Learning from French experiences with storm Xynthia

Damages after a flood

Ministerie van Verkeer en Waterstaat

HKV CONSULTANTS

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Preface

Flood risk management in the Netherlands has been gradually improved after the flood disaster in 1953. The Netherlands nowadays are less susceptible to floods. The downside to this high safety level is the decreasing awareness that things may still go wrong. We maintain our expertise and alertness by learning from floods that have occurred abroad. New Orleans in 2005 and Xynthia in 2010 are examples of events which can help the Netherlands to stay alert. The Delta Program will give our water protection an additional boost. This is unique: for the first time in Dutch history this kind of boost is given without a prior (near) flood disaster.

France and the United States are two modern societies which are comparable to the Netherlands in a lot of ways. Both in France and in the United States inadequate action was taken in response to previous storms, which could be considered as warnings. Measures taken based on previous disasters, were not enforced. The study of social processes which led to not taking or not enforcing adequate measures to prevent a flood disaster, can help the Netherlands to stay alert.

Dutch safety policy is based on three important issues:

- a legal foundation in the Water Act (previously in the Flood Defence Act);
- a financial and institutional basis (with the water boards and the government);
- a broad knowledge basis with public and private parties.

Flood risk management starts with prevention. This means that the dike rings* which protect our country have to be in good condition. Through spatial planning we have to keep flood risks manageable, especially in areas outside the dikes. Finally, the disaster relief organization has to be in order, since disasters can happen at any time.

To me, staying alert means that balanced measures are chosen, implemented and preserved within this system. The Waterdienst (*Water Management Centre*) is dedicated to this purpose. As far as I am concerned, the Waterdienst will continue to make an important contribution the next few years, among others in the Delta Program.

Luitzen Bijlsma
General Director, Rijkswaterstaat, Centre for Water Management

* A dike ring is a single flood cell which is surrounded by a continuous line of flood defences (dikes, dunes, barriers or high ground)

Summary

On the 28th of February 2010 at 2 a.m. the storm Xynthia hit the French Atlantic coast. The storm surge combined with the high tide and large waves caused flood defences to fail along the coastline from the Gironde (Bordeaux) to the Loire Estuary. A significant amount of land, (>50 000 ha) was consequently flooded and 47 people died as a result of the storm. Most people died due to the flooding (they drowned, were exhausted or died from hypothermia). A number of people died as a result of the storm itself (storm debris). The French departments of Vendée and Charente Maritime suffered the most. Some parts of the departments Gironde and Loire Atlantique were also flooded. Since 1953 the Netherlands has not had any experience with major floods. Large parts of the Netherlands are also prone to coastal flooding, even though we have very high safety standards. The Netherlands can learn from this flood in a neighbouring country with a common history and legal system. The foundation of the legal system in the Netherlands and France was laid down in the Napoleonic period with the introduction of the book on common law. Jurisprudence plays a minor role in Napoleonic law. The flood was not caused by natural phenomena alone, organisational failure plays a large role in understanding the flood.
This book describes the Xynthia storm and its consequences. Using multiple viewpoints of the "multy-layer safety": flood warning, flood prevention, special planning and disaster management, this book gives lessons from the storm for the Netherlands.

Please note: We have used all available public sources up to the beginning of August 2010. The official facts about the storm have been assembled in three French public enquiries, by each house of parliament and by the French ministry of Ecology, Energy Transport and Development MEEDEM. Our purpose is to give lessons for the Netherlands and not to give a perfect list of facts about the storm.
The Dutch, French and English versions differ slightly. Some background information has been added in each language.

The Xynthia storm, the facts:

On the February 23rd Météo France announced a low pressure area was developing into a large storm, which in the days that followed was named Xynthia. At about midnight the February 27th 2010 the storm Xynthia hit the French Atlantic coast with a Beaufort 10 gale (89 to 102 km/hour or 24.5 m/s to 28.4 m/s). Beaufort 10 is not a strong gale. The fact the storm surge and the high tide coincided caused the large water levels and made it possible for the waves to cause so much damage. Usually wave action is limited by shallow areas just off the coast. The high tide had a rating of 102 on a scale from 80 to 120, the highest tides are expected in September. The return period of this flood is probably around 100 years, this estimate is based on historical records. It is impossible to give a precise return period for the storm. There are no precise historical local homogeneous water level measurements available (at least 30 years and preferably 50 years). Fourtyseven people died on account of the storm. The damage figure was about 2.5 billion euro's (French Senate figure). A lot of the damages are difficult to calculate, they concern: infrastructure for fisheries (mussels and oysters), agriculture (> 50 000 hectares were flooded with salt water), local government infrastructure and damages to the tourist industry. The flooded areas are relatively small parts of the departments. They are narrow strips of land along the coast and estuaries and some larger polder areas where marshes have been drained.

Disaster management

The most important part of disaster management failed, the storm surge warning was not understood by the disaster management authorities and the public. Meteo France had clearly provided a warning for the storm on all the TV networks and also given storm surge warnings. But the weather maps of Meteo France that were shown on TV provided no information on the risk for flooding. A small symbol may have been enough to alert the local population to the risk of flooding. Meteo France is not responsible for flood warnings. Local water levels have to be calculated by the local (department and municipal) authorities. Local authorities have to give the warning to the public.

As the population prepared for high winds and not for flooding this was fatal for some of them. They closed windows and (electric) shutters. Electric shutters can not be opened during a blackout or flooding.

That fact that the civil servants did not understand the nature of the flood is illustrated by the interview with Mrs. Beatrice Lagarde, a high ranking official (sous préfet of the Vendée) after the flood. She spoke of the impossibility to evacuate 400 000 people on account of the storm when evacuating a few thousand people would have saved about thirty lives.

After the floods occurred (February 28th at about 02.00 and 03.00) hours depending on the department the search and rescue units saved hundreds of lives. In the four departments hit by the flooding Vendée, Charente Maritime, Gironde and Loire Atlantique at least 3000 professionals were involved with the rescue operation. At 06.00 a.m. the first units of additional rescue workers, divers and pump teams were on their way to the flooded areas from areas 150 kilometers from the disaster areas. The Gironde area was well informed on the possibilities of a storm surge, this aided their preparedness. The Gironde area had been hit at Christmas in 1999 by two storms with a gale 12 wind and some flooding.

Spatial planning and constraints by the type of construction

France has a number of laws restricting construction on the coastline (1985) and in areas prone to flooding (1995). Since 1990 however a lot of houses were built along the coast in flood prone areas, former agricultural land. These areas were protected by flood defences that are adequate for agricultural land but not for new housing areas. Maintenance costs for flood defences are covered by local organisations or private owners. A flood may hit a larger area than the parties concerned covering the maintenance costs. So maintenance costs and reconstruction costs are not covered by all beneficiaries.
A number of reasons contributed to the fatal aspects of the floods:

- Building licenses for flood prone land were given by local the government, elected officials (mayors), contrary to spatial planning laws.
- The buildings put up since 1990 are usually only on the ground floor. Buildings from 1960 up till 1980 usually had the living quarters about 2 meters above soil level.
- Insurance companies often give a rebate if you install shutters or steel bars on your windows.
- Retired people often preferred electrical shutters and houses with only a ground floor, they often do not buy a house with an extra room on the second floor.

A combination of a warning to close shutters on account of storm, flooding, electric shutters, only a ground floor and retired people often proved to be fatal. Luckily a large part of the houses were not inhabited because it was not a holiday season.

Zoning of areas with a large flood risk from the law in 1995 took another meaning after the Xynthia flood. Area's with a flood level higher than 1.50 meters were considered fatal. All housing was to be removed. The state has proposed to buy out the 1800 houses concerned by paying the market price (the price before the storm). After stiff resistance on account of part of the population the state backed down, no one will be evicted. A large number of people have accepted the government proposition. They want to live elsewhere.

The mayor of Charron (Charente Maritime) acknowledged he had made a mistake by giving out building licenses in flood prone areas. The mayor of Faute-sur-mer (Vendee) said he did not know his town was flood prone. The newspaper Le Monde reacted by publishing the fact that the mayor had been warned a number of times by the department of the Vendee that it was illegal to build in flood prone areas.

Flood Prevention

During the storm flood defences (dikes, dunes and structures) failed at numerous points over a more than 300 kilometer long coastline between Bordeaux and the Loire Estuary. At each site there were also numerous breaches in the flood defences. Flood defences were probably built (on past flooding experience) so for a hundred year return period. It is impossible to determine the return period for the Xynthia storm. There are no series of homogeneous data longer than at least 30 years for the Vendee, Charente Maritime, Loire Atlantique or Gironde. Preferably even a series of 50 years or longer should be used.

Most flood defences were from the 18th and 19th century. In the 20th century maintenance was carried out when damage occurred due to storms. It is therefore impossible to say which state the flood defences were in prior to the storm. Two centuries relative of sea level rise is 40 cm in the Netherlands and 30 cm in Brest, France. Since higher water levels also mean higher wave action this phenomenon should not be overlooked, also see chapter 10. Some flood defences were repaired after the 1940 and 1999 storms. The repairs for the 1999 storms were not finished. In some areas flood defences had been partly removed to allow boats to be taken out to sea. Drainage structures and intake structures for salt water (for Oyster farms) were also weak spots. Two centuries relative of sea level rise is 40 cm in the Netherlands and 30 cm in Brest, France. Since higher water levels also mean higher wave action this phenomenon should not be overlooked, also see chapter 10.

It is very difficult to pay for the maintenance of flood defences with small organisations and when all the beneficiaries are not paying their share.
There are a number of reasons maintenance was not perfect:

- The responsibilities for the maintenance of the flood defences is not always clear (some flood defences were lowered without anyone noticing).
- Maintenance costs were not paid by all the beneficiaries. Owners of the flood defences (communities or private people) paid the costs.
- Organisations for the maintenance of flood defences are too small to employ experts.

Lessons for the Netherlands

The coastal flooding in 1953 fundamentally changed the Dutch flood defence policy. Very high safety standards for flood defences were set in the sixties. In 1996 all primary flood defences received legal status; this legal base also provided funding for major and minor repairs. Maintenance issues had already been provided for by water boards from the 13th century

onwards, but the 1996 law provided for a national coverage and a clear set of rules.
Dutch Flood management policy can be summarized in the following three issues:

- A legal base, with the water law (previously the Flood defence law of 1996).
- A institutional and financial base, with clearly defined roles.
- A knowledge base, with a professional community at all levels (from water boards and municipalities up to the ministry) and both the private and (semi)public sector with the research institutes.

After a disaster there are always two questions:

- Could we avoid the disaster?
- Why were we not prepared for the disaster?

At this moment the Netherlands is reviewing the current safety levels based on cost benefit analysis and the acceptable number of casualties. Even though the Netherlands have focussed the flood defence policy on flood defences two other policies are also being examined: spatial planning (using the "water test") and disaster management. Spatial planning can only be applied to new housing areas. The New Orleans floods in 2005 were used to start up a project to evaluate and improve the state of Dutch disaster management on account of major floods.

The most important lessons after the Xynthia floods for the Netherlands are:

- Having high safety levels for inhabited areas is efficient (return periods higher than 1000 and 10 000 years). The primary focus on flood defences is a good choice.
- Flood warnings should be given in such a way that disaster management services and the general public can understand them and can evaluate which action they can take. This means a simple and explicit message, no technical jargon. It is important that professionals and the public understand the same message.
    - It is easy to warn for extreme wind speeds. It is a lot more difficult to give flood warnings. For use full flood warnings, information is needed about the local conditions of water levels, wave action the state of the flood defences. Only delivering warnings on account of the wind may make people do things to make them more vulnerable during flooding.
    - It has to be clear who gives which warning, who analyses flood risk and who is responsible for the communication with the public.
    - During storms a lot of equipment fails some water level meters and a lot of the wave registration devices. These means storm surge warnings and wave warnings will often be made without necessary verification procedures of data. Also communication links can fail.

Contingency planning for failure of equipment is necessary. Redundancy in measuring devices is needed.
- Managing flood defences asks for strong, democratic, independent, local organisations with very a very clear mandate for maintenance, new construction, financing and the inspection. All beneficiaries have to pay for the maintenance. For new construction you often will need help from provincial or national government.

- Do not forget people often have to save themselves. Provide information on simple measures to take (like going to your neighbours on high ground or the first floor) and to avoid (closing electric shutters).
- In large scale flood events there are multiple levee failure spots. Often it is impossible to predict these spots. Evacuation planning and for emergency response planning has to accept these incertitude's.
- Rescue and recovery operations are impressive. A lot of people are saved in a very short period. You have to realize the massive number of people needed to save a few hundred people. This is only possible when relatively small areas of provinces are flooded.
- Zoning flood risk areas is a very efficient policy measure, but how do you make people respect the rules over a thirty year period? How do you make people respect national laws when almost all choices are made locally at the community level and there is no direct control/verification by a higher government level? Also real floods usually have different flooding patterns then the scenario's used for elaborating the zones. You need to monitor the coastline and storms permanently to be able to make proper flood maps and update danger zones.
- Management of flood defences requires strong, democratic, independent organizations. Costs and benefits must be proportional for all interested parties to reduce the risk of overdue maintenance.
- If you want to do flood risk management properly and diminish the flood risk, you have to accept there is a lot of uncertainty and cope with this.

1. Protection of built-up areas by strict protection standards is a good choice. In hindsight the proverb: "prevention is better than cure" applies. However, the risk of a flood disaster can never be ruled out.
2. Warnings for impending floods must be made understandable for crisis managers (authorities) and the general public, so these groups can decide for themselves which action they want to take. Warnings must be suitable for the perception of the receiver and should not contain any technical terminology.
3. Management of flood defences requires strong, democratic, independent organizations. Costs and benefits must be proportional for all interested parties to reduce the risk of overdue maintenance.
4. Risk zoning is a tool for reducing the risk of damages and casualties caused by floods. It is only effective if clear national rules apply which are consistently maintained and complied with. Therefore, the support of administrators is necessary.

   Furthermore, risk zoning will not guarantee that floods will comply with the choices in scenarios for flooding models.
5. Insight into effective self-sufficient actions from citizens in case of storm or floods is required and should be stimulated. This also requires insight into the effectiveness and risks of government measures.
6. The fact that flood defences might fail in various locations and that this phenomena is difficult to predict, must be considered for contingency plans and disaster relief.
7. Decisions about disaster management, both during preparations and during a crisis, must be based on various scenarios, with information about risks and consequences.
8. The Xynthia case suggests that we should not only derive very rare extreme wind speeds from the few dozens of storms measured during the last fifty years, but that the corresponding characteristics of the depression are also important for determining the design conditions for our dikes.

Note: These lessons are not to be copied to other countries without making a proper analyses.

Contents

1 Introduction

1.1 Event

In the early morning of Sunday 28th February 2010, around 2.00 am, storm Xynthia reached the west coast of France and caused large-scaled floods. The storm claimed dozens of casualties and caused major damage along the Iberian Peninsula, France, Germany and the Benelux countries.

A total of 65 people were killed, mostly as a result of the floods along the coasts of the Vendée and Charente-Maritime in the western region of France (47 casualties, previous estimates stated 53, but were adapted later on). Other people died a result of the storm, for example by falling trees. This was the third flood in France in eight years time. Twenty people were killed during the flood in 2003. Nobody was killed during the flood in 2005. Twentyfive people were killed more recently in june by a flash flood in the Var prefecture.

Figure 1: *Regions and departments (counties) in France.*

In the days before the floods Météo-France (the French meteorological service) warned for possible serious consequences of the storm. However the flood warning Météo-France made was not understood by the authoroties for diasaster management and consequently almost no action was taken for possible floods. After the disaster there was a wide, emotionally and politically charged debate about how this disaster could have happened. This debate focused on a controversial subject: over the last twenty years houses (holiday homes) were built at many locations along the coast, although it was a well-known fact that these coastal areas are flood prone, despite the presence of flood defences. But spatial planning is not the only controversial subject. The various French government services found it difficult to work together to assess the seriousness of the threat and to warn the population in time. It also turned out that the protection offered by the flood defences and their condition was often unknown.

The cause and course of the floods in France can provide useful information for the Dutch water safety policy.

1.2 Purpose and scope of the booklet

The purpose of this book is to learn lessons from the floods in France for the Dutch water safety policy in the Netherlands. We have used three methods:

1. *Listing of facts*
   We offer an insight into the facts of the storm, water levels, flood and its consequences in terms of damages and casualties.

2. *Further analysis of the facts*
   We provide a further analysis of the facts for the three components of multi-layer safety: prevention, spatial planning and crisis management.

3. *The importance for the Netherlands*
   We translate facts and analysis into lessons and recommendations for Dutch experts involved in water safety policy.

This book is based on the concept of "multi-layer safety", as introduced in the National Water Plan. Multi-layer safety divides the flood defence policy into three layers:

1. disaster relief: reducing the consequences of floods by (organizational) preparations and rescue services
2. spatial planning: reducing the consequences of a flood by changing spatial planning and building rules.
3. prevention: preventing flood through flood defences (dikes, dunes, barriers).

Figure 2: *Multi-layer safety. [1].*

This book is based on information published after the French flood disaster. The authors wrote this book based on their expertise and the footage and information known to them regarding the events in France (up until August 2010). Their purpose was to obtain lessons for the Netherlands and not to create a perfect description of the facts about the storm. The official facts are collected in three public surveys by the "Chambre de Députés", the Senate and "MEEDEM". One of the authors, Robert Slomp, went to the affected area himself for observations and to speak with victims and government. His own direct observations have been of great value for creating a balanced representation of events and obtaining lessons for the Netherlands. However, we cannot offer certainty about the full facts of certain events.

There is still a continuous flow of publications in the French media. Several investigations are still being conducted by the French government. They are surrounded by political issues such as liability and the wish to be in the limelight by taking measures to prevent any future floods. Due to the political undertone the public debate is also susceptible to change. These developments can provide new facts and insights. Therefore, this book does not claim to offer a complete description of the events in France. Its purpose is to provide lessons for the Netherlands.

The Dutch, French and English translations and summaries differ slightly. Some background information has been added in each language

1.3 The importance of a flood in France for the Netherlands

Why are the events in France relevant for the Dutch policy? There are (at least) three reasons. First of all, the Netherlands have a limited knowledge of and experience with the consequences of a flood. It is important to learn from floods which have occurred in other countries in order to be better prepared for floods. We have to ask ourselves the same question over and over again:

"What does this flood mean to us?" Floods in France have parallels with the flood disaster in the Netherlands in 1953. These parallels relate to the quality of the flood defences, not responding (in time) to previous signals about the bad condition of flood defences (during storms in the Netherlands in 1943 and France in 1999) and dealing with storm warnings and critical flood threats. There are also differences. The social situation in France in 2010 cannot be compared with the situation in the Netherlands in 1953. And the knowledge of weather and water level is at a much higher level nowadays than back in 1953.

Secondly, experiences in France may be of great value to further developing the concept of multi-layer safety in the Netherlands. During the last few decades the Netherlands focused on flood prevention. The last few years this focus has been shifting towards dealing with the consequences, for example by the Delta Program and the Flood Management Taskforce (TMO). The French situation can offer more insight into the way prevention, disaster management and spatial planning can complement each other. Especially the discussion which arose in France after the flood is very important.

The third reason is that legal and administrative systems in the Netherlands and France have strong similarities, which makes it easier to use experiences with the French flood for the Dutch situation. The French legal system is more similar to the Dutch system than, for example, legislation and regulations in the United States, which are mainly based on jurisprudence. Administrative systems in France and the Netherlands have the same origin: the French revolution[1]. The 'House of Thorbecke'[2] and the model of the constitutional state originate from the body of ideas from that time. In both countries municipalities are responsible for implementing policies and they can act autonomously. Policies are not only established on a national level, but also on a regional level: by the provinces in the Netherlands and by the departments and coordinating regions in France. In case of a (impending) disaster, mayors have a responsibility to provide disaster relief and supply information to the population. In case of storms or floods, the background information about the threat will be provided by regional or national services. The Netherlands have a special Safety Regions Act which transfers the responsibilities of the provinces to the 26 safety regions. A safety region is presided by one of the mayors from the municipalities in the region.

1 An organization such as Rijkswaterstaat also dates back from the French era.
2 House of Thorbecke is the dutch administrative and legal system.

1.4 Bookmarks

The book contains the following information:

Chapter 1	contains the introduction to this book. It describes the scope and lay-out based on the concept of multi-layer safety.
Chapter 2	describes the events before, during and after the storm named Xynthia. It defines the storm, storm warnings and consequences of the floods.
Chapter 3	provides a further analysis of events for the different layers of multi-layer safety. This analysis offers detailed information about some of the current topics in the Netherlands.
Chapter 4	deals with the lessons for the Netherlands, based on experiences with the consequences of Xynthia.
Chapter 5	contains the final conclusions of the authors, based on their view of events.
Chapter 6	contains a short biography of the authors of this book.
Chapter 7	includes a list of references used.
Chapter 10	the effect of relative sea level rise

2 Storm flood Xynthia in France

2.1 Introduction

This chapter describes the development of storm Xynthia and its consequences. We will first describe the meteorological observations of the storm - wind speeds and their effects on tide and storm surge - and then the consequences of the floods in terms of casualties and damages. In between we will briefly discuss the noticeable effects of the storm in the Netherlands.

2.2 Meteorological context

2.2.1 The course of the storm since the first threat

In the evening of 23rd February 2010 Météo-France reported an active depression over the Atlantic Ocean for the first time. At that time, the depression was situated at 30° longitude west. Circumstances were such, that it could develop into a depression with a heavy storm. Meteorological services in Portugal, Spain and France then initiated their alerting procedures for regions threatened by the storm. On 26th February the depression reached the Canary Islands and caused limited material damages.

The storm, which was named "Xynthia" by German meteorologists, then grew in strength and reached the coast of the Iberian Peninsula, the Cantabric Sea and the Gulf of Biscay on the night of 27th February. By that time the Spanish meteorological service (AEMET) had already issued a statement in which they referred to the storm as "quick, intense and deep", with the characteristics of so-called explosive cyclogenesis [2]. Satellite images from NASA [3], as shown in Figure 3, show how the storm depression Xynthia reached the mainland of Europe.

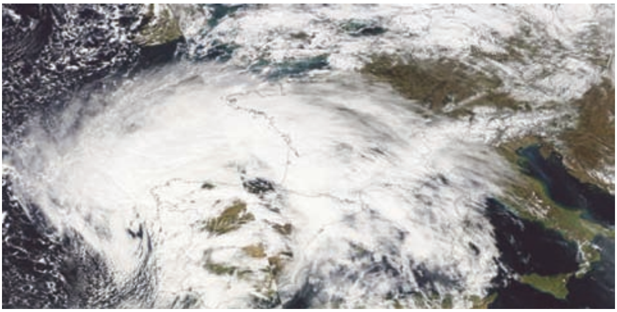

Figure 3: *Satellite images from NASA which show how storm Xynthia reached the mainland of Europe. [3].*

During the night of 28th February 2010, around 2.00 am, the storm reached the west coast of France. Especially the coastal areas of the Vendée and Charente-Maritime were several afflicted. Four hours later, around 6.00 am, Xynthia reached the region of Paris. Then the storm moved in the direction of Belgium, the Netherlands and Germany and finally died out over the southern Baltic Sea. Figure 4 shows that Xynthia moved from southwest to northeast over Western Europe and covered approximately 1400 kilometres in 24 hours.

Figure 4: *The course of storm Xynthia from the Atlantic Ocean towards the west of Europe. [4].*

2.2.2 Xynthia in the Netherlands

On Sunday 28th February Xynthia moved over the Netherlands at a speed of approximately 60 km/h. This resulted in considerable weather differences. Off the coast of Zeeland, just north of the depression, wind-force 8 was barely obtained. This situation occurs at least once or twice a month during the winter. At Maastricht Airport, on the other hand, an average south-west wind of 21 m/s was obtained, equivalent to wind-force nine (storm). Figure 5 shows the highest average wind speed per hour in the Netherlands (on 28th February).

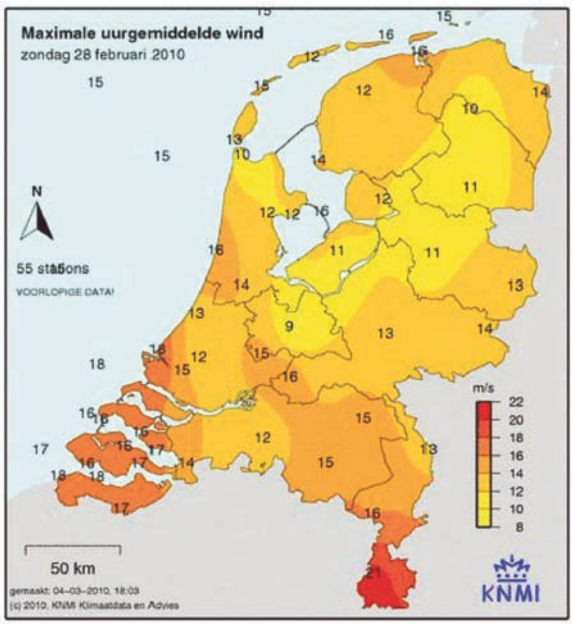

Figure 5: *Max. average wind speed per hour in the Netherlands on Sunday 28th February 2010. Source: KNMI*.

For wind statistics KNMI (*Royal Netherlands Meteorological Institute*) uses exposure corrections to convert the measured average wind speeds per hour into a so-called potential wind at 10 metres above level grassland. The potential wind near Maastricht rose to 80 km/h during Xynthia. This made Xynthia the second heaviest storm during 49 years of measurements at Maastricht Airport, just after the storm of 24th November 1984. The example above shows that depressions may be sharply defined and that small differences in the course of a depression may have major consequences for storms and storm flood forecasts. It is a major challenge to determine relevant wind and hydraulic conditions for the Dutch dikes. For many Dutch dikes these conditions have to reflect events which occur an average of once every 10,000 years. The Xynthia case suggests that we should not only derive very rare extreme wind speeds from the few dozens of storms measured during the last fifty years, but that the corresponding characteristics of the depression are also important for determining the design and assessment conditions for our dikes.

2.3 Xynthia in France

2.3.1 Wind speeds

In France the storm reached its highest wind speeds in the Pyrenees, with wind gusts of approximately 200 km/h. The highest gust speed of 242 km/h was measured at the Pic du Midi d'Ossau (in the Pyrenees). In the afflicted area (Charente-Maritime and Vendée) wind gusts of approximately 160 km/h were measured at the island Île de Ré and the department Deux-Sèvres. Stations at the coast towns La Rochelle and Les Sables-d'Olonne measured wind gusts of approximately 130 km/h. Heavy wind gusts were also detected in the Rhône valley and the Alps.

The measurement reports from Météo-France mainly show gust speeds, while in an hydraulic context (set up of water and waves generated by wind) the average wind per hour is important. Figure 6 gives an impression of the average wind speeds and directions at approximately 4.00 am. Wind speeds can be converted into a wind-force on the Beaufort scale by using Table 1. This shows that in the coastal waters of the research area a maximum of wind-force 10 (heavy storm) was reached.

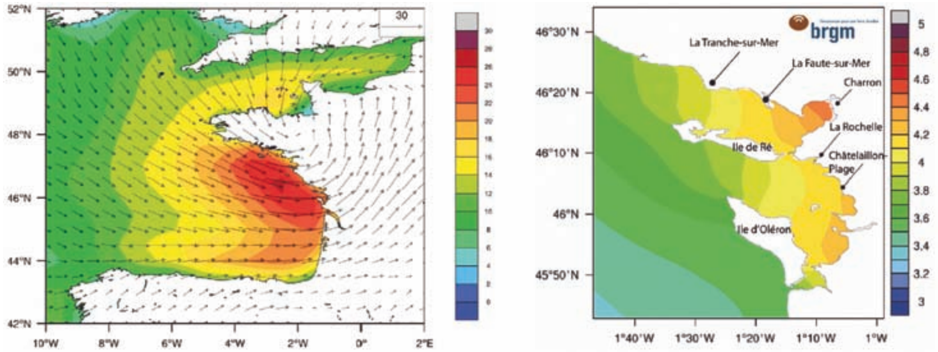

Figure 6: *Figure on the left: wind speeds (in m/s) and directions at 4.00 am on 28th February 2010.*
Figure on the right: calculated water levels in m NGF (hind cast) at 4.30 am on 28th February 2010, based on wind maps by using the MARS model. [17].

Wind force (Bft)	Wind speed (km/u)	(m/s)	KNMI description
0	0 – 1	0 – 0.2	Stil
1	1 – 5	0.3 – 1.5	Weak
2	6 – 11	1.6 – 3.3	Weak
3	12 – 19	3.4 – 5.4	Mild
4	20 – 28	5.5 – 7.9	Mild
5	29 – 38	8.0 – 10.7	Fairly strong
6	39 – 49	10.8 – 13.8	Strong
7	50 – 61	13.9 – 17.1	Very strong
8	62 – 74	17.2 – 20.7	Stormy
9	75 – 88	20.8 – 24.4	Storm
10	89 – 102	24.5 – 28.4	Heavy storm
11	103 – 117	28.5 – 32.6	Very heavy storm
12	117	> 32.7	Hurricane

Table 1: *Table for converting wind speeds in km/h and m/s into wind-force in Beaufort (Bft) and the names that KNMI uses.*

2.3.2 Storm surge and tide

It is remarkable that a storm with a mere wind-force 10 led to such large-scale coastal floods in the afflicted area. The major threat for the afflicted area, was mainly caused by a combination of wind (storm surge and waves), duration and (near) spring tide. The storm surge was 1.6 metres and the tide approximately 2.75 metres.

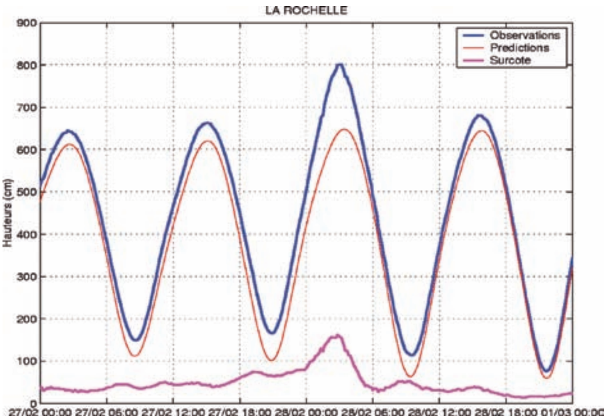

Figure 7: *red line: predicted water levels at the commercial harbour of La Rochelle (La Pallice), blue line: actual water levels, purple line: the effect of storm surge. Time frame runs from midnight 27th February to midnight 28th February. Source: SHOM.*

The tidewater level, excluding the wind effect, was virtually similar to the water level of an average spring tide[3], as shown by the tide coefficient of 102 at La Rochelle. The highest water level of 4.5 metres NGF (General Levelling of France) was measured at La Rochelle. Based on existing statistical water level data (see Figure 8) BRGM (Bureau of Mining and Geological Research) states that this water level of 4.5 metres NGF is equivalent to a frequency of 1/10,000 per year, corresponding to a return period of 10,000 years. This return peroid is based on extrapolation of existing statistics (over dozens of years) for extremely rare events. BRGM declared later on to the media [18] that the link between this water level and a return period of 10,000 (0,00001) years was misinterpreted. They also mentioned that the period of time over which the statistical data were collected, is too short to justify an extrapolation to 10,000 years. In addition, harbours have been built over the years at various locations along the coast. This can cause the tide curves to change. This casts doubts on the actual value of measurements and the extrapolation of this data to long time scales.

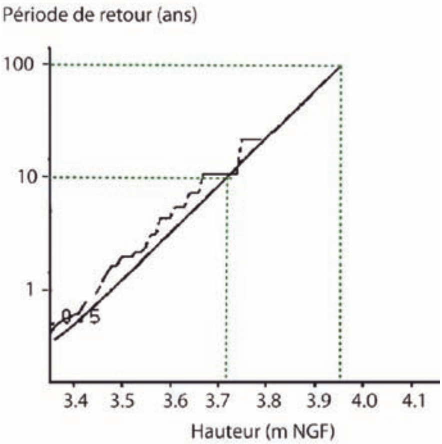

Figure 8: *Return periods for water levels (in m NGF) at La Rochelle. [17].*

2.4 Casualties and damages

The prefectures of Charente-Maritime, Vendée, Loire Atlantique and Gironde experienced wind and flood damages and the prefectures of Deux-Sèvres and Vienne were mainly affected by wind. Storm Xynthia is the first major storm since the Christmas storms Lothar and Martin in 1999. During these storms, flood damages were relatively small, despite several dike failures in the Vendée and flood incidents at the Gironde estuary, including an incident near a nuclear power station.

[3] The tide coefficient or "coefficient de marée" represents the strength of the tide on a scale from 20 to 120 (see www.wikipedia.fr). Values of 120, 100 and 95 represent the strongest tide (120), an average spring tide around the 21st March/21st September (100) and an average regular (two-week) spring tide. Values of 45 and 20 represent an average neap tide and the weakest possible tide.

2.4.1 Casualties

Due to the storm 65 people in Europe died and 102 were injured. France suffered the most: 47 people killed and 79 people injured, including 7 seriously injured. Most people were killed as a result of the floods in the coastal areas of the Vendée. The villages of La Faute-sur-Mer and L'Aiguillon-sur-Mer were most severely afflicted by the water, 29 people were killed. In some houses in La Faute-sur-Mer the water level rose to 2.5 metres within half an hour. Some people woke up to find their bed floating 1.5 metres above the floor. In Charente-Maritime twelve people were killed. In Les Moutiers-en-Retz (in the region of Loire-Atlantique) two people were killed because their camper got washed away from the pier [19].

Although most casualties suffered from the floods (drowning, hypothermia and exhaustion), some people got killed as a direct result of the storm, e.g. by fallen trees. Due to the large number of casualties and the size of the damages, some facts were overlooked by the media. The material damages in Normandy and Brittany only received marginal attention in the national media.

2.4.2 Material damages

Damage to houses

A total of 500,000 French people suffered material damages due to the storm [5]. In the Vendée 562 houses were condemned, the majority of which in the two villages which were afflicted the most: La Faute-sur-Mer (329 houses) and L'Aiguillon-sur-Mer (208 houses). In the neighbouring village of La Tranche-sur-Mer 25 houses were condemned [6]. In Charente-Maritime 4,000 houses were damaged, 120 of which were condemned.

Damage to agricultural lands and infrastructure

In the Vendée 11,000 hectares of agricultural lands were affected by the salt seawater. In Charente-Maritime 45,000 hectares of agricultural lands were flooded by seawater, which amounts to 10% of the overall surface area of agricultural lands in this department. In the northernmost departments such as Loire Atlantique this percentage was probably lower. On Île de Ré oyster farms were severely damaged. Figure 9 contains a list of the areas affected by the floods in the Charente Maritieme.

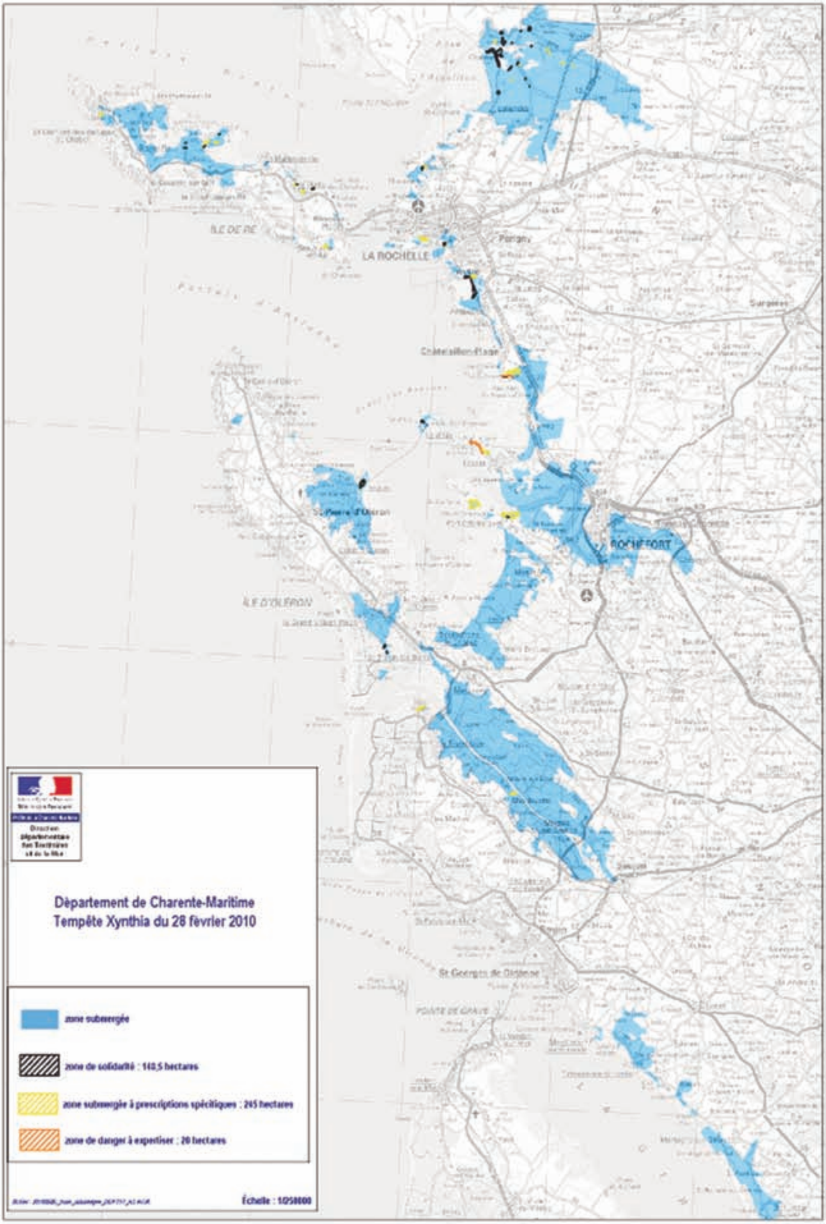

Figure 9: *The areas affected by the floods in Charente-Maritime. Source: CETMEF*

Xynthia also caused major power failures. On the morning of 28th February more than 1 million French households had no power, among which 320,000 households in the regions of Poitou-Charentes and Pays de la Loire and 375,000 in the regions of Auvergne, Centre and Limousin. The last three regions only suffered wind damage.

In La Rochelle, a major touristic seaside town, the area around the old harbour encountered serious problems due to the flood. Many other harbours were also flooded, which destroyed boats, pontoons and landings. Houses surrounding the harbours were also flooded. The coastal railway between La Rochelle and Rochefort could not be used for several weeks. The tracks near the coast got undercut by the flood water and became unstable.

Damage to dikes in other parts of France
Dikes along the coasts of Normandy, Picardy and Nord-Pas-de-Calais were also damaged. The gravel dikes of Cayeux-sur-Mer also had to be repaired. They are similar to Dutch dunes: the profile and gravel volume have to be supplemented.

Other dikes suffered from overflow and overtopping, but did not fail. Precise measurements of water levels or wave height is not available, but nevertheless it seems that the disaster could have been much bigger if the combination of storm surge and spring tide had been even more adverse. Locally major dune erosion occurred and connecting constructions of flood defences e.g. dune and revetments and the outlet sluices of marshes were damaged. Waves were a major cause for this kind of damage. Even in the Landes, near the coast along the municipality of Lacanau (in the Gironde) dunes were damaged over 70 kilometres.

It is remarkable that the national news had so little attention for local damages. The damage to the dikes in Normandy amounts to approximately 4 million Euros, but got barely mentioned on the news. Most of the attention went to the flood in La Faute-sur-Mer and L'Aiguillon-sur-Mer, because the high number of casualties.

Insured damages
On 1st March 2010 the storm events were declared a national disaster. A national coordinator for compensation of the damages was appointed. This way, the settlement of claims could be started immediately. The "disaster area" was initially limited to four departments. On 13th October 2010 the area was expanded from the area of the Loire-Atlantique up to the Gironde. The most recent estimate of the overall insured damages is 2.5 billion Euros [7].

The national disaster declaration reduced the burden of proof for the insured parties. Insurance companies deal with most of the paperwork and seem to handle claims relatively quick - compared to the French government.

3 Further analysis based on multi-layer safety

This chapter is about the flood risk policy in France and its effects during Xynthia. We follow the lines of the multi-layer safety concept, on which the Dutch water safety policy will be focused during the next few years. To learn from the events in France, we have to ask ourselves the following questions:

1. *Prevention*: What is the condition of the French flood defences and which failure mechanisms occurred during the storm?
2. *Spatial planning*: What is the role of spatial planning in the French flood risk policy and how is it dealt with in practice?
3. *Disaster management*: How was the warning process organized and implemented and what was the role of emergency workers and citizens before, during and after the disaster?

3.1 Prevention

3.1.1 Historical perspective

Over the last century the coastal area of the Vendée had to cope with several floods, for example in January 1940 when the dikes of Bouin and Aiguillon failed. Recent events were the floods in December 1999 when dikes were flooded and failed due to a storm, combined with a regular high tide (tide coefficient 78). Both storms (Lothar and Martin) were stronger than Xynthia in wind-force, but during Xynthia the tide played a bigger role (tide coefficient 102, corresponding to spring tide).

As a result of previous storms, especially storms in 1940 and 1999, the flood defences were recently reinforced in certain areas. Especially the Gironde was severely afflicted in 1999. During storm Xynthia 'only' seven dike locations failed in this department, causing less damage than in 1999. Another important factor was that people in the Gironde were relatively more aware of the possible storm surge caused by Xynthia.

During Christmas 1999 the flood defences of three agricultural polders in the Vendée failed. Therefore, a major plan was created to repair the dikes. In this new plan the dikes were to be raised by one metre [9]. Only 20 million of the available 40 million Euros was spent when Xynthia occurred. Repair on the dikes of L'Aiguillon-sur-Mer were to be carried out in 2010. Throughout France approximately 1000 kilometres of dikes are known to be unsafe [10].

During the last millennium the Vendée and Charente-Maritime regularly faced floods, as did the northern island Île de Noirmoutier [8]. There is even a word 'vimer' for the storm surges during springtides.

While this report was written France suffered from another flood in Draguignan with 25 people killed in the Var department (figure 1). This was not a storm flood, but a so-called flash flood. Extreme rainfall caused a stream to rapidly overflow its banks, flooding a town in a (tourist) area.

3.1.2 Responsibilities for prevention

France has a total of approximately 10,000 to 13,000 km of dikes and flood defences, with approximately 1300 km of sea dikes. No owner or manager is known for 3000 km of these flood defences. The management and maintenance of other flood defences is sometimes the responsibility of the owner of the agricultural plot on which the structure is situated. This means that the landowner is solely responsible for its management and maintenance, while owners of the more inland plots also profit from the flood defences. There is not always a shared responsibility between landowners as is the case in the Netherlands.

So it is no surprise that the lack of a shared responsibility and solidarity is a fundamental problem for the management and maintenance of flood defences. In addition, there is a structural shortage of resources for management and maintenance. After every disaster a large-scaled program is set up, but its implementation often fails, since there are not enough resources to complete the works. There seem to be few resources for inspection and maintenance.

To guarantee the safety of people living behind these flood defences, it was decided in 2007 that these structures have to be inspected and maintained every ten years. The Ministry of Ecology (full name in French: Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer) has to supervise inspection and maintenance [11]. Most dikes are designed on the basis of experience so for a hydraulic load level which occurs once every 10 to 100 years. This frequency would be acceptable to Dutch standards for freshwater floods on lands used for agricultural purposes. However, the areas affected by Xynthia were closely built-up areas with houses (holiday homes) on the sea shore.

3.1.3 Locations and causes of failure flood defences

Figure 10 shows the area that was most severely affected by Xynthia and the consequent floods. La Faute-sur-Mer, L'Aiguillon-sur-Mer, Aytré, Île d'Oloron, Île de Ré and Charron are among the towns that were most severely affected. With the help of the media it was possible to make a first estimate of the failure mechanisms which occurred and led to the floods soon after the disaster. In March/April 2010 the first official research report of the Bureau de Recherches Géologiques et Minières (BRGM) [17] was published. This report contained a further analysis of the causes of the floods, based on 240 km of coast line and 300 GPS observations. BRGM especially investigated two municipalities in the Loire-Atlantique, fifteen municipalities in the Vendée (region of Les Sables-d'Olonnes) and sixteen municipalities in Charente-Maritime (the region around La Rochelle). The list below of failure mechanisms is mainly based on the conclusions from BRGM [17].

Figure 10: *The area most severely affected by the floods*.

La Faute-sur-Mer and L'Aiguillon-sur-Mer

Xynthia had serious consequences for La Faute-sur-Mer and L'Aiguillon-sur-Mer, two towns on the estuary of the river Lay. This "twin town" has a few thousand occupants during the winter months, but during the summer this number rises by a factor of around ten. Another fact is that 48% of all houses in Aiguillon-sur-Mer are holiday homes and in Faute-sur-Mer even more [20]. Figure 11 and 12 show how the village of La Faute-sur-Mer is stuck between the dunes which protect the village against the sea and a dike which protects the village from the water in the river Lay estuary.

Figure 11: *Location of twin town La Faute-sur-Mer / L'Aiguillon-sur-Mer.*

Figure 12:
The flooded village of La Faute-sur-Mer is situated behind the dunes and has a long flood defence at the side of the river Lay.

The dikes of Lay near La Faute-sur-Mer and L'Aiguillon-sur-Mer are clay dikes covered with stone revetment (the diameter of the stones is more than 500 mm) or masonry from the nineteenth century.

The main reason for the flood in La Faute-sur-Mer seems to be the failure of a dune north of the village. This dune failure is clearly visible in Figure 13. A breach and deep scour hole was formed at the location of the dune failure. Most of the flood water probably (this is still unclear) came from the "back of the village" and caught the occupants by surprise. Assistance from the fire brigade, alarmed by the first reports, was impeded by this surge in the water level. Wave action was probably an important factor for the dune failure. The dune had also lowered to make an easy spot to launch boats.

The dikes along the Lay, near La Faute-sur-Mer, were overflowed but did not fail, even though they were too low. The largest amount of water entered the village from behind the flood defences. It seems that there was hardly any wave overtopping near the dikes. Figure 14 shows the chaos of caravans floating in La Faute-sur-Mer.

Figure 13:
Aerial photo of the village of La Faute-sur-Mer, oriented towards the south. The photo shows a large breach in the dune north of the village. The arrow schematically indicates where the flood defences have failed [20].

Figure 14:
Flood in La Faute-sur-Mer at the campingsite [13]. The dikes around the camping did not fail but overflowed. This accounts for the difference in waterlevel seen in the picture.

At the same time the water started to flow over the dikes in L'Aiguillon-sur-Mer. Large volumes of water flowed over the dikes; so the flood defence basically acted as a long, large spillway. Water flowing over the dikes caused regressive erosion at inner toe of the flood defence (see Figure 15). This caused the dike to failure in two places, with breaches approximately 10 to 15 metres wide.

Figure 15:
Flooding of the flood defences resulted in regressive erosion near L'Aiguillon-sur-Mer [15].

Wave overtopping was an important factor at other locations. All structures where wave overtopping or erosion occurred, showed serious damage of the structures. Damage by wave overtopping occurred, for example, south of Châtelaillon-Plage (south of La Rochelle), while erosion damage (undermining of houses on the dunes) was found near La Tranche-sur-Mer (just north of La Faute-sur-Mer).

Figure 16:
L'Aiguillon-sur-Mer, clockwise: repairs in the harbour, emergency repair of a failed concrete flood defence, munici-pal infrastructure destroyed and dune erosion.

Aytré

Figure 17: *The town Aytré is situated south of the city La Rochelle.*

The dunes near Aytré are very low: the difference in height between the line of dunes and spring tide level raised by storm surge was less than one metre. There are holiday homes and caravans at the back of the dunes, for which dunes were sometimes excavated. The houses behind the line of dunes were approximately half a metre below spring tide level (see Figure 18). A day after the flood the water depth amounted to approximately one metre.

Figure 18:
Flood in Aytré, a day after [12].

In Aytré three people were killed because a flood wall near the dunes and dune crossing (concrete steps) failed. This was probably due to overtopping water and then erosion directly behind the construction. This type of failure mechanism can occur within a short period of time, sometimes within tens of minutes. The wall was damaged during a previous, recent storm, but had been repaired. At Aytre the water was trapped between the failed dunes and a railway embankment.

The long promenade along the coast south of Aytré was also damaged. Figure 19 shows the damage: a breach in the flood defence of approximately 10 metres. This photo also shows the structure: the bottom layer of the flood defence consists of stone material (there are limestone cliffs rnorth of the promenade), while the top layer consists of clay. The asphalt of the cycle path was put directly on top of the limestone.

Consequences in Aytré could have been much worse if the camping site had not been evacuated in time. Because they knew of a possible storm flood in the Gironde and because of a personal union (an employee working for both organizations), Charente-Maritime was aware of the storm surge and the evacuation was initiated in time[4].

Figurer 19:
The promenade of Aytré after the flood. [14].

Île de Ré

Figure 20 shows the location of Île de Ré. This island basically consists of three old islands: Loix, Ré and Ars. During Xynthia two people were killed, just behind the connecting dams between the islands. This island is located a few metres above sea level. A large part of the island was flooded. Even a week after the flood a large part of the island was still covered by water.

4 The prefectores Charente Maritieme and Gironde seem to collaborate along the Gironde Estuary on account of storm surges.

Figure 20: *The location of Île de Ré.*

On this island dikes failed in at least five places: three at leeward side and two at windward side. Furthermore, a flood wall failed. Other affected villages are Saint-Clément-des-Baleines, Les Portes-en-Ré and Saint-Martin-de-Ré (see Figure 21). The failure of the flood defence on the windward side of Île de Ré is caused by the interaction between waves and very high water levels, caused by springtide and the storm surge. Dike overflow was the main failure mechanism on the lee-ward side of the Island. Intake structures far salt water for Oysters and Salt production were probably also a cause. Large waves offshore (significant wave height of approximately 7 m) were not damped sufficiently while they moved towards the coast because of the high water levels. The high water levels also caused waves to break on the flood defences instead of on the large foreshores.

Figure 21:
Failure of a flood wall near St.-Martin-de-Ré, on Île de Ré.

Île d'Oléron

Figure 22: *Location of Île d'Oléron.*

On Île d'Oléron a more than three metre high flood wall failed. TV footage showed a dune with concrete revetment. Extreme waves probably contributed to the failure of the flood wall, because overtopping water eroded the sandy inside of the flood wall. Flood defences also failed in two other places. On Île d'Oléron five people were killed, including a 10 year old boy and an 88 year old woman who drowned in her house in Boyardville [16].

Other locations

The villages of Charron and Esnandes at the estuary of the river Sèvre Niortaise (see Figure 23) also incurred considerable damage. One person drowned in Esnandes. Near Charron a grandmother and her grandchild drowned during their flight. The failure at Charron was caused by excavating the higher ground to attain a broader road. In this location overflowing of the dikes and higher grounds were the dominant failure mechanisms. At Esnandes it is also likely that some waves were responsible for the vast water volumes overflowing the dikes.

Figure 23: *Location of Charron and Esnandes, near the estuary of the river Sèvre Niortaise.*

Figure 24: *Clockwise: emergency dike in Charron, house in Charron showing that the water level rose to 1.5 m, destroyed promenade of Chay near Chatillion Plage, destroyed house near the coast only the kitchen floor is still visible.*

3.2 Spatial planning

3.2.1 Flood prone areas

In France about 5 million people live in flood prone coastal areas. Figure 25 shows the location of these areas (see dark blue zones).

Figure 25:
Flood prone coastal areas in France, marked in blue. [8].

Essentially a very restrictive building policy applies to the areas outside the dikes. However, the elected mayors, for example in La Faute-sur-Mer and L'Aiguillon-sur-Mer, have often granted permission to build in these areas over the last few years.

3.2.2 Population size and tourism in affected area

Table 2 contains the population size in the different municipalities within the research area.

Vendée	
L'Aiguillon-sur-Mer	2283
La Faute-sur-Mer	1008
Charente-Maritime	
Aytré	8687
Charron	2140
Île de Ré	17824 (10 municipalities)
Île d'Oléron	20991 (8 municipalities)
La Rochelle	76848

Source: wikipedia (French)

Table 2:
Population size in the affected area

Population size strongly fluctuates under the influence of the tourist season. The island Île de Ré for example, contains more houses used as holiday homes than permanently occupied houses [21]. There are also large numbers of holiday homes in L'Aiguillon-sur-Mer and La Faute-sur-Mer. The Vendée and Charente-Maritime belong to the departments with the highest number of camping sites (over 200); the Vendée is even leader in France with 58,000 plots.

3.2.3 Architectural styles

Despite legislation, many houses are built in flood prone areas (see section 3.2.1). Approximately one tenth to half of all houses are permanently occupied, mainly by pensioners. In the fifties, most houses were built at floor level, with only a ground floor. In the sixties and seventies it was customary to build the living area of houses on the first floor, approximately two metres above soil level. This also makes people less vulnerable to the consequences of floods. However, the architecture of many bungalows built between 1990 and 2010 were again inspired by the architectural style from the fifties. These modern houses are often equipped with electric roller shutters. The installation of shutters is encouraged by insurance companies providing contents insurances. They offer discounts if shutters are present. When the normally easy to use electric roller shutters are closed during a flood and can no longer be operated after a power failure, the house becomes a 'trap'.

Figure 26: *Affected houses in La Faute-sur-Mer: built after 1990, usually built at ground level. Most victims were caught by surprise in their sleep and could not escape their houses. [22]*

Figure 27: *Photo on the left: Aiguillon, house built before 1950, but with a first floor (style 1960-1980). Photo on the right: Near Humeau la Rochelle (1960-1980)*

3.2.4 Building legislation in flood prone areas

Storm Xynthia has put the building legislation in flood prone areas in the spotlights. In 1995 the Act on Environmental Protection became effective (Act 95-101 dated 2nd February 1995 - "loi Barnier") [23]. Local flood prone prevention plans (Plans de Prévention des Risques Inondations; PPRI)[5] are based on this Act. To manage the urban development in flood-sensitive areas, the PPRIs distinguish between different zones, based on floods which occurred in the past: high flood prone areas for which no building permits for the construction of new houses can be issued (red zones), areas where building permits are subject to constructional conditions (blue zones) and areas which are considered to be safe and where building permits are subject to traditional rules of the local zoning plan (white zones). These plans are drawn up under supervision of the prefect.

However, the effectiveness of this legislation suffers from its many exceptions, controversial decisions and slow implementation. The "decrets d'application" for the Coastal Act of 1986, for example, which dictate that no houses are allowed to be built in a strip of one hundred metres along the coast, were published eighteen years later (in 2004) [24, 25]. Currently an area of approximately 3.7 million square metres per year is built on along the coast. There is controversy about the red and blue zones from the PPRIs and the role of mayors who are responsible for granting building permits. Since the Decentralization Act of 1982, the state no longer checks decisions made by local authorities before they are finalized. This check is replaced by a legal verification afterwards by prefects and courts [26]. In actual practice this means that mayors are

5 The legal foundation for the PPR is the "Loi du 22 Juillet 1987 relative à l'organisation de la sécurité civile, à la protection de la forêt contre l'incendie et à la prévention des risques majeurs", which was adapted in 1995 by means of the "Loi du 2 Février 1995 (dite Loi Barnier), relative au renforcement de la protection de l'environnement et notamment son article 16'.

sometimes not able to resist the pressure of property developers and voters who want to build and live near the beach. Therefore, since 1999 about 100,000 houses have been built in flood prone areas all over France. This was also the case in La Faute-sur-Mer, where many houses built between 2004 and 2006 have been destroyed by Xynthia. Within four years land prices were doubled by real estate speculation. Along the coast of the Vendée uncontrolled urbanization took place over the last twenty years. The State Secretary of Ecology, Chantal Jouanno, calls this a "perpetual battle to enforce the red zones" and wants "stricter rules for building in flood plains and behind dikes" [27]. Authorities now seem determined to restrict building practices in coastal areas and to destroy flood prone houses.

The information above clearly shows the complexity of upholding flood prone zoning. This kind of zoning is only effective if it is supported throughout the years. This zoning will also have to be able to "resist" to all kinds of (social and political) developments.

3.2.5 Debate after Xynthia about spatial planning

The mayor of Charron has publically admitted that he is guilty of violating the spatial planning act ('loi Barnier' dated 1995) [28]. The mayor of La Faute-sur-Mer claimed that he was not aware of the dangers, but a reaction in Le Monde [29] stated that the prefect had formally warned the mayor in writing in 2001, 2006 and 2008 about the flood danger from sea and the lack of adequate protection.

On 8th April 2010 the government decided to destroy 1510 houses in the affected areas: 915 in the Vendée and 595 in Charente-Maritime. The government has promised to fully compensate all home-owners, based on the value of the real estate prior to the storm. The ministry of finance will pay an average amount of 250,000 Euros per house (another source mentions an amount of 150,000 Euros). But these houses will not be rebuilt. The government first declared these areas to be "black zones", where it is too dangerous to live. In addition to the black zones the government announced yellow zones, where houses can be built, subject to proper protection (by warnings and evacuation or physical protection of buildings) [30]. The vulnerability of some areas had to be investigated first. These were called orange zones [31]. All orange zones were later on converted into black zones.

Occupants usually do not agree with these decisions, especially since they also involve houses which were not or barely affected by the floods. They feel left out by the swift decision-making and the lack of consultation and have no intention of leaving their houses [32]. The mayor of Charron also refuses to cooperate for the same reason [33]. On 12th April 2010 the Préfecture of Charente-Maritime issued nineteen maps, containing the black zones (declared unfit for habitation), yellow zones (fit for habitation under certain conditions) and orange zones (no destination yet, due to further investigations) [34]. By way of illustration one of these maps is shown in Figure 28.

Figure 28:
Black and yellow zones in the municipality of Aytré. The area within the blue line is marked as a flood prone area [35].

The council of Charente-Maritime unanimously signed a motion in which they demand further investigation into the possibilities and costs for protecting flood prone areas, before declaring them unfit for habitation. They do not agree with the way areas are divided into black, yellow or orange zones [36]. At first the government stuck to their decision and would not reconsider the allocation of the black zones [37]. However, the government is now gradually revoking the policy for the black zones. Since May 2010 the black zones are called solidarity zones and since June 3rd 2010 people are no longer compulsorily expropriated.
A lot of issues have not been clarified, e.g. will the remaining houses be provided with essential services (water, gaz, electricity).

3.2.6 Occupants' responsibility

In addition to failing legislation, media also emphasize the responsibility of inhabitants in flood prone areas. Citizens can visit the town hall to enquire after the risks in their municipality in various registers, including the PPRIs (Plans de Prévention des Risques Inondations). Mayors are obliged to place risk maps in public schools and public institutions. Small municipalities sometimes lack resources to provide more specific digital information. In addition, a recent interim report of a Senate Committee revealed that insufficient attention is paid to coastal floods in the PPRIs [7]. Nearly one third of the municipalities in the affected areas has not (yet) ratified a PPRI (they often did have plans for a PPRI) and do not dispose of a (complete) contingency plan. It also seems that the majority of these plans do not include flood scenarios. Within the scope of the EU Flood Risk Directive so-called flood risk maps are being developed. These maps will be published on the internet (cartorisque.prim.net).

Since 2006 notaries and owners have to provide adequate information about the main environmental risks, including flood, when selling of renting out real estate. Buyers or tenants also have to be informed about the damages that a building and/or object has suffered in the past due to natural disasters [38]. This makes citizens responsible: after all, they are aware of the risks.

3.3 Crisis management

In case of a threat and crisis there is a distinction between proactive and reactive actions. Proactive actions take place prior to a disaster and are intended to limit the number of casualties and damages as much as possible. Proactive actions include monitoring threats, initiating the disaster relief organization, communicating with the population in the threatened area (warnings) and, if required, carrying out evacuations. Reactive actions take place during or after a disaster and are focused on saving lives and providing assistance. For crisis management the government is often the only party considered to provide disaster relief: the government will assist their citizens. But in many cases citizens will render first aid (first responders). Citizens can also act proactively by preparing themselves for disasters, for example by enquiring after the meaning of risks for themselves and exploring safe places and escape routes.

Before concentrating on the actions taking during storm Xynthia, we will first discuss the institutional aspects of crisis organization.

3.3.1 Crisis organization set-up

This section contains a rough draft of the general organization of disaster relief in France. The next section will discuss the organization of hydrological/meteorological warnings.

Because of the limited time frame for writing this book, the description of the French crisis organization is mainly based on knowledge from the international FIM-FRAME project (www.fimframe.net), which will be reported later on.

The administration layers Commune (municipality), Departement (department) and Région (region) are responsible for crisis organization in France, completed by a regional coordinating centre in case of disasters. On government level COGIC (Centre Opérationnel de Gestion Interministérielle des Crises) seems to have the same function as the Dutch NCC (National Crisis Centre).

Disaster prevention starts with French municipalities which check the risks related to installations (industry, dams, etc.) and natural disasters (fire, avalanche, flood, etc.). If any risks are detected, municipalities have to formulate a Plan Particulier d'Intervention (PPI) for disasters involving installations and a Plan de Prévention de Risques Naturels (PPR) for natural disaster risks. Since 2004 a municipal contingency plan (Plan Communal de Sauvegarde, PCS) is compulsory, in addition to a PPI or PPR, in case of external risks. Municipalities sometimes seem to be behind with their municipal contingency plans (PCS) and smaller municipalities sometimes lack resources to communicate effectively.

COGIC (Centre Opérationnel de Gestion Interministérielle des Crises) can be seen as a departmental maritime crisis organization.
Due to recent reorganizations in the crisis organization, contingency plans by COGIC and the municipal contingency plans may not yet complement each other optimally. This applies especially to evacuation and aftercare, where responsibilities are not always clear. A difference in focus can also cause problems: municipal contingency plans will tend to focus on small-scaled events such as flooding problems, while the COGIC contingency plans are focused on large-scaled events. However, coastal floods seem to be have been included as a risk in many municipal contingency plans.

3.3.2 Warning and alerting in case of floods and storms

An adequate crisis organization in case of floods always starts with adequate and timely hydrological/meteorological forecasts. In France the Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations (SCHAPI) was established after the floods in 2003. Real-time river water levels are monitored by approximately 1500 measuring stations. Data are used, among others, for a daily update of the so-called flood alerting map [39]. This alerting map (see Figure 29) distinguishes between four threat levels, varying from green (no special alertness) to red (risk of major floods).

At this time the system does not seem to be focused on coastal floods. During a recent parliamentary inquiry a representative of the French hydrographical/oceanographical service (SHOM) stated that water level measuring stations at the French coast currently do not have the ability to read real-time data and that they break down too often [53].

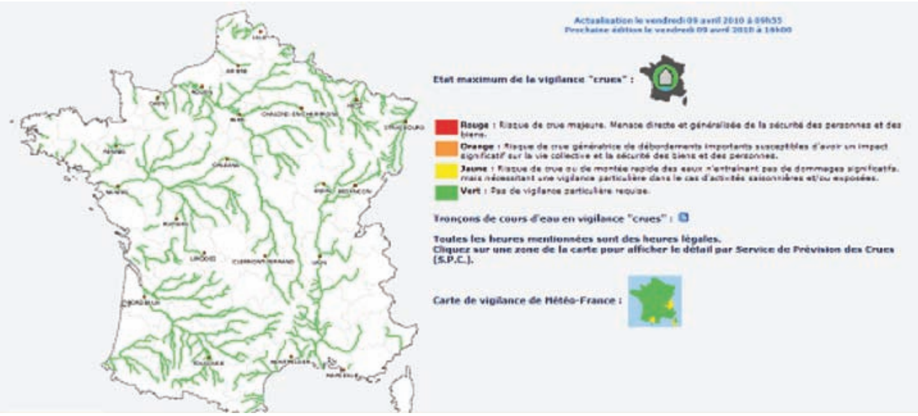

Figure 29: *Flood alert map.*

A similar flood alert map as shown in Figure 5-1 is made for storm risks. In case of dangerous weather conditions the population is alerted through the 'Vigilance Météo' procedure by Météo-France [40]. Forecasts and warnings are issued for each department for the next twenty-four hours. Similar to the flood alert map, four threat levels are distinguished, varying from green (no special alertness required) to red (absolute alertness required, see Figure 30).

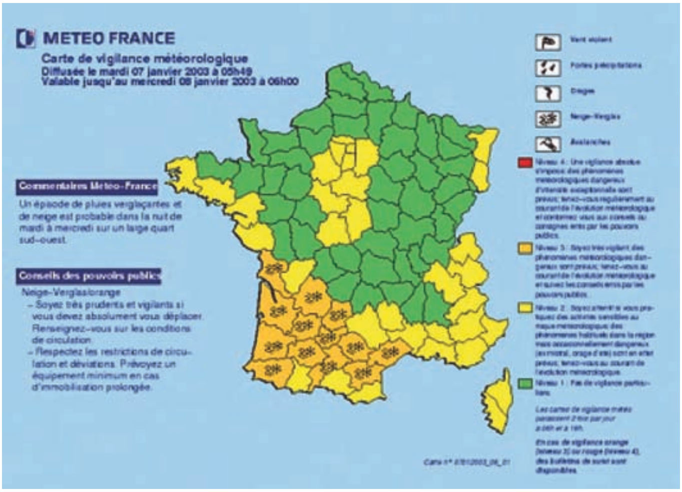

Figure 30: *Storm alerting map.*

This map is updated twice a day and subsequently spread by the media. The information is also sent to the prefect who decides whether or not the mayors of the municipalities involved should be warned. In case of an important event, people are warned by the national warning signal.

The mayor (as in the Netherlands) is primarily responsible for the safety of persons and goods in his or her municipality. Based on an alarm from a prefect or otherwise, the mayor can retrieve real-time information about storm or flood threats by using the flood alert maps and subsequently take all measures required. In municipalities with an external safety risk by natural disasters, the mayor has to formulate a municipal contingency plan (Plan Communal de Sauvegarde, PCS), in addition to the Plan de Prévention des Risques Naturels (PPRN). If an event affects more than one municipality, the prefect of the department is responsible for coordinating crisis management. In case of large-scaled disasters, additional operational support may be required. The prefect will then mobilize all resources intended for the affected areas. The Centre de Gestion Interministérielle de Crise (COGIC), the crisis management centre of the Ministry of Internal Affairs, will mobilize national resources to support disaster relief in the affected areas.

3.3.3 Warning for storm Xynthia

On Saturday morning 27th February 2010 the warning bulletins of Météo-France announced storm Xynthia, with wind gusts up to 150 kilometres an hour. In the afternoon a code red (highest possible alarm code) became effective for various departments, i.e. Charente-Maritime, Vendée, Deux Sèvres en Vienne. Code orange was effective in 69 regions (see Figure 31). It was the second time since the introduction of this warning system in 2001 that a code red was issued for strong winds.

3.3.4 Evacuation before the flood

Due to the strong wind and probably also due to the possible flooding, various camping sites in the Charente Maritieme were evacuated. The meteorological institute also predicted high waves for the coast. A combination of various factors (depression, wind , tide) would probably lead to a "temporary rise of the sea level, causing parts of the coast to flood". This combination is especially dangerous in estuaries and harbours. Even though Météo-France had reported the risk of rising water levels, they could not forecast exactly how high the water would rise. The subsequent conversion into local water levels is explicitly a job for the prefectures. Prefectures and local authorities claim that they were not focused on the rising water levels and the need to warn for flood risks, because this information was "melted" into the usual list of hazards and subsequent storm recommendations. Procedures are too limited in this kind of situation. One party was not explicit enough and the other not responsive enough, so no large scale evacuations were recommended or carried out [41].

Commentaries from the involved parties also reveal powerlessness. L'Express, for example, asked why there was no evacuation after the warning by Météo-France. Prefects say that it was not that simple. "I signed a code red on Saturday 27th February, at 16.00 pm, which was sent to the officials, along with a press release to inform the general public", says Beatrice Lagarde, subprefect of the Vendée. "There were no warnings about floods or failing flood defences. We cannot fantasize about risks and dangers ourselves. And what were we to do at the time that the risk spread over the entire territory of the Vendée – 600,000 persons? Where could we have gone at 22.00 pm to evacuate the 400,000 occupants who were threatened? To the Sahel?" [42]. A large-scaled evacuation is complex and normally evacuations are not carried out in case of storms. In case of heavy storms people are advised to stay home [43]. Wind gusts, flying debris and falling trees and installations can cause dangerous and traffic-obstructing situations. An evacuation of a few thousand people about 300 to 500 meters would have saved most people. The lack of knowledge about flood scenarios has had a negative effect on the evacuation. On the other hand, the opinion about the actions taken by the rescue services is positive in France. The questions remains to what extent these plans could have contributed to an improved disaster relief system.

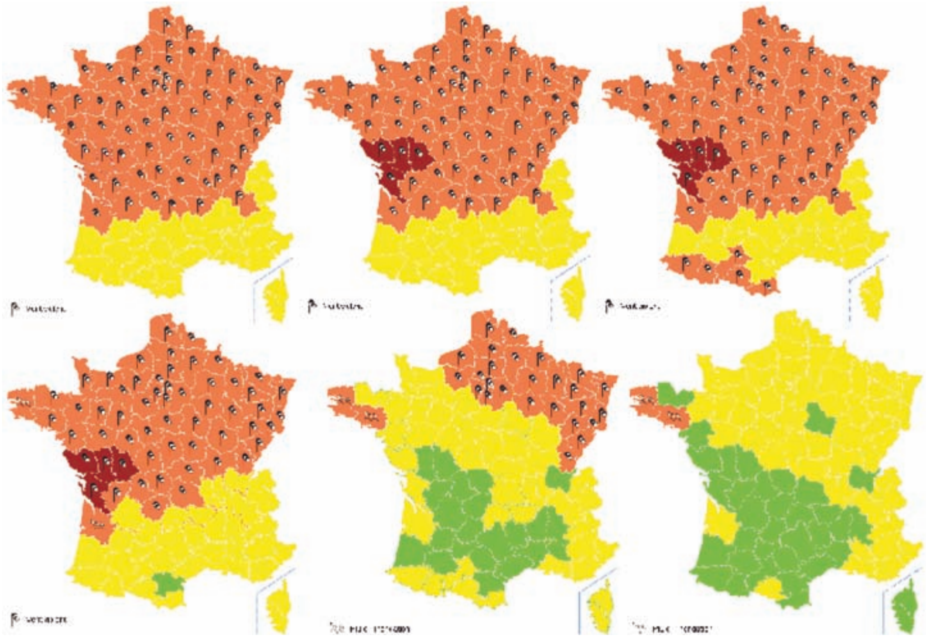

Figure 31: *The course of the vigilance maps on 27th and 28th February 2010. The times that these maps were issued, in reading order: 10:46 am (27-02), 16:00 pm (27-02), 19:30 pm (27-02), 6:00 am (28-02), 12:24 pm (28-02) and 17:00 pm (28-02). [44]*

3.3.5 Disaster relief

Emergency workers

Rescue operations faced high time pressure. Just after midnight the first dikes failed and people had to be rescued before the next tide. The closing gaps in the dikes could not be closed on account of the tide. First impression was that rescue services acted effectively immediately after the disaster. On Sunday TV footage was shown of the fire brigade saving people in flooded villages in the night from Saturday to Sunday. At 6.00 am on Sunday 28th February divers, rescue services and pump teams from other regions (Gironde: Langon and Libourne) were sent to Île d'Oléron. They stayed there for five days. In La Faute-sur-Mer divers continued to search all sixty houses with water depths of more than 2.50 metres until 4th March. After three days emergency services were exhausted both physically and mentally [45]. Administrator centres and coordination centres were not flooded. However, the interim report by the Senate Committee reveals that at the time of the disaster a large part of the telecommunications broke down [7].

Figure 32: *Saving occupants (location unknown). [46]*

In the departments of Charente-Maritime and Vendée alone 3000 emergency workers were deployed. After a few days, these people were assisted by people from the army. In the department of Charente-Maritime 12,500 interventions took place since Saturday night. This is about one third of the annual number of interventions by emergency services. In the following days another 4000 interventions were expected to be carried out. The Minister of Internal Affairs, Brice Hortefeux, told France-Info that 9240 firemen were deployed to help out the flood victims [47]. In small boats they searched the area on Sunday, especially the houses of which the roller shutters were closed. They feared that people were still trapped inside their houses. More than 500 survivors were taken to different centres in the night from Sunday to Monday [48].

Citizens

According to Paris Match [49] the high number of casualties can be partially attributed to the relatively high age of the occupants. The Vendée region received 80,000 new occupants over the last few years. They are mainly pensioners who have bought a house by the sea, some in the flood prone areas.

Stories in other media also show that the casualties of storm Xynthia and the subsequent floods belonged to a vulnerable group. Among the 29 victims in La Faute-sur-Mer seventeen were more than 70 years old, five were between 60-69 years old and three were between 50-59 years old. Younger victims included a baby (2 years) and two children from the same family on holiday in La Faute-sur-Mer. During the flood the father of the two children made a hole in the ceiling of their holiday home. He managed to escape together with his daughter, but his wife (43 years old), two sons (4 and 13 years old) and mother (73 years old) drowned [50]. In Charron one of the houses also had a hole in the roof where someone had climbed out. For most elderly people this escape route turned out to be impossible.

Self-sufficiency

It is common knowledge that mostly elderly people and children are vulnerable. The limited self-sufficiency of people is connected to bad communications about the threat of the storm, the failed flood warnings, a lack of risk awareness, a lack of knowledge from the occupants to recognize the storm in time as a danger to themselves and a lack of an effective action perspective (staying at home only in case of a regular storm, but evacuating, often just 300 to 500 meters, or finding a safe high shelter in case of a storm with a flood risk) [51].

A case in point is the anecdote about the fireman from La Faute-sur-Mer who first went home to take his wife and children to safety. Only a few days before, they had agreed to escape to the roof of their house in case of a flood: "nous étions préparés" (we were prepared) [52]. The flood victims were surprised by the rising water levels. They were left to their own devices and were insufficiently informed of the risks they were facing or just not capable to save themselves. Finally they died of hypothermia, exhaustion and drowning. They could not be saved.

4 The importance for the Netherlands

This chapter contains lessons and recommendations for the Dutch water safety policy, with regards to the three layers of multi-layer safety: prevention, spatial planning and disaster relief.

The floods along the west coast of France have proven that in Western Europe there are also risks involved when it comes to living in coastal areas, despite the physical protection by dunes, dikes and other flood defences. Even floods in a relatively small coastal strip will put the emergency services to the test and will have a considerable and possibly long-term impact. Precautionary measures reduce the flood risk. In actual practice these measures do not guarantee absolute safety, due to overdue maintenance and uncertainties.

Although the administrative organization of France has parallels with the Netherlands, there are also differences when it comes to water management. Contrary to the Netherlands, France has just started with regular tests and has no structural approach for management and maintenance. Flood risk alerts are also different. Furthermore, the Dutch Watermanagementcentrum (*Water Management Centre*) and Landelijke Coördinatiecommissie Overstromingsdreiging (*National Flood Risk Coordinating Committee*) have no equivalent in France. To make the French experiences useful for the Netherlands, they have to viewed in Dutch context. For example, the relative scope of a flood along the coast of France is much smaller than in the Netherlands. A small coast strip was affected in France, with a dry refuge in the vicinity. Most of the lower regions of the Netherlands have no such refuge. Flood prone areas in France are less densely populated than those in the Netherlands. Discussions about zoning in France can be compared to the discussions about areas outside the dikes in the Netherlands as in Katwijk with 8.000 houses at risk.

The Dutch knowledge of flood defences is better developed and formal systems for testing and maintaining these structures are implemented. As for prevention, France has done a lot of university research into the strength of dikes and the danger of erosion processes along the coast of the Vendée [53]. However, this information did not alarm the administrators or might not even have reached them. Whether this information could actually have contributed to preventing the flood or to limiting its consequences, is hard to say. If available regional hydrometeorological centres probably would have warned more explicitly about the flood threat, if they had had more knowledge about the system. Citizens could have tried to get to safety.

Management responsibilities for flood defences are fragmented. In France local managers or landowners often have to pay the maintenance costs of a flood defence. Due to relatively high costs, flood defences are often not improved and well-intentioned plans are never carried out. This situation contrasts sharply with the situation in the Netherlands, where regional water authorities keep on growing due to mergers and funding is settled on a national level (in case of large scale reinforcements).

4.1 Lessons from France for the Netherlands

Xynthia has enhanced the awareness that it is not always possible to prevent floods, despite extensive precautionary measures. Flood risks can be limited by reducing the risk of their occurrence (prevention) and by limiting the consequences (spatial planning and disaster relief). In the National Water Plan the Netherlands has chosen prevention as the most important aspect, in addition to spatial planning and disaster relief. Prevention involves requirements for flood defences based on a risk approach, as well as systems for periodic tests, management and maintenance to keep flood defences in working order. The lessons below were formulated during a discussion between the authors, with input by experts from Deltares.

> Lesson 1, *Multi-layer safety:*
> Protection of built-up areas by strict protection standards is a good choice. In hindsight the proverb: "prevention is better than cure" applies. However, the risk of a flood disaster can never be ruled out.

The number of people killed (47), considerable damages (2.5 billion Euros) and destruction of essential services during the French storm disaster clearly shown the importance of proper prevention. Immediately after a disaster, images and consequences make a deep impression on people and the question arises how it could have been prevented. It often turns out that damages caused by floods are much larger than the investments required for preventing a disaster, even in France with relative smalle areas to protect [54]. Benefits of prevention usually outweigh the costs. Analysis of the disaster shows that consequences not only depend on the natural phenomenon, but can also be influenced positively or negatively by human actions.

Lesson 2, *Warning and alerting:*
Warnings for impending floods must be made understandable for crisis managers (authorities) and the general public, so these groups can decide for themselves which action they want to take. Warnings must be suitable for the perception of the receiver and should not contain any technical terminology. In France, the flood warnings, if any, were too technical.

Focus areas are:

- During a storm flood it is relatively easy to warn for a "certain" wind, but more difficult to warn for an "uncertain" flood.
- Actions taken as protection against wind may have a negative effect on protection against flood.
- It must be made clear which organizations are responsible for giving warnings, which are responsible for making forecasts and which are responsible for analysing forecasts and area knowledge.
- Facilities for communications can overload or break down during the threat phase or an actual flood, so warnings will be garbled.

Prior to Xynthia, it was clear that a heavy storm was coming. Météo-France predicted a set-up and the flood threat. Still the regional centres of the prefects did not explore the flood hazard. They did not recognize the danger for third parties, including citizens. In the end, the population got clear warnings for wind and corresponding recommendations. But this did not or to a lesser degree apply to the flood hazard.

The interim report of the French Senate Committee shows that the forecasts by Météo-France about wind and offshore hydraulic conditions were correct. However, there was a lack of tools, knowledge and responsibilities to convert these forecasts into local flood risks. Therefore, Météo-France could not issue local flood warnings. This was partly the reason why communications about flood risks got overridden by the much more specific wind warnings. Therefore, regional and local administrators only used the wind warnings in their communications. So it is very important to identify where knowledge of hydraulic loads (possible water levels and waves) and the actual strength of flood defences is required.

A shared (and accepted) risk perception for experts and administrators is a prerequisite for unambiguous warnings and adequate advice to citizens. A proper coordination between the various crisis organizations (for the Netherlands: KNMI, LCO and Watermanagementcentrum Nederland) is crucial. Another matter that requires attention, is networks get overloaded during a threat phase and measuring devices breaking down during a disaster.

Lesson 3, *Management and maintenance*:
Management of flood defences requires strong, independent, democratic organizations. Costs and benefits must be proportional for all interested parties to reduce the risk of overdue maintenance.

Funding for repairs and maintenance of flood defences is very fragmented in France. Wrong priorities from local parties have led to overdue maintenance, while a much larger area depended on the protection offered by the flood defences. This shows the added value of the Dutch model with centralized funding (for major renovation), local professional (independent) implementing organizations, local taxation for maintenance, and periodic testing using a legal set of procedures and standards.

Lesson 4, *Risk zoning as a policy instrument*:
Risk zoning is a tool for reducing the risk of damages and casualties caused by floods. It is only effective if clear rules apply which are consistently maintained and complied with. Therefore, the support of administrators is necessary.

Risk zoning is a tool which can be used to make areas less susceptible to damages and casualties in case of a flood. Risk zoning is only useful if zones and conditions are upheld. The question is how zoning can be upheld over the years if local interests change.

Risk zoning was applied in France, but was ineffective because rules were evaded and exceptions were approved. The mayor of Charron admitted this. Even if risk zoning is upheld, damages during a flood cannot never be excluded, because floods can have very different effects. Zones are established based on a few (mathematical) criteria and a limited set of possible floods. In reality other situations may occur, depending on the breach locations and water levels at sea, causing areas marked as refuge areas to flood. Therefore, disaster management remains important, even if risk zoning applies.

Zoning in France is more similar to the areas on the coast outside the dikes than dike rings in the Netherlands. Flood prone areas in France are small strips which quickly develop into higher grounds. If flooded a Dutch dike ring is a large area. Zones can only be distinguished based on the severity of a flood or dune erosion. Legislation applies to areas outside the dikes in the Netherlands. As is the case in France, rules are difficult to uphold due to local interests. No zoning applies (yet) within a dike ring. However there are spatial planning rules which take into account facts like local flooding or water logging.

These considerations show that zoning must be established and applied with care. Communications are challenging: compliance requires a focus on the accuracy and status of standards, while dealing with residual risks requires some relativity.

> Lesson 5, *Self-sufficiency*:
> **Insight into effective self-sufficient actions from citizens in case of storm or floods is required and should be stimulated. This also requires insight into the effectiveness and risks of government measures.**

Citizens concluded from the warnings that it was best to "lock" themselves inside their houses because of the storm. They were not properly prepared for possible floods. The precautions that they took, were effective for storms, but made the possible flood danger even worse. Lowering the electric roller shutters for example, turned houses into coffins.

Floods caused by Xynthia occurred in rather small zones. The authors suspect that is the reason why emergency relief was initiated quickly and effectively, more effective than in case of large-scaled floods in the Netherlands. The French Senate report shows how labour-intensive airborne rescue operations can be: each operation took approximately one flight hour. Therefore, self-sufficiency in case of large-scale floods is crucial in the Netherlands. Lesson 2 shows that different disasters ask for different forms of self-sufficient behaviour. In case of a storm, "locking" yourself into your house is relatively safe, but in case of floods it is definitely not. If a combination of a storm and a flood threat occurs, it is often difficult to modify a behavioural strategy (staying at home, seeking shelter or evacuating). Adequate recommendations for various threat scenarios (storm, flood, etc.) are crucial. In these recommendations actual forecast terms for threats and the time required to comply with the recommendations, have to be considered.

Lesson 6, *Multiple failures:*
The fact that flood defences might fail in various locations and that these are difficult to predict, must be considered for contingency plans and disaster relief.

In case of a storm flood, a coastline of hundreds of kilometres is threatened. Experiences in New Orleans (2005), Hamburg (1962) and Zeeland (the Netherlands), the UK and Belgium (1953) show that during a flood several dikes often fail at the same time. In case of Xynthia dikes collapsed in several places as well. This situation will most likely occur if hydraulic loads are considerably higher than the strength of the flood defences. Emergency workers and spatial planners have to consider situations with multiple dike failures in which the exact locations of the collapses cannot be predicted.

Lesson 7, *Decision-making based on risks and uncertainties:*
Decisions about disaster management, both during preparations and during a crisis, must be based on various scenarios, with information about risks and consequences.

According to the a high ranking official (sous préfet) of the Vendée, Beatrice Lagarde, there was uncertainty about the need to map out flood risks and the way this information was to be used.

When making decisions, "sufficient" information is required. At the same time it should be acknowledged that (1) there is always a lot of uncertainty, (2) the available information probably does not provide an accurate representation and (3) the implementation of measures is always a complex matter. It is important that decisions about measures are always taken based on possible risks. Not only forecast values of wind and water levels are important, but also scenarios, their impact and the chance that they will actually occur: a complete risk consideration focused on what is known and unknown, but also on what is uncertain. This provides clear guidelines for assessing the need for certain measures and scenarios which should influence decisions.

The situation in France shows that the conversion from meteorological warnings into possible flood scenarios poses a serious problem for disaster management. Therefore, regional centres in France will have to extensively prepaie for this conversion. In the Netherlands the SvSD (Storm Surge Warning Service) centres have been active since 1926 and the hydrological/meteorological centres since 1953. The Watermanagementcentrum from Rijkswaterstaat (in formation) and LCO are responsible for creating scenarios. LCO explicitly focuses on different what-if scenarios on a "national" level, each with their own probability of prevention to be used as input for decision-making. The procedure has only been used in test situations. There is no hands-on experience with initiating this procedure.

> **Lesson 8,** ***Storms can vary models cannot predict everything***
> The Xynthia case suggests that we should not only derive very rare extreme wind speeds from the few dozens of storms measured during the last fifty years, but that the corresponding characteristics of the depression are also important for determining the design conditions for our dikes.

On the November 1st, 2006 the Delfzijl in the Netherlands was surprised by an exceptional high storm surge about 75 cm higher than predicted. These water levels correspond with a return period of around 200 years. This very intense storm could not properly be reproduced in the hind-cast. One of the reasons is that the grid size of our model is too large. The second reason is more general depressions may be sharply defined and that small differences in the course of a depression may have major consequences for storms and storm flood forecasts. It is almost impossible to predict all possible courses [55]. Some redundancy is needed in measuring devices for water levels and waves. During storms usually a large number measuring devices fail. It is only through good monitoring that models can be improved.

4.2 Recommendations for the Netherland

Looking at the events surrounding Xynthia from a distance, it is clear that not only prevention is required, but also insight into the degree of protection offered by spatial planning and disaster relief. This insight is required to:

1. define in advance the requirements with which prevention, spatial planning and disaster management have to comply (how safe is safe enough) and how we can supervise this compliance;
2. analyse afterwards whether a disaster was caused by overdue maintenance or other policy decisions resulting in a low safety level, technical failures or unexpectedly high water levels and waves.

We therefore recommend organizing a debate about suitable combinations of prevention, spatial planning and disaster relief in the Netherlands, their organization and their supervision. If it is clear to citizens which circumstances may occur during a disaster and which assistance the government can or cannot provide, they can decide for themselves if they want to make preparations and if

so, which preparations they want to make.
Preparations may involve spatial planning, self-sufficiency and business continuity, during a threat or as structural preparations. People in France who were preparing for the storm by seeking shelter in hermetically sealed houses, took action after recognizing the storm threat. If they had also recognized the flood threat, they may have considered leaving an escape route. As a structural preparation they could have reduced their vulnerability by building houses with a first floor instead of bungalows. In the Netherlands where the scope of a flood disaster would probably be much larger than in France, divers and other emergency workers will not be able to search an entire disaster area within a day. People in the Netherlands will have to rely on self-sufficiency for much longer. The risk of hypothermia and exausttion will be much bigger, because the demand for emergency relief will exceed the supply.

The limited (flood) risk awareness in the Netherlands and France is a sign that part of the information about flood risks did not reach the citizens and administrators at all, not sufficiently or without an effective perspective for proper action. The consequent research question is: what would be suitable and based on which criteria?

Recommendations for the Netherlands below are formulated based on experiences and lessons from Xynthia and a reflection on the Dutch situation by experts from HKV, Rijkswaterstaat Waterdienst and Deltares.

> *Recommendation 1:*
> Use the disaster caused by Xynthia to once again emphasize the need for a good prevention policy, but also to formulate clear performance criteria for the other layers of multi-layer safety and their supervision.

Nature is unpredictable. Organizational measures, flood defences and provisions may fail or malfunction. By taking this into consideration during spatial planning, in contingency plans and while working on better self-sufficiency, consequences can be limited and risks can be kept controllable.

> *Recommendation 2:*
> Make clear what water safety entails and what is expected of the government if things go wrong. Discourage the idea that floods are impossible.

Feasibility of Dutch contingency plans and consequences of less probable scenarios are still unknown. It is recommended to test the current set-up of disaster management, together with the improvements based on the Dutch Taskforce Management Overstromingen (TMO) (2008), by using a scenario like Xynthia. Its result can be expressed in terms of damage, casualties and administrative and social impact. Passing the test of a Xynthia scenario does not guarantee good results in case of a future (more large-scaled) disaster in the Netherlands.

> *Recommendation 3:*
> Test the contingency plans for feasibility by using different scenarios, taking into account the build up and uncertainty of the scope of a flood and the forecast horizon.

KNMI and Watermanagementcentrum Nederland can communicate proactively about this subject with administrators, citizens and professionals, with the assistance and expertise of the Nationaal Crisiscentrum.

> *Recommendation 4:*
> Make it clear to professionals and society that there will always be uncertainties regarding forecasting and alerting in case of extreme weather conditions and high water levels. Make it clear that so-called false alarms are inevitable.

The transfer of knowledge from experts to administrators and stakeholders is also important. Both in 1953 and during Xynthia, some people were already aware of the weak flood defences and imminent (erosion) processes. This knowledge did not reach the right people in time. The Netherlands have done a lot to improve the transfer of practical knowledge by establishing Deltares and the BSIK program Living with Water, but there is still a lot of work to do. Recently France has also started to focus more on the transfer of knowledge, partly by establishing ONEMA (L'Office National de l'Eau et des Milieux Aquatiques - National Office of Water and Water

> *Recommendation 5:*
> Use the Directive for Flood risks as a tool to implement the lessons and do not consider this to be a mere symbolic activity.

Environments). However ONEMA does not have any competance in the matters about flood risk. The European Directive on Flood Risks offers the possibility to guarantee the required safety level per layer, to involve citizens and to deal with uncertainties. However, the implementation of this directive could become a symbolic activity if maps and plans are only filled out for form's sake, without the intention of actually mapping flood risks (including less likely events) and making clear which level of protection is offered by the government and how this is organized and upheld.

5 Final conclusions

In this book we have outlined the problems in France and converted them into lessons for the Netherlands, based on the components of multi-layer safety. For this we have used our expertise and footage and information available to us regarding the events in France.

The Delta Committee has called the flood problems "urgent, but not acute". This suggest that the Netherlands may be flooded in the future, but that there are no short-term risks. This may lead to a lack of investments in safety, if resources are limited. This undoubtedly will increase the flood risk for the Netherlands. Due to the densely populated nature of the Netherlands, a flood will result in many fatal casualties and billions of Euros in damages. The next generations of citizens, administrators and policymakers will be facing the consequences of the choices which are currently made. The consequences for excluding and reducing flood risks will be passed the next generation.
The principle of multi-layer safety enables us to compare effects of spatial planning, prevention and disaster relief. At the same time, multi-layer safety provides insight into what the government can or cannot do in case of a large-scaled disaster. In our opinion structural attention is required to both prevention and consequences of floods, by analysing disasters worldwide and converting them to Dutch context[6]. By discussing this conversion with citizens, policymakers, emergency workers and administrators, risk awareness will increase and we will learn what will work and what will not. It is also useful to evaluate actual events with high water levels in our own country and extrapolate them to flood level. These activities will give us more insight into water safety and will keep us alert.
These choices are on funding, safety levels and responsibilities of organisations.

6 The same was done for the lessons from New Orleans (hurricane Katrina, 2005) and the UK (river floods 2007; see http://archive.cabinetoffice.gov.uk/pittreview/thepittreview.html for evaluation).

6 About the authors

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Bas Kolen works for HKV LIJN IN WATER as Disaster and Information Management Senior Consultant. His areas of expertise include water safety, crisis management, evacuations and self-sufficiency. He is involved in the Flood Control 2015 innovation program, among others, and in the past he was involved in several activities for the Flood Management Task Force and the Dutch Water Test. In addition, he is working on a thesis on "the feasibility of mass evacuation in case of floods" at the VU University of Amsterdam.

Robert Slomp

Robert Slomp has been working for Rijkswaterstaat, an agency of the Ministry of Transport,Public Works and Water Management, since 1998. His current job is Project Manager of Test and Design Tools (TOI) Senior Consultant. Robert Slomp is a member of the Warning Service for the Dikes of the IJsselmeer area (a storm flood warning service) and is actively involved in implementation projects such as the Flood Risk Management program and the Room for the River plan. In 2007 and 2008 he was lent to the Ministry of Internal Affairs for the National Safety program.

Wim van Balen

Wim van Balen graduated from the University of Technology in Delft and obtained a doctorate in hydraulics. He mainly worked on very detailed, three-dimensional numerical simulations of turbulent floods. Since 2009 he has been working for HKV LIJN IN WATER as a consultant dealing with issues relating to flow modelling and water safety.

Teun Terpstra

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Cover photo: Fotopersbureau WFA, The Hague

8 Résumé[1]: Dégâts après une inondation
Retour d’expérience après la tempête Xynthia en France

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Au petit matin du 28 février 2010, une partie importante de la côte Atlantique de la France a été frappée par la tempête Xynthia. La surcote et les vagues liées à cette tempête étaient concomitants à une marée haute de fort coefficient, ce qui a causé de nombreuses submersions des défenses et des dizaines de brèches dans les digues et dunes. De grandes superficies ont ainsi été inondées, causant des dizaines de morts (pour la grande majorité par noyade, épuisement ou hypothermie plutôt que par les effets directs du vent). Les départements de la Vendée et Charente Maritime ont été les plus durement touchés. Ces inondations côtières fournissent des enseignements pour de nombreuses régions côtières susceptibles aux inondations, notamment aux Pays-Bas. Malgré un niveau de protection en moyenne plus élevé au Pays-Bas, les inondations causées par la concomitance de surcote, de marée haute et de vagues y sont toujours possibles. Les enseignements du cas Xynthia en France sont d’autant plus intéressants pour les Pays-Bas que là aussi une partie importante de la législation a été mise en place pendant les années de Napoléon. Enfin, un tel désastre n’est pas qu’un phénomène naturel car les actions (ou manque d'actions) humaines y jouent un rôle crucial.

Les volets de protection sont illustrés par ces images :

1) mesures de l’ordre de protection civile par exemple l’évacution préventive et secours
2) mesure d’urbanisation: des constructions et les routes doivent être plus hautes que le niveau de l’eau et de vagues
3) mesures de prévention: les digues, barrières et dunes évitent les inondations

Figure 33: Les volets de protection

Dans la réalité la protection est souvent une combinaison de ces trois volets.
Le type et le niveau de protection sont souvent des choix politiques ou un acquis historique.

1 Il s’agit notamment des rapports officiels sur la tempête Xynthia, suite aux enquêtes de la Chambre de Députés, du Sénat et du Ministère de l’Ecologie (MEEDEM) et les journaux Paris Match, Le Monde, Figaro, Ouest France en Sud-Ouest qui sont disponibles sur internet

Ce livre décrit - à partir de sources publiques disponibles jusqu'au 1 Août 2010 - la tempête Xynthia, l'inondation qui en suivit et ses conséquences. Après cette description, des leçons pour les Pays-Bas[2] sont présentés sous forme de conseils spécifiques et concrets. Nous considérons plusieurs volets de la gestion des risques liés aux inondations: prévision, prévention, aménagement du territoire et urbanisation, protection civile.

La tempête Xynthia, les faits:

Déjà le 23 février, Météo France avait signalé une dépression active au sud-ouest de l'île de Madère, qui avait le potentiel de devenir une forte tempête (qui sera baptisée Xynthia quelques jours plus tard). Vers minuit le 27 février, Xynthia a atteint la côte Atlantique Française, avec des vents soutenus (jusqu'à 10 Beaufort soit 89 à 102 km/h ou 24.5 à 28.4 m/s) mais n'en faisant pas de ce point de vue une tempête d'une très rare intensité (certainement pas par rapport aux tempêtes de décembre 1999 par exemple). Par contre, la concomitance d'une surcote importante avec une marée haute de fort coefficient (102) semble être la cause principale des niveaux d'eau extrêmes à la cote, auquel s'est ajouté, l'action de vagues hautes et une forte houle. Faute de données suffisamment homogènes, complètes et longues, il est difficile d'établir avec précision la période de retour des niveaux d'eaux pendant Xynthia. Cependant, une période de retour supérieure à cent ans semble très probable au vu des données historiques sur la région.

En France, 53 personnes ont trouvé la mort à l'occasion de Xynthia, la plupart directement par les effets des inondations. Les dégâts sont estimés à environ 2,5 milliard d'euros par le Senat. Les inondations ont aussi touché d'autres zones géographiques et d'autres secteurs socio-économiques où les dégâts sont difficiles à évaluer :

- le secteur de pèche et de l'aquaculture (mytiliculture et ostréiculture) et de l'agriculture (destruction d'infrastructure, salinisation des terres),
- les infrastructures des communes et départements,
- le secteur touristique.

La prévision et la protection civile

Pour la protection des populations, la prévision de la tempête a fait défaut : il y a eu des avertissements clairs pour le coup de vent mais il n'y en a pas eu ni pour la surcote et ni pour les niveaux d'eau locaux. La population est donc restée chez elle en se préparant pour la tempête, sans se préparer à une inondation : ceci a pu contribuer aux conséquences mortelles de Xynthia.

2 Le but de notre livre n'est pas de faire un retour d'expérience exhaustif sur la tempête Xynthia mais bien de distiller les leçons de ce désastre pour les Pays-Bas.

Dès le 26 Février, Météo France a publié des cartes de vigilance pour le vent : la carte du 27 Février midi (12.00 heure) montrait un code rouge (le plus haut niveau) pour la Vendée. Selon Alain Ratier, directeur général adjoint de Météo France, Météo France a aussi averti d'une surcote importante. La diffusion avertissements spécifiques est la responsabilité des services de la préfecture ou des villes et n'est possible qu'en intégrant les prévisions et les données hydrauliques, la connaissance de chaque zone potentiellement inondable, et l'état des défenses (dont les digues). L'interview de Beatrice Lagarde (sous-préfet de la Vendée) montre que les messages de Météo France sur la tempête n'étaient pas bien compris par les services de protection civile et elle évoque l'impossibilité d'une évacuation de 400 000 personnes à 22 heures du soir quand une évacuation de quelques milliers de personnes aurait suffit.

Après les premières sur verses et les premières brèches (environ vers 02.00 heures) et inondations de terrains, les interventions de la protection civile ont été rapides et efficaces. Dans les 4 départements les plus touchés le niveau d'eau extrême (ie. Vendée, Charente Maritime, Gironde et Loire Atlantique) au moins 3000 professionnels de secours étaient au travail directement après le désastre. A 06.00 heures des sauveteurs, nageurs et 'équipes de pompage' de Gironde étaient déjà en route vers les sinistrés de Charente Maritime. Les départements de Gironde et de Charente Maritime semblent avoir été plus au courant de l'imminence de la surcote et de l'inondation avant la pic de la tempête. Ils y étaient donc mieux préparés.

Implantation des habitations / urbanisation /code de construction

La France est dotée de lois restrictives pour assurer la protection du littoral (1985) et des régions inondables (1995). La loi Barnier (1995) offre la possibilité de délimiter des zones à risque. Des nouvelles habitations depuis 1990 ont cependant été établies dans des zones inondables souvent protégées par des ouvrages simples pour des zones non urbanisées. Le financement de la construction et l'entretien des ouvrages de protection contre la mer est de la responsabilité des propriétaires particuliers des ouvrages voire d'associations locales. Une éventuelle inondation au travers de l'ouvrage touche souvent un plus grand nombre de bénéficiaires.
Plusieurs raisons cumulées ont aggravé la situation :

- Pour ce qui concerne l'urbanisme, les permis de construire (même pour des zones inondables) sont délivrés localement par les maires élus, donc impliqué en même temps dans la prévention des risques que dans le développement de leur commune.
- Les constructions depuis 1990 sont souvent des plains pieds. Par contre, les maisons construites entre 1960 à 1980 sont souvent des maisons surélevées, ou la zone habitable est 2 mètres au dessus du niveau de sol.

- Les assurances offrent une remise si les propriétaires mettent en place des volets ou des grillages.
- Pour se faciliter la vie, les retraités ont souvent installé des volets électriques, même si de tels volets risque de ne pas s'ouvrir en cas de rupture d'électricité.

Le maire de Charron a reconnu sa responsabilité pour avoir donné des permis de construction dans les régions inondables. Le maire de Faute-sur-mer a nié d'être au courant de zones à risques. Le journal Le Monde en réaction sur ces paroles mentionne de multiples mises en garde de la mairie par la préfecture sur la construction dans des zones inondables.

La perception du risque de la tempête par la population a aussi augmenté le taux de mortalité. En fermant les volets pour le vent, les maisons se transformaient en pièges mortels après l'inondation, car souvent, la force de l'inondation et la rupture d'électricité ne permettaient plus de rouvrir les volets et les portes. Heureusement, la tempête Xynthia n'a pas eu lieu en période d'été, si bien qu'une grande partie des maisons était inoccupée[3].

Après la tempête le zonage initial avant la tempete de zones inondables a pris une autre dimension. D abord après la tempête elles sont devenus des zones noir (non constructibles) apres des zones de solidarité. Maintenant l'état rembourse la valeur des maisons construites dans des zones à risques sans obliger les propriétaires catégoriquement à quitter les lieux. La discussion sur le zonage n'est donc pas encore terminée.

Prévention

Pendant la tempête, les ouvrages, digues et dunes ont cédé a des dizaines d'endroits entre Bordeaux et La Loire, s'étendant sur plus de 300 km de côte. Par endroit il y avait de multiples brèches. Les ouvrages ont probablement été construits pour un incident centennal. Faute de base de données locales, et suffisamment homogènes et longues (aux moins 30 ans et de préférence plus que 50 ans), on ne peut pas donner une classification précise de fréquence de niveaux d'eau causé par la tempête Xynthia.

Quel était l'état des ouvrages avant la tempête? Combien d'ouvrages étaient mal entretenu? Combien d'ouvrages étaient déjà renforcés depuis les tempêtes de 1999? En principe, c'est difficile de financer l'entretien des ouvrages par les associations trop petites. Certaines choses n'ont pas aidé à assurer un bon entretien des ouvrages :

- Les rôles pour l'entretien des ouvrages ne sont pas toujours clairs,

[3] Par contre les tempêtes sont les plus sévères en hiver.

- Le financement d'entretiens d'ouvrages n'est pas toujours bien, donc porté proportionnellement par les bénéficières,
- Des associations trop petites pour embaucher des experts.

Pour des ouvrages datants du 18ème et 19ème siècle, l'effet de deux siècles de monte de niveau de la mer relative n'est pas négligeable. Au Pays Bas ceci est environ 20 cm par siècle, en France a Brest c'est environ 15 cm par siècle[4].

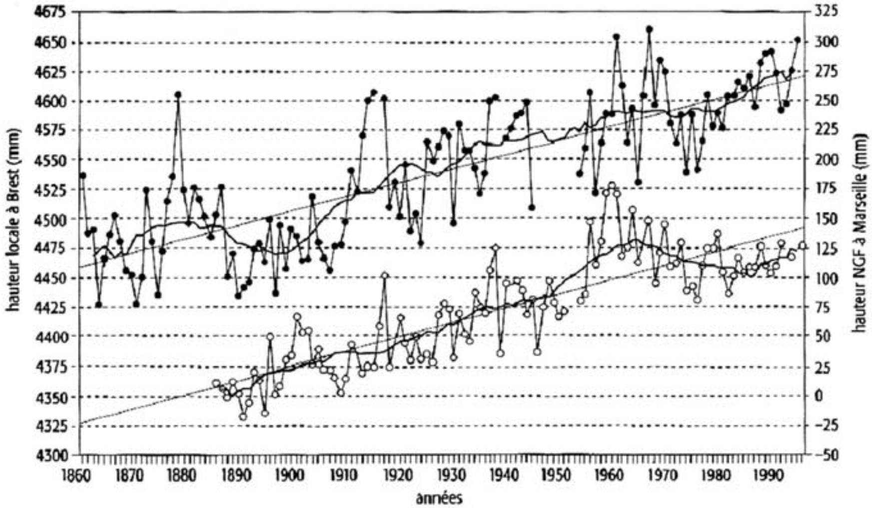

Figure 34: Changement de niveau de la mer a Brest et Marseille

Des leçons pour les Pays Bas

Apres l'inondation de 1953 la culture de risque aux Pays-Bas a pris son envol. La culture de risque vise surtout sur la prévention avec de très hautes normes de protection et un enracinement légal.

Ceci se résume en trois volets :

- un enracinement légal du niveau de protection dans la loi d'Eau ('Waterwet'),
- une base institutionnelle et de financement avec des rôles bien définis,
- un savoir faire d'une communauté des professionnels dans le privé et dans tous les niveaux du secteur publique (de l'état jusqu'à la commune).

[4] Servane Gueben-Venière, Université de Paris 1

Apres une catastrophe on se pose toujours deux questions :

- Est-ce que la catastrophe était inévitable?
- Pourquoi la société n'était pas préparée pour la catastrophe?

En ce moment les Pays-Bas revoient les normes de sécurité basée sur une analyse et une optimalisation coûts-bénéfices, en les comparant avec des normes sur des risques aux victimes (risques personnel et du groupe) déjà existants dans le domaine de sécurité extérieure. Ce volet de prévention est maintenant supplémenté par deux autre volets : la planification spatiale (avec l'instrument d'évaluation 'watertoets') et par l'amélioration de la protection civil (plans d'évacuation). Le développent des nouveau plans d'évacuation a été poussé par les événements de 2005 avec l'ouragan Katrina à Nouvelle Orléans. Ainsi, ces trois volets contribuent à la gestion intégrale de risques d'inondation, prévue par la directive Européenne (2007/60/CE) relative à l'évaluation et à la gestion des risques d'inondation.

Le cas de Xynthia nous permet de tirer les leçons suivantes pour les Pays Bas:

Note: Les polders Néerlandais ne sont pas les côtes Françaisse. Pour chaque région il faut décider de la meilleur façon de la protection, l'évacuation à temps est souvent aussi un volet valable. L'abandon du terrain a cause des risques pour faire des nouveaux parcs nationaux est aussi parfois une nécessite.

- La tempête Xynthia montre de nouveau que des normes strictes avec des périodes de retour supérieur à 1000 et 10 000 ans sont efficaces pour les régions habitées. De viser surtout sur la prévention y est un bon choix.
- Il faut traduire les messages Météorologiques pour que les services civils, les services des ouvrages et la population puissent comprendre ces messages et traduire en actions appropriés.
- Il faut passer un message univoque et compréhensible. La perception du risque doit être la même pour les professionnels et la population.
  - C'est facile d'alerter pour du vent, mais alerter sur la possibilité d'inondation est plus difficile.Il faut aussi tenir comte des niveaux d'eau et de vagues locales et la résistance des ouvrages le long de la cote. Étant donné que les actions appropriés pour se protéger contre le vent sont différent des (et parfois incompatible aves les) actions à prendre en cas d'inondations, un simple avertissement pour le vent – sans tenir compte de la possibilité d'une inondation – peut même mettre les gens en danger. Le défi est de fournir à la population un avertissement intégral, clair et univoque.

- Entre les cellules de crise, il faut des rôles très clairs. Qui donnent l'alerte, qui fait l'analyse du risque et qui fait la communication avec le publique?
- Il faut tenir compte de l'absence des données sur la hauteur de l'eau et de moyens de communication pendant la tempête. Une meilleure traduction du message météo est nécessaire, pour que les services et la population puissent réagir Il faut souvent des nouveaux services pour ceci.

- La capacité de la population à se sauver elle-même est plus importante que l'on ne pense et elle est indispensable pour les inondations d'une échelle qui dépasse les moyens de secours immédiatement disponibles. Des simples mesures peuvent augmenter (fermer les volets électrique) ou baisser le risque (aller chez un voisin avec un étage). Il est important de recenser les mesures simples et efficaces en même temps contre la tempête et l'inondation et de les communiquer à la population.
- Pendant Xynthia, il y avait de multiples brèches sur des centaines de kilomètres. C'est souvent impossible de prédire avec précision quand une telle brèche se produit, et où. Pour les plans d'évacuation et l'organisation de protection civile il faut bien tenir en compte de cette incertitude.
- La rapidité et l'efficacité des services de secours face au désastre est impressionnant, mais la capacité de secours est limité. Il faut beaucoup de moyens pour sauver quelques centaines de personnes. Parce que les zones n'étaient pas trop grandes par rapport aux tailles des départements c'était possible. Pour les communes avec les PPRI, quels rôles ont joué ces plans pendant le sauvetage?
- Le zonage est efficace si des règles sont respectées. Comment faire respecter les lois pour la protection du littorale et pour les zones a risques d'inondation sur des dizaines d'années, quand plusieurs taches de planification spatiale et de permis de construction sont dévolus aux communes? En plus le zonage est fixé sur des scenarios. Si l'inondation réelle est très différente des scenarios calculés, le zonage n'est plus adéquat. C'est pour cela il faut suivre toutes les tempêtes et établir des procédures univoques pour pouvoir adapter de tels zonages. Une analyse permanente et profonde sur les côtes et leurs dangers est nécessaire.
- La gestion des digues demande des organismes locaux forts et indépendants, avec des rôles très clairs pour l'entretien, la réfection à neuf, le financement et le contrôle. Tous les bénéficiaires doivent participer aux frais d'entretien, il faut une solidarité locale. Pour la réfection à neuf il faut une solidarité nationale et départementale, car ceci dépasse souvent les ressources locales. Pour l'entretien et la construction du neuf il faut des institutions locales dotées des pouvoirs, voue à leurs taches. Il faut aussi une réglementation nationale: pour la faciliter,
  - une réglementation sur les organismes,

- sur les normes des ouvrages etc.

- Prendre des décisions pour baisser les risques à la population demande une flexibilité de traiter l'incertitude.

9 Samenvatting: Schade door overstroming
Leren van Franse ervaringen met de storm Xynthia

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Op 28 februari 2010, rond 2 uur in de ochtend, bereikte de storm Xynthia de westkust van Frankrijk. Op meerdere locaties bezweken de waterkeringen, met kustoverstromingen tot gevolg. Meer dan 50.000 hectare aan land overstroomde. In totaal vielen in Frankrijk 47 doden, de meesten door het water en een enkeling door de gevolgen van de storm. Vooral de regio's Vendée en Charente-Maritime kregen het zwaar te verduren. De schade en de slachtoffers van de overstroming zijn niet alleen veroorzaakt door het natuurverschijnsel zelf, maar zijn ook door het menselijk handelen of het uitblijven daarvan. Nederland kan uit deze Franse kustoverstromingen lessen trekken. De omstandigheden in Nederland en Frankrijk zijn voor een groot deel vergelijkbaar. Zo is ook in Frankrijk sprake van laaggelegen kustgebieden die gevoelig zijn voor overstroming. Weliswaar is het beschermingsniveau in Nederland veel hoger, maar ook in Nederland is een overstroming denkbaar. Net als in Frankrijk wordt een overstroming langs de Nederlandse kust veroorzaakt door een combinatie van getijde, stormopzet en golfaanval. Ook wet- en regelgeving vertonen overeenkomsten; de basis hiervan is gelegd in de tijd van Napoleon.

Dit boek beschrijft de overstroming door de storm Xynthia en de gevolgen daarvan. We trekken hier lessen uit en doen aanbevelingen voor Nederland. We zoeken aansluiting bij de drie onderdelen van meerlaagsveiligheid: preventie, ruimtelijke inrichting en rampenbeheersing.

De storm Xynthia

De avond van 23 februari 2010 signaleerde Météo-France een actieve depressie die zou uitgroeien tot een zware storm. Deze stormdepressie is later in de media en diverse publicaties aangeduid met de naam 'Xynthia'. Rond middernacht op 27/28 februari bereikte Xynthia met ongeveer windkracht 10 de Franse kust, een windkracht die niet extreem te noemen is (89 tot 102 km/uur). Door een combinatie met springtij waren de waterstanden en golven echter wel extreem. Een dergelijke combinatie treedt volgens schattingen eens in de 100 jaar op, maar de schattingen lopen uiteen. Een correcte schatting is moeilijk te maken, omdat de beschikbare metingen slechts enkele decennia bestrijken, niet homogeen zijn en bovendien niet compleet lijken. De gevolgen waren ernstig. In eerste instantie is geraamd dat in Frankrijk 53 mensen zijn overleden, met name door de overstroming maar ook door de wind. Recente

studies stellen het getal naar beneden bij tot 47 vanwege dubbeltellingen.
Volgens de meest recente schatting van de Franse senaat bedraagt de schade 2.5 miljard euro. Ook aan landbouw (verzilting, meer dan 50.000 hectare land is overstroomd met zout water), infrastructuur en toerisme is grote schade aangebracht, maar die is moeilijk te schatten. Toch was de overstroming een lokale gebeurtenis, die beperkt bleef tot enkele smalle kuststroken van de Franse Departementen. Er was geen sprake van volledige ontwrichting van deze qua omvang veel grotere departementen.

Preventie

Tijdens de stormvloed Xynthia zijn op tientallen plaatsen waterkeringen bezweken, over een kustlengte van meer dan 300 kilometer. Per gebied waren er meerdere doorbraaklocaties. De exacte sterkte van de keringen was en is onbekend. Veel keringen stammen uit de achttiende en negentiende eeuw. De waterkeringen zijn vermoedelijk ontworpen voor een gebeurtenis met een frequentie van ongeveer 1/100 per jaar. In de twintigste eeuw vond onderhoud met name plaats na schade door een storm of overstroming. Zo waren de reparaties naar aanleiding van de storm van 1999 nog niet overal afgerond. We kunnen dan ook geen betrouwbare uitspraken doen over de vraag of de waterkeringen de waterstanden als gevolg van Xynthia hadden moeten kunnen keren. Dat vereist veel gebiedskennis, in combinatie met (in dit geval beperkte) waterstandstatistieken.

Duidelijk is dat de waterkeringen door een scala aan oorzaken zijn bezweken. Vaak was sprake van achterstallig onderhoud. Een belangrijke verklaring daarvoor is dat de kleinschalige lokale beheerders de kosten voor beheer en onderhoud moeten opbrengen. De kosten zijn onevenredig verdeeld over de belanghebbenden. Ook was het niet altijd duidelijk wie nu verantwoordelijk was voor onderhoud van een kering. Door de kleinschaligheid waren ook niet overal experts aanwezig. Onze conclusie is dat de slechte staat van de waterkeringen vooral het gevolg was van het niet eenduidig toewijzen van dijkbeheerderstaken en de ontoereikende financieringsstromen.

Inrichting

Sinds 1995 legt de Franse wet over de ruimtelijke ordening het gebruik van overstromingsgevoelige gebieden aan banden, maar vanaf 1985 golden al beperkingen voor bouwen in kustgebieden. Er zijn risicozones benoemd en er gelden strenge procedures voor het bouwen in overstromingsgevoelige gebieden. Langs de kust zijn dit over het algemeen oude landbouwgronden, die vaak door eenvoudige waterkeringen beschermd worden. Soms zijn de keringen niet eens als waterkering te herkennen. De lokale beheerder of de landeigenaar is verantwoordelijk voor de financiering van de waterkeringen en het beheer en onderhoud. Het gebied dat zij onder hun hoede hebben, beslaat meestal maar een klein deel van het gehele gebied dat door de waterkering beschermd moet worden.

Ondanks de strenge wetgeving is sinds 1990 veel gebouwd in de overstromingsgevoelige gebieden, bijvoorbeeld in La Faute-sur-Mer en in l'Aiguillon-sur-Mer. Dit is gebeurd met toestemming van de gekozen burgemeesters. De nieuwbouw bestaat vaak uit (semi)permanent bewoonde bungalows. De traditionele bouwstijl van de jaren zestig, met een woonlaag op twee meter boven de grond, heeft plaatsgemaakt voor een gelijkvloerse variant. Veel bungalows hebben (electrische rol-) luiken of stalen hekken als inbraakbeveiliging, de aanleg hiervan wordt gestimuleerd door het beleid van de inbedoelverzekeraars. De bewoners van de nieuwe huizen zijn veelal ouderen die niet zijn opgegroeid in het kustgebied. Zij zijn onbekend met de gebiedshistorie en de mogelijke gevolgen van een overstroming. De bouwvergunning geeft geen signaal dat wonen in het overstromingsgevoelige gebied niet veilig is.

Naar aanleiding van de waarschuwingen troffen de burgers voorzorgsmaatregelen voor de storm. Ze volgden het advies om ramen en deuren te sluiten. Ook de elektrische rolluiken gingen dicht, vaak met noodlottige gevolgen. Toen tijdens de overstroming de stroom uitviel, konden de rolluiken niet meer open. De moderne bungalows veranderden van een veilige haven in een val en op deze manier zijn veel mensen verdronken. De gevolgen hadden veel erger kunnen zijn als het toeristische seizoen al was begonnen. Ten tijde van de ramp was een groot deel van de woningen niet bewoond.

De overstroming heeft een discussie over nieuwe overstromingrisicozones losgemaakt. Het is onduidelijk wie welke rol in het verleden heeft vervuld. De burgemeester van Charron heeft openlijk bekend dat hij de ruimtelijke-ordeningswet heeft overtreden. De burgemeester van La Faute-sur-Mer stelt dat hij niet op de hoogte was van het gevaar. Volgens een artikel in Le Monde was de burgemeester wel degelijk op de hoogte door herhaaldelijke waarschuwingen van de prefect.

De zones die zijn aangemerkt als gebieden met een groot overstromingsrisico hebben na Xynthia een andere betekenis gekregen. Besloten werd om alle huizen te verwijderen in zones waar het water volgens de beschikbare scenario's meer dan 1.5 meter hoog kan komen te staan. De autoriteiten hebben voorgesteld om 1800 huizen op te kopen en daarvoor de marktprijs van voor de storm te betalen. Na veel weerstand uit de maatschappij is dit niet verplicht, maar een groot deel heeft het aanbod toch aanvaard.

Rampenbeheersing

Een kritiek element van de rampenbestrijding heeft gefaald: de stormwaarschuwing werd niet op waarde geschat door de crisisorganisaties van de autoriteiten en door het publiek. De bevolking in het kustgebied kreeg waarschuwingen voor harde wind en voor een mogelijke overstroming. De overstromingswaarschuwingen kwamen echter niet duidelijk over: ze werden ondergesneeuwd door andere informatie en adviezen over de harde wind. De bewoners hadden zich daarom wel voorbereid op wind, maar niet op een overstroming, met soms noodlottige consequenties.

Météo-France gaf op 27 februari al waakzaamheidskaarten voor de wind af die beschikbaar waren via allerlei kanalen. Voor de kustgebieden gold vanaf twaalf uur voor de stormpiek de hoogst mogelijke alarmcode (code rood). De verhoogde waterstanden waren bij Météo-France bekend, maar deze dienst is niet verantwoordelijk voor overstromingswaarschuwingen aan het publiek. Het is de taak van de hydrologische diensten van de prefecten (provincies) waterstanden te vertalen in overstromingsdreiging (kans op het bezwijken van de waterkeringen). De burgemeester stelt in dat geval het rampenplan in werking en informeert de bevolking over de dreiging. Aan de vooravond van Xynthia vonden de prefecten in het bericht van Météo-France onvoldoende aanleiding om ook voor een overstroming te waarschuwen. De onzekerheid van een mogelijke overstroming in relatie tot een zeker lijkende storm speelde hierbij een grote rol. De subprefect van de Vendée zegt hierover in een interview na de ramp: *"Ik ondertekende een rood alarm op zaterdag 27 februari, 16 uur, en dat is verspreid onder de ambtenaren, evenals een persbericht om het publiek te informeren. Nergens is gewaarschuwd voor overstromingen of het falen van waterkeringen. We (de prefecten, red.) kunnen niet zelf gaan fantaseren over het risico en het gevaar. (…) Waar kunnen we om 22 uur naartoe om de 400 000 bedreigde inwoners evacueren? Naar de Sahel?"*

Onze conclusie over de berichtgeving is dat de waarschuwing voor een mogelijke overstroming niet helder genoeg was. Ook de vertaling van stormwaarschuwingen in een handelingsperspectief voor overheid en burger was niet adequaat. Na de eerste doorbraken, die rond 2 uur ’s nachts op 28 februari plaatsvonden, is wel snel en voortvarend gehandeld door de hulpverleners. Direct na de ramp zijn zo’n 3.000 hulpverleners ingezet in de vier departementen die door de stormvloed getroffen waren (Charente-Maritime, Vendée, Gironde en Loire Atlantique).

Lessen voor Nederland

Na een overstromingsramp worden altijd twee vragen gesteld:

1. hadden we deze ramp kunnen voorkomen?
2. waarom waren we niet voorbereid op deze ramp?

Na de overstroming van 1953 heeft Nederland het waterveiligheidsbeleid sterk ontwikkeld. Het beleid richt zich met name op preventie, met hoge beschermingsnormen, onafhankelijke (lokale) uitvoeringsorganisaties en de wettelijke verankering daarvan. De relatief strenge normen in Nederland, die volgens het advies van de Deltacommissie in 2008 nog hoger zouden moeten worden, gelden in het buitenland vaak als voorbeeld. Een ramp als Xynthia bevestigt opnieuw de noodzaak van strenge normen, maar laat ook zien dat een overstromingsramp niet altijd te voorkomen is.

Nederland ontwikkelt het preventiebeleid verder naar een risicobenadering, waarin naast het voorkomen van slachtoffers ook de optimalisatie van kosten en baten een belangrijke rol krijgt. Sinds kort kijken we ook naar twee andere lagen van waterveiligheid: ruimtelijke ordering (bijvoorbeeld via de Watertoets) en rampenbeheersing. De ontwikkeling van nieuwe rampenplannen heeft in Nederland een stimulans gekregen door de overstromingsramp in New Orleans als gevolg van Katrina.

Uit de Franse overstromingen kan Nederland de volgende lessen trekken:

Op basis van deze lessen van Xynthia geven we enkele aanbevelingen. Xynthia kan worden gebruikt om de noodzaak voor preventie te onderstrepen, maar ook om duidelijk te maken dat een overstroming niet uit te sluiten is. Aanbevolen wordt een breed debat te voeren over passende combinaties van preventie, inrichting en rampenbeheersing in Nederland, met als doel:

1. vooraf te kunnen definiëren aan welke eisen preventie, inrichting en rampenbeheersing moeten voldoen (hoe veilig is veilig genoeg) en hoe we op de naleving daarvan toe kunnen zien;
2. achteraf te kunnen duiden of een ramp het gevolg was van achterstallig onderhoud of andere beleidskeuzen die leiden tot een te laag veiligheidsniveau, technisch falen of onverwacht hoge waterstanden en golven.

Daarnaast wordt aanbevolen om Xynthia te gebruiken als casus om klimaatbestendige inrichtingen en rampenplannen en maatregelen op gebied van zelfredzaamheid te toetsen op hun werking. Hoe goed zijn onze rampenplannen en wat is het effect van een scenario op het ontwerp? Is achteraf verdedigbaar dat goede keuzen zijn gemaakt?

10 The effect of relative sea level rise

The relative sea level rise in the Netherlands over the past two centuries has been 20 cm per century. In France at Brest in Brittany this is about 15 cm per century Pirazolli, 2001. This graph was provided by Mrs.Servane Gueben-Venière, Université de Paris 1,Panthéon-Sorbonne. If the sea level is higher then the wave action is not reduced by the fore shore. In France two centuries of neglecting sea level rise can mean an increase of hydraulic loads (combined action of waves and water levels) of around 40 tot 50 cm. At many spots where dikes failed in the Xynthia Flood the flood defences were exceeded by a comparable figure. So in other words dikes were often just 40 tot 50 cm to low to handle the combined action of water levels and waves. If the material on the inner slope consisted of sand (Ile de Re, Ile de Oleron, Aytre), this was quickly removed by the flow of water.

The IPCC panel has predicted higher sea level scenario's for 2100. Since 2009 in the Netherlands new designs are based on a sea level rise of 60 cm per century. 20 cm per century was observed. Dikes are built with a design live of 50 years, so predicted sea level rise will account for only a raise of 30 cm of the design height.

A rise of 50 cm in France in the Gironde in sea level will change a water level with a return period of 100 years into a water level with a return period of 10 years.
Flood defences in France will increasingly become unsafe if no large scale reinforcement and the raising of the flood defences are carried out. Abandoning areas is also feasible option and is one of the purposes of the "zones de solidarities", the former black zones, "zones noirs".

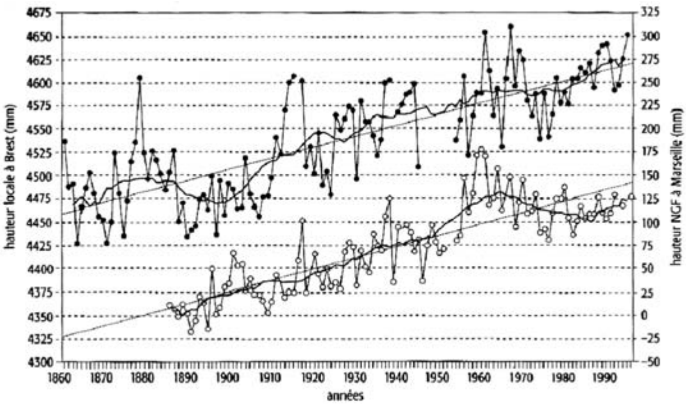

Figure 35: Changement de niveau de la mer a Brest et Marseille

Op 28 februari 2010, rond 2 uur in de ochtend, bereikte de storm Xynthia de westkust van Frankrijk. Meer dan 50.000 hectare aan land overstroomde. In totaal vielen in Frankrijk 47 doden, de meesten door het water en een enkeling door de gevolgen van de storm. Een ramp als Xynthia bevestigt opnieuw de noodzaak van strenge normen zoals we die in Nederland hebben. De ramp laat tegelijk zien dat een overstromingsramp niet altijd kan worden voorkomen. Dit boek beschrijft lessen en aanbevelingen die kunnen worden geïdentificeerd op basis van de gebeurtenissen in Frankrijk. Deze lessen aan aanbevelingen zijn opgesteld aan de hand van het principe van meerlaagsveiligheid zoals genoemd in het nationaal waterplan: preventie, inrichting en rampenbeheersing.

On the 28th of February 2010 at 2 a.m. the storm Xynthia hit the French Atlantic coast. A significant amount of land, land (>50,000 ha) were consequently flooded and 47 people died as a result of the storm. Large parts of the Netherlands are also prone to coastal flooding, even though we have very high safety standards. The Netherlands can learn from this flood in a neighboring country with a common history and legal system. This book describes the Xynthia storm and its consequences. Using multiple viewpoints of the "safety chain": flood warning, flood prevention, spatial planning and disaster management. This book gives lessons from the storm for the Netherlands.

Au petit matin du 28 février 2010, une partie importante de la côte Atlantique de la France a été frappée par la tempête Xynthia. Par conséquent, des grandes superficies de terre ont été inondées (> 50,000 ha), causant 47 morts en France, bien plus que le nombre des victimes liés aux effets directs du vent. Malgré le fait que le niveau de protection est plus haut au Pays Bas, les inondations causées par la concomittance de surcote, marée haute et des vagues y sont toujours possible. Nous considérons plusieurs volets de la gestion des risques liés aux inondations: prévision, prévention, planification spatial, protection civil. Le but de notre livre n'est pas de faire un retour d'expérience exhaustif sur la tempête Xynthia mais bien de distiller des enseignements de ce désastre pour les Pays Bas.