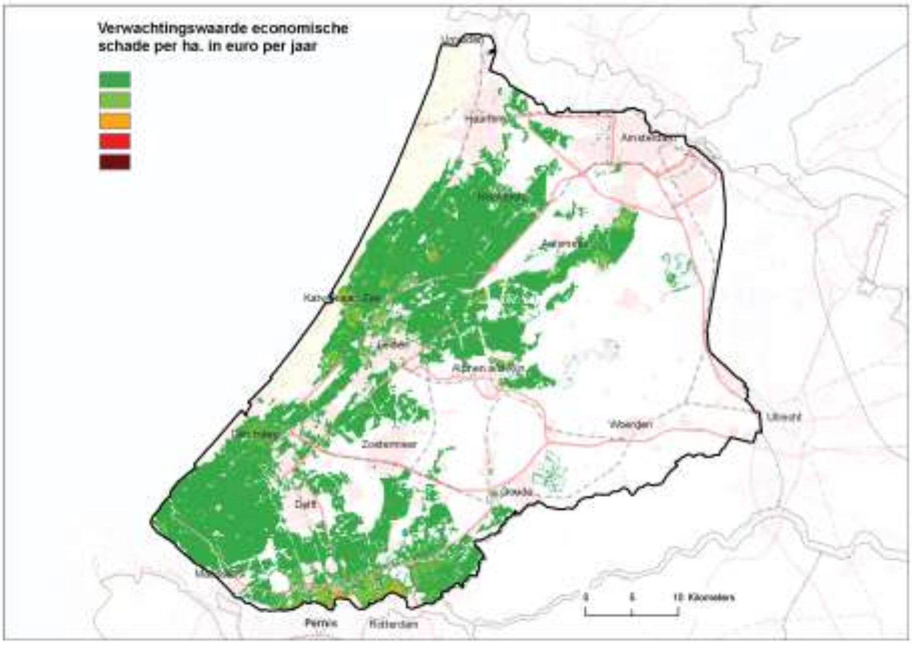


Figure 35

Schematic plots casualties/flooding probabilities in dike ring.

Source: Projectbureau VNK2 (2011), *De methode van VKN2 nader verkllard*

Left: Equally severe events.

Middle: Change due to measures contrasting frequent events only.

Right: Changes due to measures also contrasting events with severe consequences

CHAPTER

4 VNK 2 and the future

The VNK 2 programme is running at the time of writing this document and a final report of VNK 2 has not been released yet. The booklet *De methode VNK2 nader verklaard* (The VNK2 Methodology in Detail) has been published during the production of this report, and is available online in Dutch[21]. Figures 29 to 35 in the previous chapter are authorised previews of information from VNK 2.
This chapter can only briefly describes the major upgrades expected with respect to VNK 1.

4.1 THE RECOMMENDATIONS OF VNK 1 (2005)

At the conclusion of the first round of studies, the VNK 1 report recommended that the following actions had to be undertaken:

- Bringing the accuracy of the flooding probabilities to a higher level and implementing the risk-based approach for all the 53 dike rings and a 3 dike rings along the river Meuse;
- Further involvement of Water Boards, especially to increase the accuracy flooding scenarios;
- Persistence in building a knowledge-based model where the inclusion of the most recent developments may result in lower flooding risk. In particular, further research on piping was indicated as a priority, starting with more extensive soil sampling;
- Developing a method for the cost-benefit analysis in order to eventually assess the investments made for flood protection.

4.2 ONGOING PROGRESS OF VNK 2

Ongoing results

The consortia started working on VNK 2 in 2008 along the lines of the closing recommendation of VNK 1. The action plan for VNK 2 has been divided in a system-test phase (2008-2009, comprising the full assessment of 3 dike rings) and a production phase started in 2009.

The production phase is under way. The tasks have been further grouped in the following phases

- *Phase 1A*: comprising the full assessment of 6 dike rings (5,14,17,36,38,52). This has been completed in 2010;
- *Phase 1B*: currently under way and comprising the full assessment of 8 dike rings (12, 15, 31, 34, 41, 44 and 50/51);

[21] Projectbureau VNK2. *De methode van VNK2 nader verklaard. De technische achtergronden (HB 1267988)*. March 2011.
http://www.helpdeskwater.nl/publish/pages/27082/de_methode_van_vnk2_nader_verklaard.pdf

- *Phase 1C*: comprising the full assessment of 8 dike rings, scheduled for 2012;
- *Phase 2*: comprising the full assessment of 26 dike rings and scheduled for 2014/15.

This far, the following results can be mentioned:

- The correctness and robustness of the software *PC-Ring* for the calculation of the flooding probabilities has been enhanced;
- The method for the piping failure was improved twice between 2006 and 2008 thanks to studies financially supported by the VNK Project Office;
- The levels of uncertainty were lowered or removed so as to improve the risk estimates (recall that uncertainty is explicitly accounted for in the flooding probability, so that a high risk is attached to also events where uncertainty plays a large role);
- The assessment of the 53 dike rings (plus 3 dike rings along the river Meuse) with a higher development level than in VNK1 has been undertaken.

In March 2011 the Project Office VNK2 has also issued the booklet *Tussenresultaten VNK2* which summarises the results of Phase 1A. This document[22] is in Dutch and, to date, has not been made available on-line yet.

4.3 FUTURE AND SPIN-OFFS OF THE VNK EXPERIENCE

VNK is a multi-year programme that is naturally conditioned by the budget constraints due to changes of government and to the general economic climate. The current progress assessments set the end of VNK 2 for 2015.

Experts from many countries have already shown their interest in the rational risk approach developed under VNK. It is likely that similar programmes are being implemented in other countries as well. Through sharing expertise and experiences, others can benefit from this approach which, in the end, not only makes flood-prone areas safer, but also does so at reasonable and explainable costs.

[22] Projectbureau VNK2. *Tussenresultaten VNK2 (HR1268008)*. March 2011.

Colophon

DISSEMINATION DUTCH COASTAL PROTECTION

CLIENT:

REGIONE LAZIO (ITALY) - DIREZIONE REGIONALE AMBIENTE - CENTRO DI MONITORAGGIO G.I.Z.C

STATUS:

Final

AUTHOR:

dr G. Lipari
Michiel van Reen
Diederik van Hogendorp
Rob Steijn

CHECKED BY:

Michiel van Reen, Rob Steijn (each for parts he has not written)

RELEASED BY:

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10 June 2011
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