Politecnico di Milano
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Master of Science in

Civil Engineering for Risk Mitigation

MASTER THESIS

Theory of prevention and disaster risk reduction from post-disaster damages and losses database: the floods in PACA region in 2015 and in Seine and Lorraine basins in 2016 in France.

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Index

Figures index

Table index

Abbreviations

EU	European Union
EUSF	European Union Solidarity Fund
LPG	Liquefied petroleum gas
LNG	Liquefied natural gas
ERCC	Emergency Response Coordination Centre
TFEU	Treaty on the Functioning of the European Union
Climate-ADAPT	European Climate Adaptation Platform
PPP	Polluter Pays Principle
OIEWG	Open-ended Intergovernmental Expert Working Group
DRMKC	Disaster Risk Management Knowledge Centre
JRC	Joint Research Centre
ISO	International Organization for Standardization
UNISDR	United Nations Office for Disaster Risk Reduction
PPR	Plans de Prévention des Risques
PPRn	Plans de Prévention des Risques Naturels
PLU	Plan Locaux d'Urbanisme
PPRI	Plans de Prévention des Risques Inondation
CatNat	Garantie Catastrophes Naturelles
PCS	Plans Communaux de Sauvegarde
DDRM	Dossier Départemental des Risques Majeurs
DICRIM	Document d'Information Communal sur les Risques Majeurs
PPI	Plan Particulier d'Intervention
PAPI	Programme d’actions de prévention des inondations
PCA	Plan de Continuité d’Activité
MNR	Mission Risques Naturels
FFA	Fédération Française de l'Assurance
GEMA	Groupement des Entreprises Mutuelles d'Assurance
CCR	Caisse Centrale de Réassurance
ONRN	National Observatory for Natural Risks

DOM	Départements d'Outre-Mer
DDR	Disaster Risk Reduction
CCA	Climate Change Adaptation
GIR Maralpin	Groupe interdisciplinaire de réflexion sur les traversées sud-Alpines et l’aménagement du territoire maralpin
CNRS	Centre National de la Recherche Scientifique
SNGRI	Stratégie Nationale de Gestion des Risques d’Inondation
GLIDE	Global Disaster Identifier Number
VNF	Voies Navigables de France

Introduction

Loss data are a useful tool for the implementation of disaster risk reduction strategies at different scales and to better understand disaster loss trends at global level.

A list of the main regulations at international, European, and national levels for France will be presented for a better understanding of the actual legislative situation about floods and natural disasters in general.

The main topic of this thesis is the work done by the French team of LODE project, initiative established by the European Commission - DG ECHO – Directorate General for European Civil protection and Humanitarian Aid Operations. The main goal is the development of a European damage and loss data information system for DRR and CCA to support policies and strategies at different decisional levels.
First, an investigation about collected data from past disaster events has been performed, in order to understand the current state of art. The French team analysed one study case regarding the flood in October 2015 in PACA region. It has been chosen because particularly relevant for recent French history of flooding in terms of post-disaster damages and management problems faced during the crisis. In addition to that, a second study case has been taken into consideration: floods in 2016 in Seine and Lorraine basins. This second study is interesting because of the higher availability of quantitative data compared to the first study case, and several cartographic and georeferenced data about the capital city Paris.
At this purpose, it had been necessary to consult several official reports and documentations in original language, produced by public institutions and private stakeholders, such as Mission Risques Naturels and Caisse Centrale de Réassurance.

To collect the found data, an "ideal" database schema is presented, following the main structure proposed by the initial LODE directives. The data of the two study cases are then classified following the initial category's framework exposed.

1 Loss data and databases in EU and in France

1.1 Importance of loss data

“Disaster loss data recording is the result of a systematic, (nationally) consistent, coordinated process to collect human, physical, and economic losses as well as social and environmental consequences immediately following an emergency or a disaster.” (De Groeve, et al., 2014).

“It is often said that what is not measured cannot be managed. As a consequence, a lack of loss data is an obstacle to understanding societal resilience.” (De Groeve, et al., 2013).

Loss data are a useful tool for the implementation of disaster risk reduction strategies at different scales and to better understand disaster loss trends at global level.

Increasingly, the international communities and in particular the European Union face the necessity to collect in a detailed and structured way the disaster damage and loss data. Many databases have been created in the past years but characterised by different recording methods and reporting data about disasters managed with various governance approaches. The lack of standards represents the main challenge for loss and damage data sharing and comparison. In addition, disposing of standard procedures, it would be possible to carry out cross-border cooperation more easily.

Having a look to existing statistics, it is possible to notice the upwards trends in number of disasters, affected people and death toll (Figure 1). Scientists, practitioners, policy makers and the general public have started questioning the reliability of this result; it is not excludible the possibility that this trend is only due to a more scrupulous reporting and data availability. Several reasons could exist behind this trend: the diversity of intent, the insufficient agreed definitions, the scarcity of standardization on collection data methods, and the lack of legislation and accompanying funding measures to support mandated institutions (De Groeve, et al., 2013).

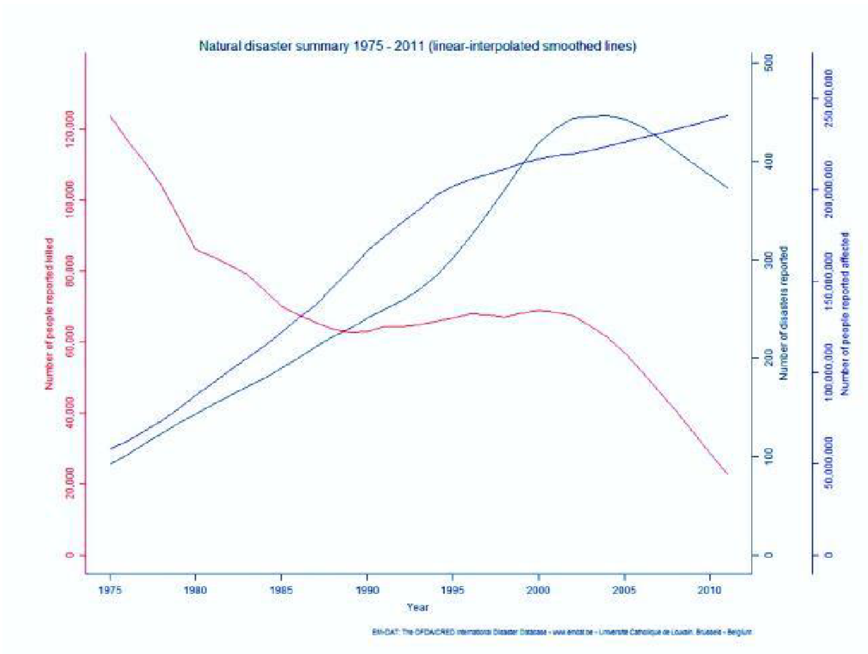


Figure 1 Trends in number of disasters, affected people and death toll (Source: EM-DAT CRED)

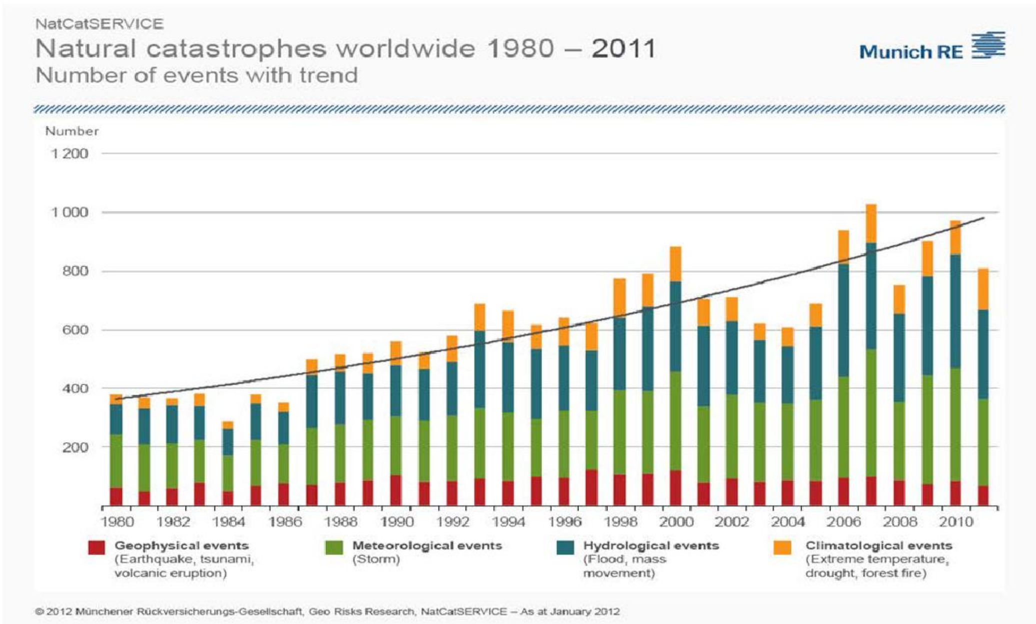


Figure 2 Number of natural disasters in the years 1980-2010 (Source: Munich-Re)

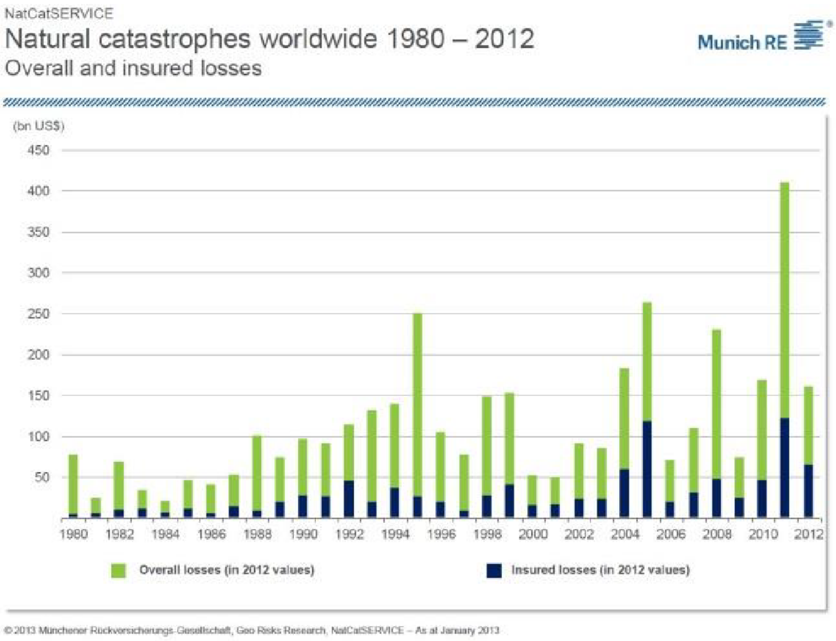


Figure 3 Overall and insured losses due to natural catastrophes worldwide 1980-2012 (Source: Munich RE)

Other reasons for the upward trend (Figure 2 and Figure 3) are the increased exposure due to the augmenting number of people concentrated in big cities and the fast and rapid urbanization which often corresponds to an increasing vulnerability (Figure 4).

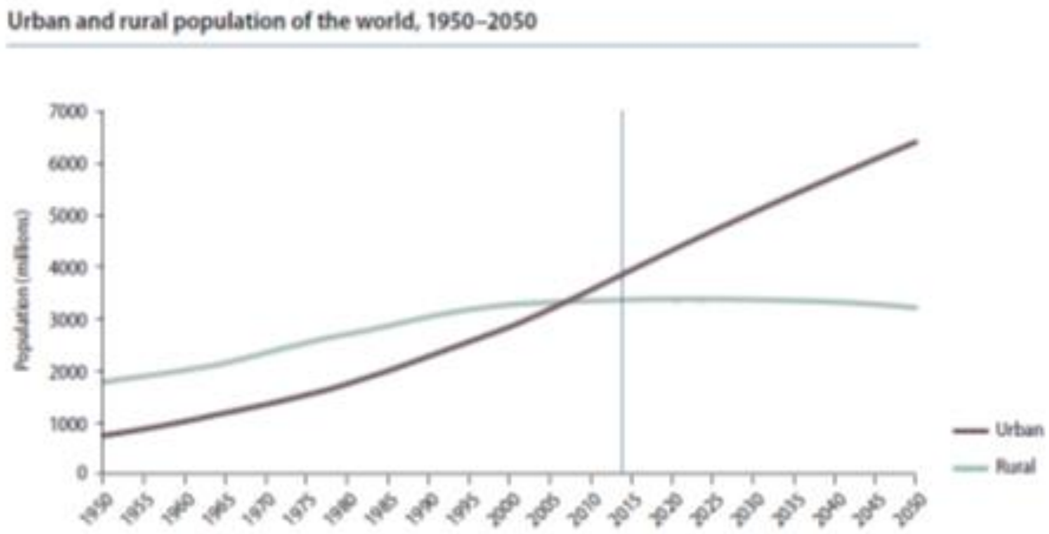


Figure 4 Urban and rural population of the world 1950-2050

According with the increasing number of natural disasters and vulnerability of people and assets, it is visible an increasing in the loss and damages due to natural disaster.

Starting from this fact, the creation of a structured common database of losses and damages becomes more and more a necessity.
A systematic reporting and collecting mechanism, together with a legal background and mandated institutions, can efficiently contribute to improving the disaster resilience across the EU.

1.2 The role of EU

The European Union disaster prevention framework promotes projects finalised to improve the disaster management preparation and to satisfy the necessity of collecting data in a structured way and sharing information among Member States. The European Commission assists the Member States providing technical advises and guidance to implement the national or local disaster loss databases (JRC, 2015). To establish loss databases at local level for operational use is the starting key. In this way, data could be easily aggregated at national or global level for political and strategical purposes.
Thanks to a structured common database framework, the comparison among databases would be possible, giving an important additional value to the systematic reporting on indicators for global disaster risk reduction targets (JRC, 2015).

The main fields of application of loss data are: disaster loss accounting, compensation, disaster forensics and risk modelling (De Groeve, et al., 2013). They differ in terms of scale and scope requirements.

1.2.1 EU goals

"The worst disasters have not happened yet"[1]

[1] UNISDR, 2013. Global Assessment Report on Disaster Risk Reduction 2013; From Shared Risk to Shared Value: the Business Case for Disaster Risk Reduction. Geneva, Switzerland: United Nations International Strategy for Disaster Reduction

The aims of the European Commission are multiples. First of all, the creation of a framework that could satisfy the EU principles at different levels, local, regional, national and EU level, providing a harmonisation of the loss data at international level. This aspect is aimed at being a systematic and consistent respond to the multiple and global policies in EU. In addition, the homogeneity in databases can guarantee the interoperability and comparison, facilitating the exchange and sharing of data among Member States, which is a powerful tool in case of cross-border operations (Ferrer, et al., 2018). Another important point regards the central role of the EU for the Member States as provider of guidelines in their choice of implementation on methods of hazard, assessment, risk mapping and analysis. After finding a mechanism to record systematically the damages and loss in the EU area, it becomes fundamental to consider the data sharing and quality assurance mechanism. In this way, as EU Community, it would be possible to take part to international initiatives targeted at providing global loss trend (De Groeve, et al., 2013).

The EU conceptual model is based on three application areas (Figure 5):

- Disaster loss accounting: the documentation of trends and the statistics aggregation is the primary scope of recording disaster loss, in order to understand the potential exposure of society to disasters and to better measuring and evaluating disaster risk reduction policies (De Groeve, et al., 2014). Therefore, a spatial comparison is possible at different levels: decision makers at local level, at sub-national and national level for fund allocation, promoting disaster reduction and mitigation, and at international level for international financial and humanitarian aid.
- Disaster forensics: the analysis of the unfolding of a disaster, starting from loss drivers, through measures of relative contributions of exposure, vulnerability, coping capacity, mitigation and response (De Groeve, et al., 2013). This area contributes to the reconstruction process and to quantify risk and implement risk reduction and mitigation measures, but the level of detail of loss information must be sufficient to understand the context of the disaster.
- Risk modelling: the modelling of future losses identifying sectorial areas and vulnerabilities. The main aims are the improvement of risk assessment, of the

forecast methods and the calibration and validation of model results. Spatial, temporal and quantitative uncertainty are necessary to find correspondence between losses recordings and detailed hazard models.

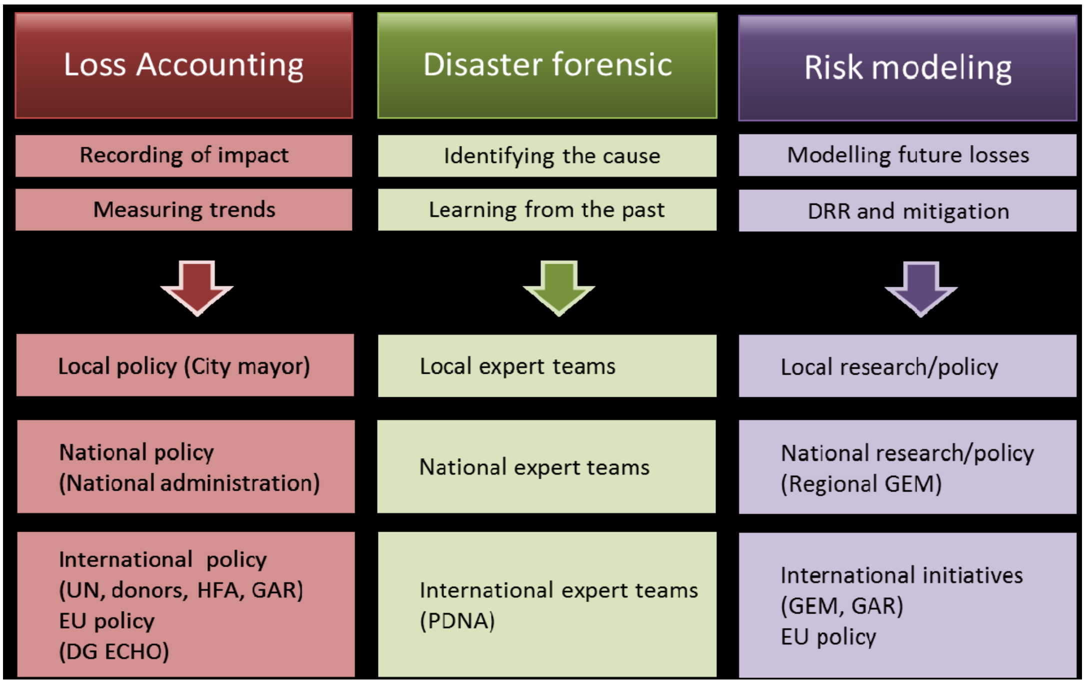


Figure 5 Conceptual model of application areas for loss data (JRC, 2013)

1.2.2 EU legislation on disaster loss data and catastrophe regulation

Multiple Directives at European level have been established throughout the years. The main ones are listed below (De Groeve, et al., 2014):

- The *European Union Solidarity Fund* (EUSF) was set up in response to the flooding that central Europe in the summer 2002. Since then, 80 catastrophes occurred in 24 European counties have received support through the Fund (Kołodziejski, et al., 2020). The Fund was established to support Member States involved in negotiations for accessing the EU, in their effort to deal with the consequences of a 'major[2]' natural disaster with serious repercussions for living conditions, the natural environment or the economy in one or more regions and

[2] A natural disaster is regarded as 'major' if it results in direct damage in excess of EUR 3 billion (2011 prices) or more than 0.6% of the gross national income of the beneficiary State (Kołodziejski, et al., 2020).

need support for emergency relief costs (Ferrer, et al., 2018). The EU budget available each year is up to 500 million (2011 prices) and it tries to alleviate the non-insurable damages. The main measures applied by the Fund are: the immediate restoration to the lifelines operability, the provision of temporary solutions for accommodation and other services for the affected population, the consolidation of preventive infrastructure, the protection of cultural heritage items and sites, the cleaning-up of the disaster-stricken areas (Kołodziejski, et al., 2020). The affected State, in order to receive assistance by the EUSF, must estimate the total direct damage caused by the natural disaster and the impact on the population, the environment and the economy.

- The *Solidarity clause of the European Treaty (Article 222)* is a clause implemented after the terrorist attacks in Madrid in March 2004. It provides the option for the EU Community:
    - to act jointly.
    - to prevent the terrorist threat in the territory of an EU Country.
    - to help another EU country in case of a natural or man-made disaster.

  (European Commission)

  It ensures that all the parties at national and at EU levels work together in a quick and effective respond.

- The *European Programme for Critical Infrastructure (Directive 2008/114/EC)* has been established in 2004 by the European Council, following the 9/11 terroristic attacks in the United States, Madrid and London (Ferrer, et al., 2018). The EPCI focus on critical infrastructures located in Member States, the destruction or disruption of which would have a significant impact on at least two Member States. The considered sectors are energy and transport (European Commission - DG Migration & Home Affairs, 2013).

- The *INSPIRE Directive 2007/2/EC* established an infrastructure for spatial information in Europe to support environmental policies of Member States. The Directive addresses 34 spatial data themes necessary for environmental applications (European Commission, 2007). It also provides a standardization of terminology and technical standards in order to ensure that the infrastructures are compatible and usable in transboundary contexts (Ferrer, et al., 2018). The Member States are encouraged to adopt common Implementing Rules (IR) in several specific areas. These IRs are acquired as Commission Decisions or Regulations, and the stipulation of them are supervised by a regulatory committee formed by Member States' representatives (European Commission, 2007).

- The *Floods Directive 2007/60/EC* established on 26 November 2007, is centred on the assessment and management of flood risks. This Directive demands the flood risk assessment for all water courses and coast lines, to map the flood extent and georeferenced information about assets, humans, and activities at risk in the Member States' area and to take measures for the flood risk reduction. The aim was to reduce the impact on human health, environment, cultural heritage and economic activity, producing flood risk managements plans and river basin management plans in collaboration with the Water Framework Directive and the public (European Commission, 2019). The first national reports were due in 2012, and reports are to be provided every 6 years thereafter (Ferrer, et al., 2018).

- The *Seveso Directive 82/501/EEC* was established after the catastrophic accident in the Italian town of Seveso in 1976, in response to the need of preventing and controlling major accidents involving dangerous chemicals minimising the associated risks. From later accidents such as Bhopal, Toulouse or Enschede, the *Seveso-II Directive 96/82/EC* was amended. In 2012 the *Seveso-III Directive 2012/18/EU* was adopted considering the changes in the chemicals' classification in the Union Legislation and the increased involvement of citizens in information sharing and justice (European Commission, 2020).

  "The Directive applies to more than 12 000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical and petrochemical industry, as well as in fuel wholesale and storage (incl. LPG and LNG) sectors" (European Commission, 2020).

- The <u>*EU Strategy on adaptation to climate change*</u> adopted in April 2013, "sets out a framework and mechanisms for taking the EU's preparedness for current and future climate impacts to a new level" (European Commission, 2013). It aspires to set a strategy to play a part to make Europe more climate-resilient (Ferrer, et al., 2018). The international community has agreed that global warming must be kept below 2ºC compared to the pre-industrial temperature, in order to prevent too catastrophic consequences of climate change.

  The EU Adaptation Strategy has three objectives:

  1. **Promoting action by Member States**: The Commission encourages all Member States to adopt comprehensive adaptation strategies, prioritising coherent, flexible, and participatory approaches. The EU Commission takes charge to provide guidelines and funding, since the results of studies show that to take early, planned adaptation action will be much cheaper than to pay the price of not adapting to climate change (European Commission, 2013).
  2. **Promoting better informed decision-making:** Building a solid knowledge base on the impact and its consequences lead therefore to a better-informed and more effective decision-making (Ferrer, et al., 2018). In addition, the Commission and the European Environment Agency will develop the European Climate Adaptation Platform (Climate-ADAPT) whose aim is to improve access to information and begin an interaction between Climate-ADAPT and other relevant platforms, including national and local adaptation portals (European Commission, 2013).
  3. **Promoting adaptation in key vulnerable sectors**: The Commission ensures that Europe's infrastructure is made more resilient through agriculture, fisheries, and cohesion policy, providing Guidelines aimed to help managing authorities and other stakeholders involved. In addition, it encourages the use of insurance against catastrophes, in fact the *Green*

Paper on the insurance of natural and man-made disasters represents the first step towards this objective (European Commission, 2013).

- The *Union Civil Protection Mechanism (decision 1313/2013 / EU)*, adopted on 17th December 2013 and in force since 1st January 2014, is "the key legal instrument covering DRR, and thus orients decisions at both EU and national levels" (Ferrer, et al., 2018). Its overall objective is to strengthen cooperation in the membership of 28 European Union Member States and of the three countries belonging to the European Economic Area (Norway, Iceland and Liechtenstein) in the field of Civil Protection (Governo Italiano), with the intent of improving prevention, preparedness and response to disasters (European Civil Protection and Humanitarian Aid Ope, 2020). It consists in a well-coordinated response which ensures that the assistance meets the real needs of the involved region. The EU Civil Protection Legislation stresses the importance of disaster prevention, risk management and disaster preparedness improved through trainings, simulation exercises and experts exchange, in order to improve inter-operability of the Member States' teams on the ground.

  In May 2013, the *Emergency Response Coordination Centre* (ERCC) was set up, ensuring a cover of 24/7 on monitoring, and responding to disasters. It takes care of informing the Member Stated of the situation and it decides about the provision of financial and in-kind assistance, as well as quickly mobilising the resources to be available in the voluntary pool (ECHO Factsheet, 2014). The EU Civil Protection is also supported by the Copernicus Emergency Management Service which provides timely and precise geospatial information that is useful to delineate affected areas and plan disaster relief operations (European Civil Protection and Humanitarian Aid Ope, 2020).

  A summary of the risk management capability assessments and the redefinition of the national risk management planning and mapping are required to the Member States. The risk assessment and mapping guidelines for disaster management indicate three categories of impacts for which loss data should be collected (Ferrer, et al., 2018):

    - Human impacts,

    - Economic and environmental impacts,
    - Political/social impacts.

  For the risk assessment, past disaster loss data are essential evidence, in fact these guidelines also highlight the critical issues of data quality, comparability, recording and reporting methods.

  "The proposal of EU Civil Protection will help achieve the objectives of Europe 2020, improve the security of EU citizens and strengthen resilience to natural disasters and man-made disasters" (Governo Italiano).

- The *State aid regulation (Article 107(1))* established in 2016 is an "advantage in any form whatsoever conferred on a selective basis to undertakings by national public authorities" (European Commission, 2019).

  To be State aid, a measure needs to have these features (European Commission, 2019):

    - It must be an intervention by the State or through State resources which can take a variety of forms,
    - the intervention gives the recipient an advantage on a selective basis,
    - the competition has been or may be distorted,
    - the intervention is likely to affect trade between Member States.

  According to the Article 107 of the TFEU (Treaty on the Functioning of the European Union), the State Aid is incompatible with the EU internal market. The coma 2(b) of the same Article declared an aid to make good the damage caused by natural disasters admissible (Ferrer, et al., 2018). Aid measures can only be implemented after approval by the Commission. Moreover, the Commission has the power to recover incompatible State aid (European Commission, 2019).

  The procedure to receive a State Aid follows these points:

    1. The regulation declared 'earthquakes, landslides, floods (in particular floods brought about by waters overflowing river banks or lake shores), avalanches, tornadoes, hurricanes, volcanic eruptions and wildfires of natural origin' (ibid, recital 69 and Article 50(1)) as events constituting a natural disaster.

2. The competent authorities have to recognise the damaging event as a natural disaster and the total cost of the damages (including insured ones).
3. The aid scheme must be introduced within three years, and any aid granted within four years after the disaster.
4. The eligible damage costs include the direct costs (material) and indirect costs (economical activities for a period of six months after the disaster event occurred).

(Ferrer, et al., 2018)

- The *Environmental Liability Directive 2004/35/EC* on environmental liability regarding the prevention and remedying of environmental damage, establishes a framework based on the 'Polluter Pays' Principle to prevent and remedy environmental damage. The Directive defines "environmental damage" as damage to protected species and natural habitats, damage to water and damage to soil (European Commission, 2004).

  The *Polluter Pays Principle* (PPP) was first mentioned in the recommendations of the OECD of 26th May 1972 (European Commission, 2012). As a main function the recommendations specify the allocation "of costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment." The polluter should bear the expense of carrying out the measures "decided by public authorities to ensure that the environment is in an acceptable state" (OECD 1972).

- The *Sendai Framework for Disaster Risk Reduction 2015-2030* (Appendix 3) is "a global agreement to reduce and prevent disaster risks across the globe. It aims to strengthen social and economic resilience to ease the negative effects of climate change, man-made disasters, and natural hazards" (European Commission, 2019). It has been proposed by the Open-ended Intergovernmental Expert Working Group (OIEWG) and it comprehends 38 indicators in relation to the four priorities and seven global targets agreed to measure global progress (Ferrer, et al., 2018). Member States' actions should be guided by these priorities and targets.

The risk assessment and mapping guidelines for disaster management indicate the following three categories of impacts for which loss data should be collected:

- Human impacts (number of affected people)
- Economic and environmental impacts
- Political/social impacts (rated on a semi-quantitative scale)

1.2.3 Guidelines

The Disaster Risk Management Knowledge Centre (DRMKC) assists EU Member States in delivering exchangeable and comparable loss databases and recording procedures. These data are the main input into complex multi-variable models that enable evidence-based risk assessment. Simultaneously, data collection that feeds the models provides the local and multi-sector input needed for the consistent implementation of DRR actions and activities (Ferrer, et al., 2018).

At European level, some reports, and articles with guidelines for the Member States have been published by JRC (Joint Research Centre):

- *Recording disaster losses — Recommendations for a European approach* (De Groeve, et al., 2013) provides standards for loss data recording and databases within EU. It puts the basis for a loss data framework considering loss accounting, disaster forensics and risk modelling.

- *Current status and best practices for disaster loss data recording in EU Member States* (De Groeve, et al., 2014) investigates the state of art in 2014 of methodology and technology of the Member States in collecting and recording losses, identifying the common points.

- *Guidance for recording and sharing disaster damage and loss data* (JRC, 2015) indicates the minimum set of indicators that should be present in any operational disaster loss database of each Member Stare. In this way, communication and sharing of loss data would be more structured and encouraged.

At international level, the ISO published in 2018 some guidelines for risk management. ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies.

- *ISO 31000:2018, Risk management – Guidelines* provides principles, framework, and a process for managing risk. Its aim is to put any organization in the condition of locating, preventing, and managing all the incoming risks, through a structured approach. It can be used by any organization regardless of its size, activity, or sector. Even if ISO 31000 cannot be used for certification purposes it does provide guidance for internal or external audit programmes. Organizations using it can compare their risk management practices with an internationally recognised benchmark, providing sound principles for effective management and corporate governance (Ferrer, et al., 2018).

The United Nations Office for Disaster Risk Reduction (UNISDR) took care of deliver documents about technical guidance for global targets:

- *Technical guidance for monitoring and reporting on progress in achieving the global targets of the Sendai Framework for Disaster Risk Reduction*. This document was delivered to support the refinement and finalization of the technical guidance for countries reporting on the indicators to monitor achievement of the global targets of the Sendai Framework for Disaster Risk Reduction 2015-2030.

- *Report of the open-ended intergovernmental expert working group on indicators and terminology related to disaster risk reduction*, adopted by the United Nations General Assembly in February 2017, presents suggested indicators to monitor the global targets of the Sendai Framework, the follow-up to and operationalization of the indicators and recommended terminology and definitions relating to disaster risk reduction.

1.3 The role of France

In France, as we can see in Figure 6 , the regulation structure is huge. We will see in the following paragraphs some of the main regulations more in deep. The insurance companies have a key role in the damage and losses data collection due to compensation needs, and often the public authorities collaborate with insurances to develop related documentations (such as PPRI).

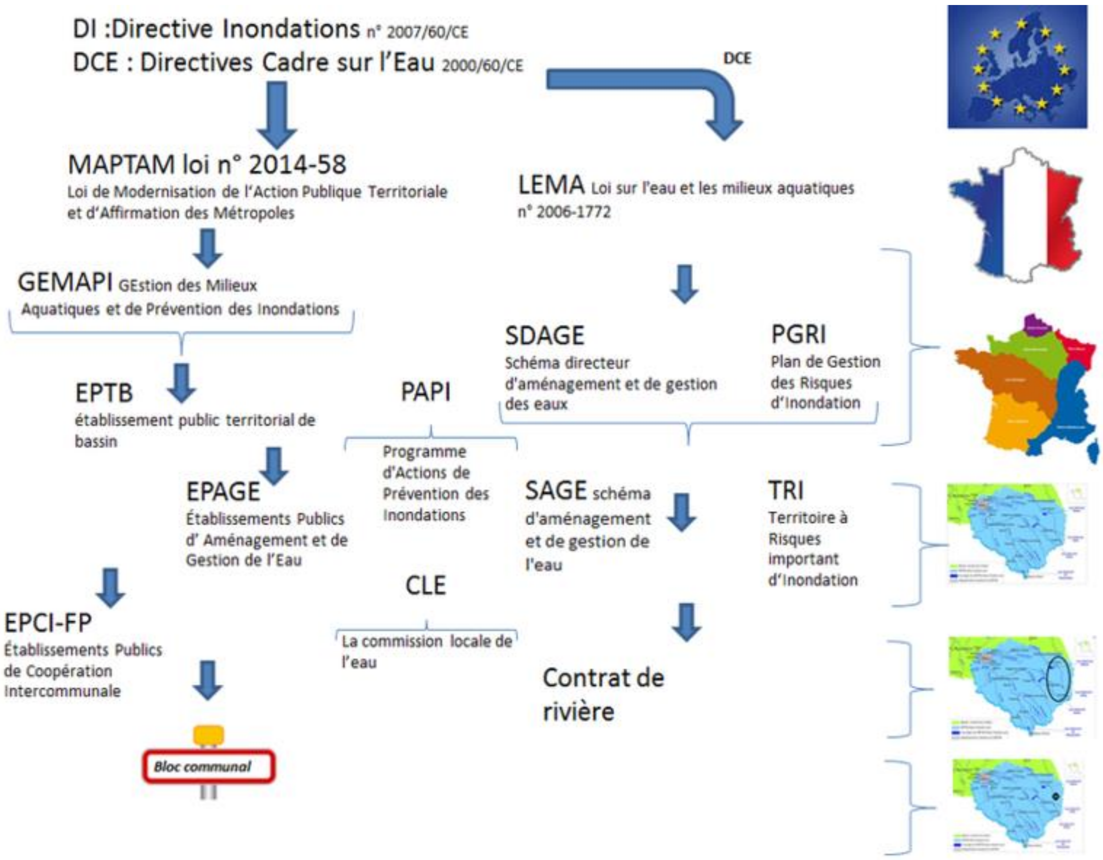


Figure 6 Regulations framework at different governance levels

1.3.1 Regulation in France:

- *Plans de Prévention des Risques Naturels (PPRn) / Prevention Plan for Natural Risk*, established with the law of 2nd February 1995, represents one of the essential tools of the Government action in terms of natural risk prevention, to reduce vulnerability of people and assets. It is a regulatory prevention dossier which shows the risky zones to population and to urban planners, and it defines the measures to reduce the vulnerability. The PPR had to be attached to the PLU (Plan Locaux d'Urbanisme/ Local Urban Plan) of the municipality. Its aim is to highlight the natural risks in the urban planning, construction, and management of territories. It encourages the urbanists to focus for the urban growing on the less exposed areas in order to reduce the damages to people and assets. The elaboration of the PPR is conducted by the government departments and it is revised by the municipalities and a public examination. Finally, it needs the approval of the Departmental Prefect (Ministère de la transition écologique et solidaire).

- *Plans de Prévention des Risques Inondation (PPRI) / Prevention Plan for Flood Risks* established by the articles 40-1 to 40-7 of the law n.87-565 of 22nd July 1987 related to the organization of the public security and the major risk prevention. It is issued by the Departmental Prefecture in association with the municipalities and the population. The PPRI delimits the exposed areas and it provides urban planning and land use regulations, in function of the level of the hazard and the land use (Préfet de la Région d'Ile-de-France, 2020). The level of hazard is defined according to the maximum water level during the flood and the runoff speed.
  The PPRI comprehends three zones distinguished by colours: red, green and blue (the colours could change) (Table 1).

Table 1 PPRI zones according to the hazard level (DREAL d'Auvergne-Rhône-Alpes, 2018)

	Natural zone	Partially urbanized	Activity zone	Urban centre
High hazard	Dark green	Red	Red	Red
Medium hazard	Light green	Dark blue	Dark blue	Light blue
Low hazard	Light green	Light blue	Light blue	Light blue

  - Red zone (« zones d'interdiction de construire ») :

    - Prohibit any new construction or building.
    - Reduce or eliminate the settlements present in water flow.
    - Reduce the vulnerability of existing issues in risky zones.
    - Allow the transformations of the existing constructions that want to improve their condition.
  - Green zone:
    - Preserve their storage and expansion capacities.
    - Do not establish new activities or new housing.
    - Reduce the vulnerability of existing issues in risky zones.
    - Enable the continuation of existing agricultural activity.
  - Blue zone (« zones soumises à prescriptions »):
    - Allow further urbanisation to proceed in a limited and secure manner.
    - Allow the transformations of the existing constructions that want to improve their condition.
    - Reduce the vulnerability of existing issues in risky zones.

(SEDIPEC) (DREAL d'Auvergne-Rhône-Alpes, 2018)

The multiple aims of the PPRI are:

- Identify the zones which risk being flooded.
- Prohibit any new construction in such areas.
- Reduce the vulnerability of existent constructions in risky zones.
- Protect flood expansion areas in order to avoid worse future floods.

(SEDIPEC)

- *La Garantie Catastrophes Naturelles (CatNat)/ the Natural Catastrophes Guarantee* was created with the law of 13th July 1982, and it allows a coverture for natural risks which were not much insured since then. The insured person is compensated for the damages from a natural disaster in the following cases:
  - If the Major applies for a request of recognition of a state of natural catastrophe.

- If, following this request, an interministerial natural disaster ordinance is published in the official gazette.
- If the insured's property is covered by damage insurance (fire, theft, water damage, etc.). Items covered only by a civil liability insurance policy are not insured by the Natural Catastrophes Guarantee.

The CatNat Insurance is an extension of the mandatory guarantee for every insurance contract on damage. So, only insured items can be compensated by the CatNat insurance.

This Guarantee takes charge of "direct material damages not insurable, whose main cause is the unusual intensity of a natural agent and where the usual measures to be taken to prevent such damage could not prevent its occurrence or could not be taken" (L125-1 article of Insurances Code).

The hazards covered by the CatNat Guarantee are:

- Floods
- Droughts
- Soil movements/ landslides
- Cyclones and Storms
- Earthquakes
- Avalanches
- Vulcanism
- Tsunamis

If a construction has been built in a red zone according to a PPR, the insurance is not obliged at compensate the damage due to the natural catastrophe (article L125-6 du Code des Assurances). If it has been built before the establishment of the PPR but the prevention measures were not applied in the 5 years after the introduction of the PPR, again the Insurance is not forced to cover the damage cost.

Legal minimum deductibles (Table 2), fixed by the State, mandatory and non-redeemable (Valid from 1st January 2001):

- Residential properties and vehicles: 380€
- Business assets: 3 working days with a minimum of 1140€
- Business interruption: 3 working days with a minimum of 1140€

Table 2 Legal minimum deductible (from CCR - Garantie Cat Nat)

Biens à usage non professionnel	Dommages directs	380 €	Sécheresse 1 520 €
Biens à usage professionnel	Dommages directs	10 % mini 1 140 €	3 050 €
	Pertes d'exploitation	3 jours ouvrés mini 1 140 €	

If in the same municipality, multiple natural disasters occur in a 5-year period, and in case of absence of a PPRn:

- 1 to 2 recognition: basic deductible
- 3 recognition: double deductible
- 4 recognition: triple deductible
- 5 recognition or more: quadruple deductible

(CCR)

- *Loi Barnier* is a French law which reinforce the legislation about the protection of the environment. It establishes the general principals of Environmental Right. Specifically, it is relative to the organization of civil safety, to the protection of forests against wildfires and to the prevention to major risks (République Française, 1995).

- The *Plans Communaux de Sauvegarde (PCS)* created by the law of 13th August 2004. The PCS is a tool for majors to manage exceptional crisis on the municipal territory, implying special measures for the safety of inhabitants. It is based on the analysis of the hazards potentially affecting the municipality and the risk study is made with the data present in the Dossier Départemental des Risques Majeurs (DDRM) established by the prefect. The PCS is a mandatory document for municipalities situated in areas in danger according to a PPRI or a nuclear or technological PPI (Plan Particulier d'Intervention). The PCS must be completed with a DICRIM (Document d'Information Communal sur les Risques Majeurs), which is an informative support for citizens. It explains the major risks present in the territory and the proper behaviour to adopt in crisis time. (Préfet de l'Aube, 2017)

- The *Programme d'actions de prévention des inondations (PAPI)* is a contractual instrument among territorial collectivises or groups of them and the State. Its goal is to promote an integrated management of flood risks in basins with comparable risk conditions, in order to reduce damages in terms of human lives, goods, economical activities and natural system (Préfet de la Région d'Ile-de-France).

- The *Plan de Continuité d'Activité (PCA)* represents the set of measures to insure, according to different scenarios, the economic activities facing crisis affecting their essential needs, impeding the continuity of the commercial businesses. The main purpose of a PCA is ensuring an organized recovery after a crisis and the continuity of the activities in case of damages caused by an extreme event.

- The *Stratégie Nationale de Gestion des Risques d'Inondation (SNGRI)* is a collective elaborate born in October 2014 from the collaboration of the Commission Mixte Inondation (CMI) and the State. It has three main objectives: raising the security of exposed population, stabilize at short term and reduce at medium terms the total damages cost due to flooding, shorten the time necessary to a return to normalcy of affected territories. In order to reach these goals, some national strategies have been applied, such as the identification of 14 indexes useful as support to damages evaluation and insurance (Ministère de la Transition écologique et solidaire - République Francaise, 2017).

1.3.2 The role of insurance market

In France, the insurance companies have a key role in the support to disaster recovery and disaster risk reduction (Figure 7). The larger amount of post-catastrophe data occurred in the French territory is collected and owned by private insurances. This is a crucial reason why obtaining data about disasters in France is so challenging and hindered. On the other hand, Insurance industry has an interest in obtaining reliable disaster loss figures to calculate insurance premiums, financial worst-case scenarios and provide an opportunity to include incentives to reduce risks. (Ferrer, et al., 2018)

At the European level, The *Green Paper on Insurance of Natural and Man-made Disasters* is a document whose objective is "to raise awareness and to assess whether or not action at EU level could be appropriate or warranted to improve the market for disaster insurance in the European Union" (European Commission, 2013). More in general, EU wants to promote insurance as a tool of disaster management and to encourage an improvement in the culture of risk in all Member States. This process will consequently expand the knowledge base and bring in further data and information.

In France, all members of the national insurance market took the initiative to participate in risk knowledge and awareness raising development creating the association Mission Risques Naturels (MRN), born in 2000 between FFSA (Fédération Française de l'Assurance) and GEMA (Groupement des Entreprises Mutuelles d'Assurance).
An agreement among MRN, CCR (Caisse Centrale de Réassurance) and the French State made possible the creation of the developed National Observatory for Natural Risks (ONRN). This cooperation is centred in data sharing and it allows more systematic and improved loss recording (De Groeve, et al., 2014).

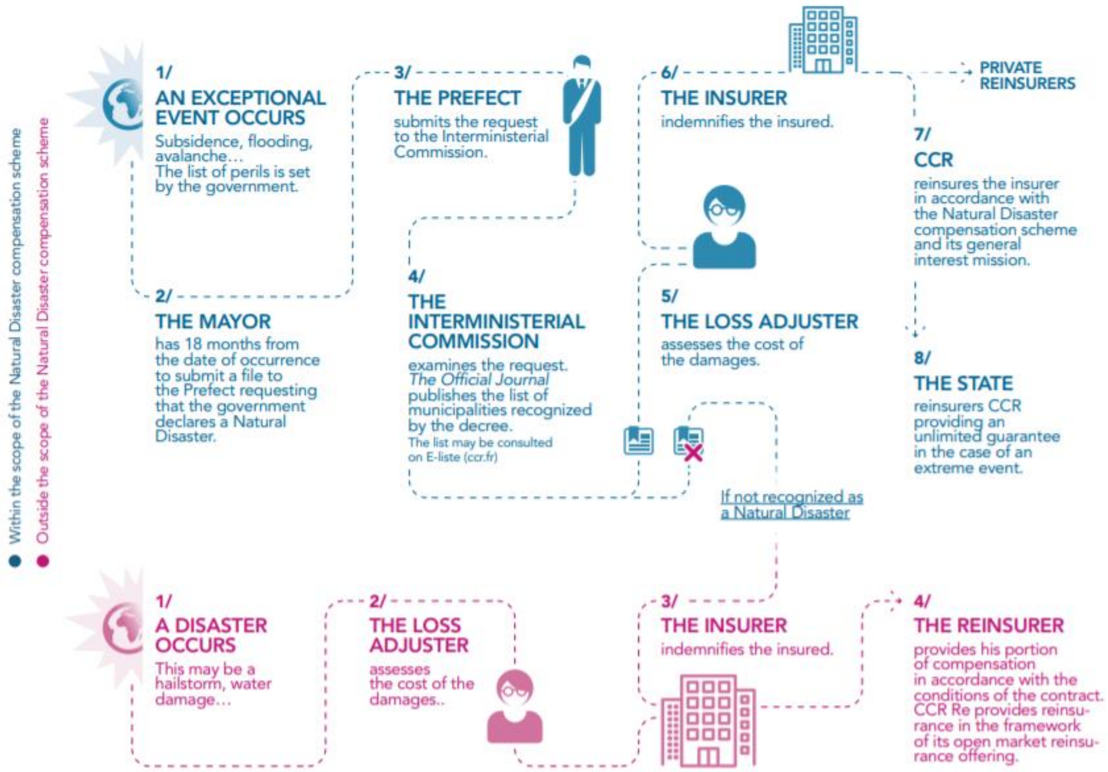


Figure 7 Steps identified by CCR to follow a disaster occurs (2019 Activity Report — CCR Group)

2. Analysis framework: the process of the disaster loss data collection, recording and sharing

2.1 Data collection

Data collection is a process developed at different

- Time scales: emergency phase, recovery phase, reconstruction phase
- Spatial scales: asset level, municipal level, regional level, national level, global level.

Loss data are often information collected from media reports or unverified government figures that lack evidence-based measurements. In addition, only data referred to national or regional spatial scales are usually identified and shared.

Ideally all databases should present the same data typologies and standardized aggregation methods in order to make all databases comparable among each other.

Since loss databases are often used to calibrate and validate risk models, linking loss accounting to other application with local benefit may be a way to achieve this objective.

2.2 Data recording

Data recording is directly depending on the scale at which the data are collected. The lower is the scale, the harder is to standardize the process. But the standards covering asset scale, for example, are applicable also at larger scale. Because of that, the EU methodology should start from the scale where definitions, units, collection methods and uncertainty estimates are most concrete (asset scale) (De Groeve, et al., 2013).

First, a European identification number associated to each disaster, such as the Global Disaster Identifier Number (GLIDE), could be a starting point.

The GLIDE is a project initiated and maintained by the Asian Disaster Reduction Centre (ADRC), so it is made to be applied to context very different from the European one. Therefore, the GLIDE number cannot be directly applied but a modified version can be a valid allied. An interesting characteristic of GLIDE numbers is the possibility to deal with cascading events (using prefixes) and with hierarchical spatial units (countries, provinces, districts; using suffixes) (De Groeve, et al., 2013).

Fundamental elements for risk modelling and forensics are georeferenced data. Georeferencing methods and procedures should be standardized, with an associated uncertainty estimate.

Data recordings should be classified according to the categories of elements affected by disasters. Based on the ECLAC[3] nomenclature, a catastrophe can affect (De Groeve, et al., 2013):

- The exposed elements (**direct damages**). This category consists of damage to assets that occurred right at the time of the actual disaster. If direct damages are converted in monetary value, they become **direct losses**.

[3] The Economic Commission for Latin America (ECLA) -the Spanish acronym is CEPAL- was established by Economic and Social Council resolution 106(VI) of 25 February 1948 and began to function that same year. The scope of the Commission's work was later broadened to include the countries of the Caribbean, and by resolution 1984/67 of 27 July 1984, the Economic Council decided to change its name to the Economic Commission for Latin America and the Caribbean (ECLAC); the Spanish acronym, CEPAL, remains unchanged. (https://www.cepal.org/en/about-eclac-0)

- The flow to produce goods and services (**indirect losses**). They are more difficult to estimate because the consequences of physical destruction can become apparent at different times after the disaster and the non-physical damages are harder to identify.
- The performances of the main economic variables of the country/region (**macroeconomic effects**). This category is often not considered in databases since macroeconomic effects quantification is usually done for the national economy as a whole and so considerations are highly complex. Nevertheless, the European Solidarity Fund has a category of regional disasters where the economic stability of region is also considered.

Some data such as collections of assets (e.g. hospitals in a municipality) should be recorded using statistical distributions of values, for practical reasons.

Already existing classifications are available (De Groeve, et al., 2013):

- Eurostat's classification: suitable for buildings
- HAZUS classification: suitable for lifeline utilities, transport, and communication facilities.

2.3 Data model and sharing

Many well-known and widely used methodologies are present in the state of art (De Groeve, et al., 2014):

- a **Damage and Loss Assessment (DALA)** developed by the UN Economic Commission for Latin America (ECLAC) in the 1970s to address international catastrophes.
- A methodology is developed by CRED (Centre for Research on the Epidemiology of Disasters) at Louvain University in Belgium and is implemented in the **Emergency Events Database (EM-DAT)**, mainly focused on human loss indicators.
- **Insurance companies** (e.g. Munich RE or Swiss RE) are able to provide detailed economic losses both insured and uninsured attributable to the event.

3. LODE project

In 2030 Agenda for Sustainable Development approved and discussed in major UN conferences and summits held over 2015 and 2016, the Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) are central topics. The increasing effects of natural and man-made catastrophes and the following economic losses are making Member States and big private companies aware of the need of successful mitigation and recovery strategies. Effective measures can be studied starting from detailed databases (European Commission, 2019). This common interest among different public and private stakeholders, pushed the European Union towards different initiatives, such as the Sendai Framework for Disaster Risk Reduction 2015-2030 (SDRR), and research generally leaded by JRC.

3.1 What is LODE

LODE is a project funded by the European Commission - DG ECHO – Directorate General for European Civil protection and Humanitarian Aid Operations under the Program: Union Civil Protection Mechanism Prevention and Preparedness Projects in Civil Protection and Marine Pollution 2018-2020.

The main goal is the development of a European damage and loss data information system for DRR and CCA to support policies and strategies at different decisional levels. Starting from the a priori knowledge of partners and stakeholders, coming from several countries and institutions (Figure 8), data from national databases about specific disasters have been collected.

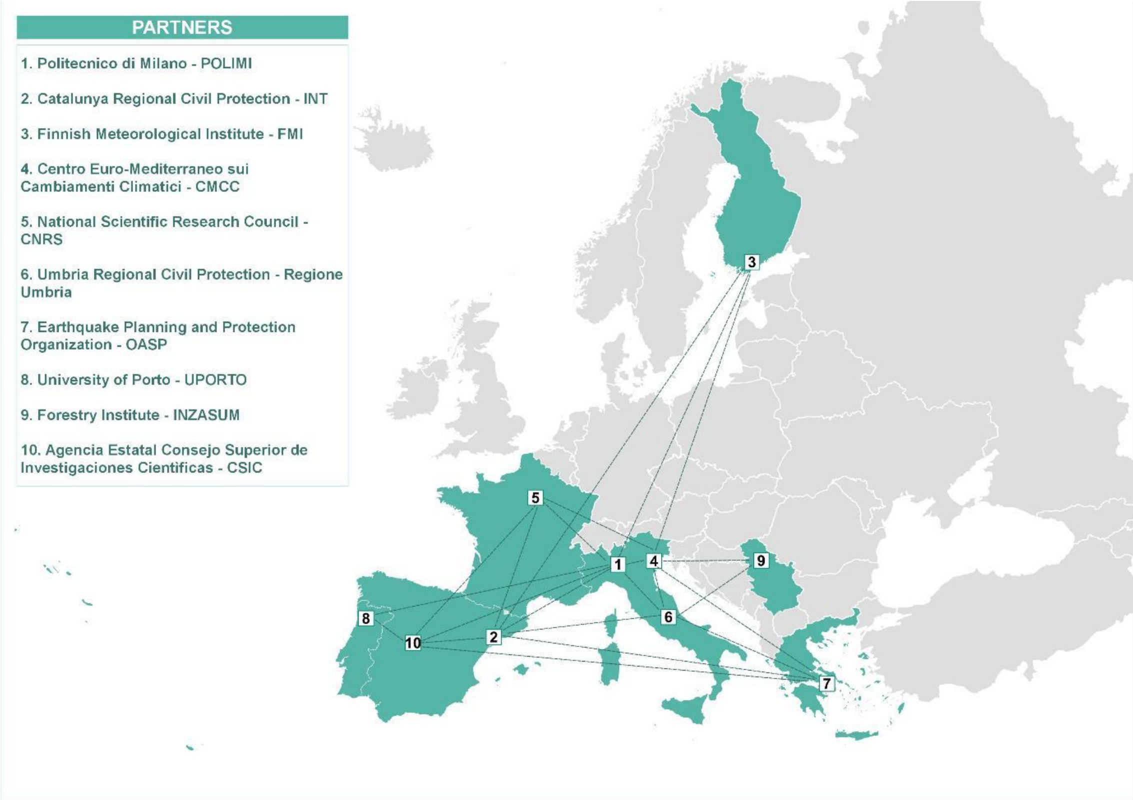


Figure 8 Lode's Partners and countries

The action of collecting data were focused on numerous sectors (Figure 9):

- lifelines as part of critical infrastructures with particular attention to telecommunication, power, and transportation.
- economic activities, including agriculture, industrial and commercial facilities.
- cultural heritage.

To achieve a multipurpose use of this database, the framework should allow to aggregate data at different spatial and temporal scales.

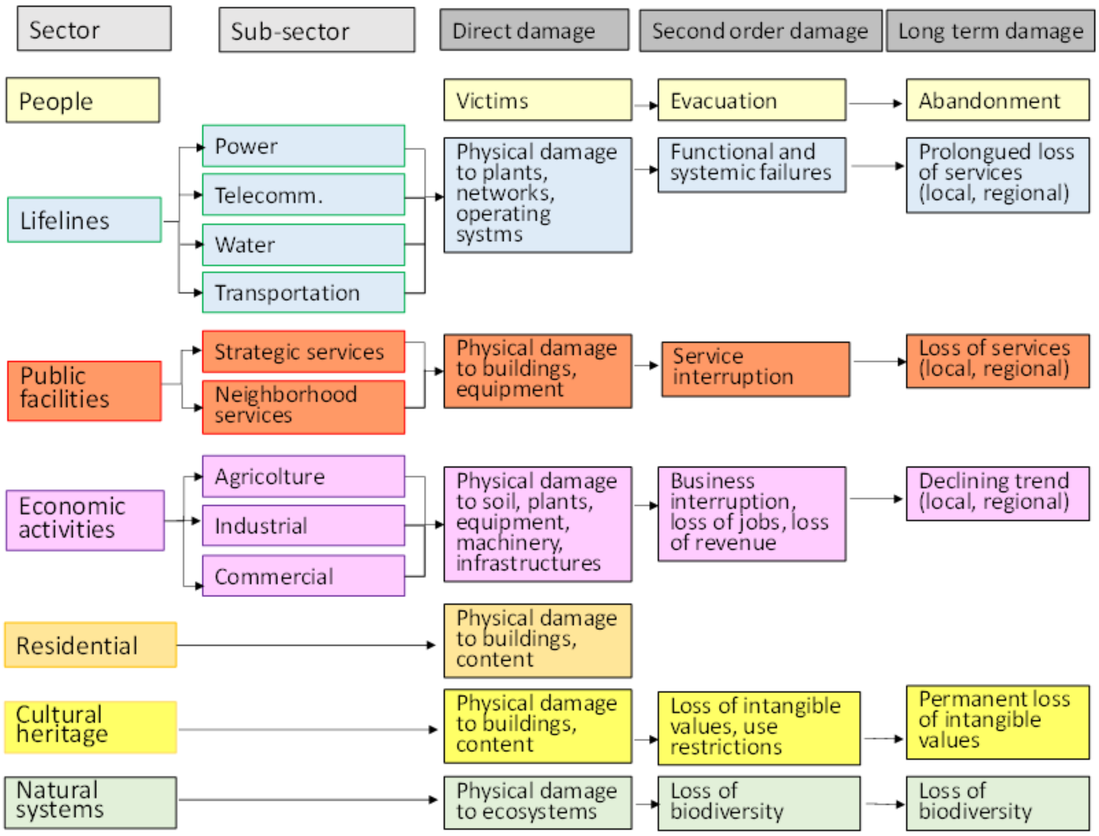


Figure 9 Preliminary LODE database framework

3.2 Why European level?

LODE project was established by the EU and this necessity of developing a collaboration among Member States is born from many reasons. Fundamental and crucial aspects for the disaster management are the trans-boundary effects (De Groeve, et al., 2014). Loss trends and spatial patterns obtained from the collaboration of the involved States can be a key tool to better improve DRR policies on national and European levels. This implies the possibility to compare data among States, possible only with a common database or common standards for national databases.

3.3 What does it mean “acceptable risk”?

“The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions” (UNISDR, 2009).

The level of risk acceptability depends on several factors: first of all, the type of owner who bears the losses influence its gravity. If the damages affect private small businesses, consequences are heavier than for big companies. In addition, if the losses involve governmental or semi-governmental organizations, special assistance funds are present (De Groeve, et al., 2013).
It is fundamental in an international project to define and agree on clear definitions for all the possible categories and damage typologies.

3.4 France study cases

In the annual financial report, CCR (Activity Report — CCR Group, 2016) estimates the cost of insured damages due to natural disasters around 650 to 870 million euros. In 2015, the flood occurred in the Alpes-Maritimes region in October (1st study case) totalized more than 60% of the total. The FFA estimated that the total cost of damages due to natural catastrophes in 2016 reached 1.4 billion euros due to the flood occurred in Seine and Loire rivers' basins (2nd study case).
Floods, in terms of hazard, are the higher percentage over the total of present hazards in France (Figure 10). As we can see in the Figure 11, the most affected areas in terms of cumulated cost due to floods are: the French Riviera, the departments in correspondence of the Seine's basin and the central-west coastal departments where the Xynthia storm occurred in 2010. The first two are the location of investigation for the two study cases.

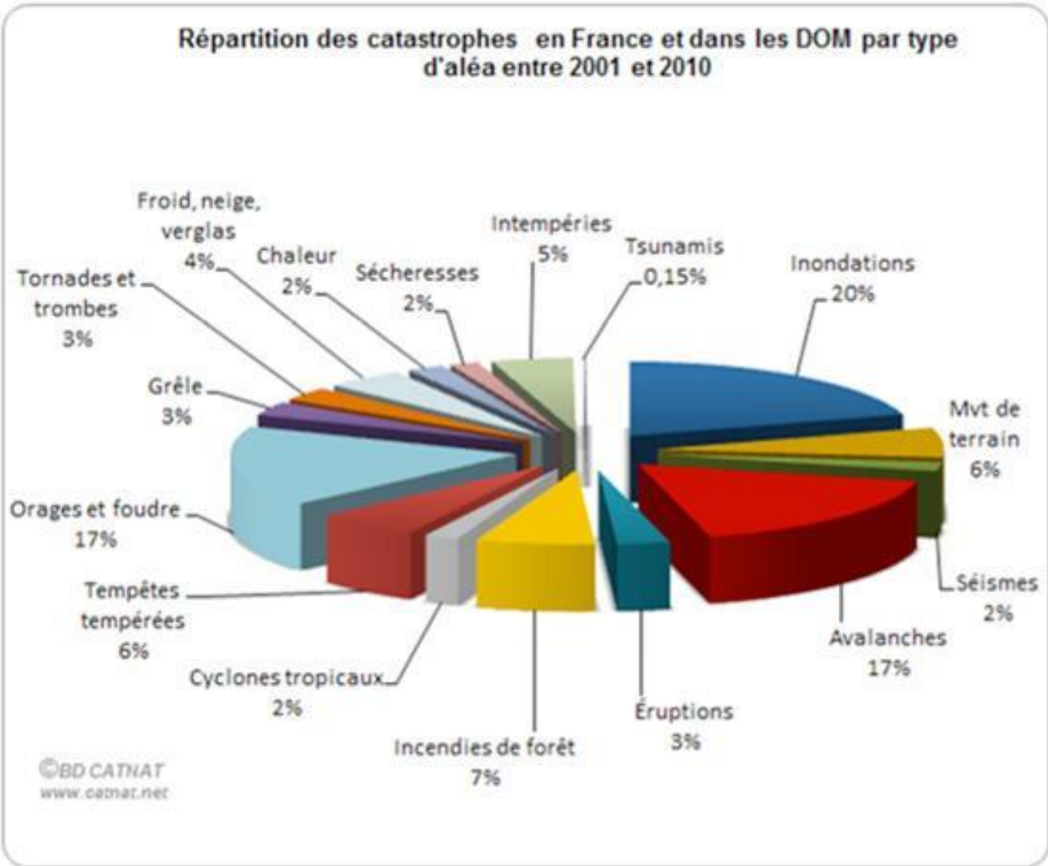


Figure 10 Repartition of natural disasters in France and DOM by hazard between 2001 and 2010

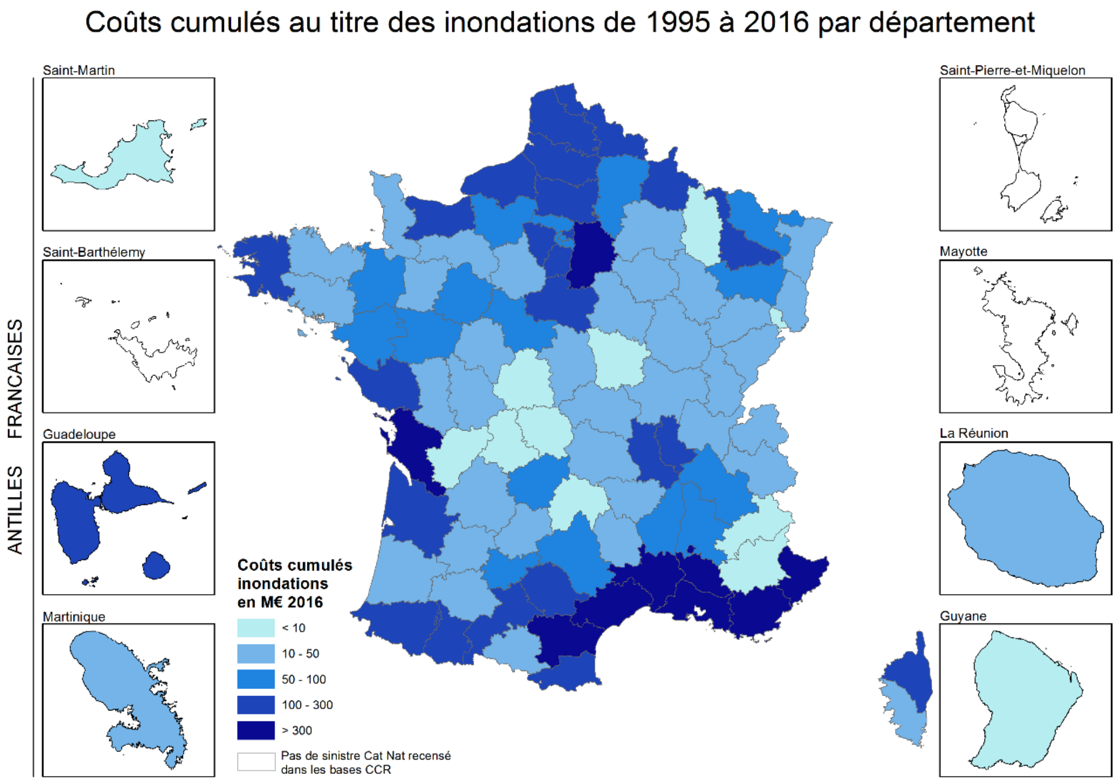


Figure 11 Cumulated cost due to floods between 1995 and 2016 per department

Two study cases have been chosen in two different environments and two different types of flooding: a flash flood with runoff and mudflow in Alpes Maritimes in 2015, and a slow flooding with rivers overflow in different zones in Seine and Loire rivers' basins in 2016. In addition, the amount and the type of data available for the two events are very different. The flood in 2015 occurred in a peripheric area of France, while the 2016 floods occurred in a central area involving the capital city Paris.

Study case 1: October 2015 flood in the Maritime Alps and Var regions

During the night between the 3rd and the 4th of October 2015 a flood devasted large part of the Maritime Alps and Var regions. An extraordinary rainfall event caused a fast rising of the waterways level and a significant runoff flow. This combination, aggravated by the steep morphology of the region, led consequently a high cost in terms of direct, indirect damages and life losses. The official reported number of fatalities is 20, so it represents one of the deadliest floods in the last 30 years in France. The abundant runoff flow seems to be a direct consequence of both the increasing urbanization of the area and a drizzle in the days before the major event that saturated the soil.

A great contribute to the losses is represented by the late warning which put both rescuers and citizens in the condition to have a shortened time (a few hours) to organize and move out from the flooded areas. This is the outcome of the exceptionality of this climatic event: even though the storm was being monitored by French and Italian meteorological services (e.g. Météo-France), the event has been so fast to be able to forecast the imminent torrential rainfall only some hours before the peak of the event. The morning of October 3, the *vigilance orange* (orange warning, national procedure of information by Météo-France) was declared, but already between 7 and 10 p.m. the cumulated rain reached its peak.

Approximately 1200 people from the principal affected urban centres had to be temporary or long-term relocated. Many damages to the infrastructures have been detected: several waterway obstructions in correspondence of the bridges, damaging the structures themselves, multiple roads and railways were submerged or damaged by the debris carried by the flood, 70.000 houses were without electricity on Sunday at 23h00 (peak of the crisis).

As a general estimation of the total cost of the damages the French insurance association (FFSA et GEMA) declared 550-660 million euros for 65000 recorded claims, where the 60% is referred to private houses, 27% to vehicles and 13% to commercial activities (estimations of April 2016); 40 million euros was the evaluation of damages only on public domain (buildings, canals, highways).

Study case 2: 25th May – 6th June 2016 floods in the medium basin of Seine and Loire rivers

Between the 25th May and the 6th June 2016, extraordinary rainfall events caused a rising of the waterways' levels in the complex network of tributaries of Seine and Loire rivers, aggravating therefore the conditions of the main canals. A great contribute to the losses is represented by the extension in time of the system of events. This introduces to a *Culture of slow flooding*, which can induce excessive confidence that corrections and repairs on the network could be made without major difficulties during the event. In this case, the crucial values are not only referred to the intensity of the rainfall but mostly to the cumulated one.

1148 municipalities were declared in state of *Natural Catastrophe* (CatNat), along the 3 consequent sessions of 7th, 13th and 21st Jun. 8 departments have been involved in the disaster: l'Essonne, le Loir-et-Cher, le Loiret, la Seine-et-Marne, Paris, les Yvelines, le Cher, l'Yonne. While the most damaged municipalities were Villeneuve-Saint-Georges, Montargis, Moret- Sur-Loing, Nemours, Montrichard, Melun, Longjumeau, Romorantin-Lanthenay. Around 1500 people had to be temporary or long-term relocated.

According to Perrin, Sauzey, Menot, & Roche, 2017, it was the second more expensive event after Xynthia storm with more than 1 billion euros of damages. CCR proposed 1.2 billion € as an estimation of insured damages, according to the model results. They represent the so-called professional damages which hypothetically could represent up to three quarters of the total damages. These estimates consider direct damages and a part of the operating losses. The average cost per municipality for this event was calculated of 860 000 €. The damage considered eligible represents only about one third of the damage declared by the local authorities.

The area has already been affected by numerous flood events with a large percentage with considerably cumulated damages. In addition, the majority of the inhabitants and of industries is still located in flooding zone. It means that the prevention measures and the urban planning need to be revised.

4 Proposed solutions

4.1 Proposed definitions

- HUMAN LOSS

  Typically include casualties, injured and displaced people.

- DIRECT LOSS

  Direct loss is the monetary value of physical damage to capital assets (adapted from ECLAC 2003 and Benson and Clay, 20006). Generally, direct loss and damages are referred to buildings and infrastructures damages, which are quantified by engineers and then translated into monetary loss, and damage to the agricultural system and the natural environment.

- INDIRECT LOSS

  Indirect loss refers to the damage to the flow of goods and services (adapted from Benson and Clay, 2000). Generally, indirect losses relate to business interruptions and systemic damages due to lack of service of lifelines.

- TANGIBLE

  Tangible assets capture all physical assets such as property, financial instruments, and cash. In terms of balance sheets, insurers have predominantly tangible assets (European Commission, 2016).

- INTANGIBLE

  Costs that accrue to assets without an obvious market price (difficult to depict in monetary terms) (EU expert working group on disaster damage, 2015). They cover non-physical assets such as intellectual property, goodwill, and brand recognition (European Commission, 2016).

4.2 Proposed ideal database structure for France

Starting from the initial database framework of LODE project, a preliminary ideal database structured on the French study cases has been created. The structure is

divided in damage categories and the data are meant to be collected at different time scales.
All the categories are meant to be collected as post-disaster appraisal and disaster appraisal few years later.

- PEOPLE:

  This category is meant to be filled at municipal level.

- RESIDENTIAL BUILDINGS:

  This section is meant to be filled with data at single asset level.

- ECONOMIC ACTIVITIES: agriculture, productive, services and commerce.

This category presents a large variety of conditions in which damage may occur. This uncertainty has to be added to the lack of specific tailored tools to collect and analyse damage to the economic sectors. To reduce the variety and improve the classification methods, identifying key aspects in terms of differences and commonalities is fundamental.
As well as the previous section, data should be collected for the post-disaster appraisal and the disaster appraisal few years later, but in this case an analysis at long terms is even more important to understand the trends.
This section is meant to be filled with data at regional, municipal and single asset levels.

The damage categories are:

- PUBLIC FACILITIES: City Hall, Court, Police Station, Fireman Station etc.

  This sector is meant to be filled with data at single asset level for direct and second order damages, municipal and regional levels for long term damages.

- CULTURAL HERITAGE: historic sites, monuments, towns.

  This sector is meant to be filled with data at single asset level.

- LIFELINES: critical infrastructures with particular attention to telecommunication, power and transportation.

  This sector is meant to be filled with data at single asset level for direct and second order damages, municipal and regional levels for long term damages.

- NATURAL SYSTEMS: natural parks, protected reserves, ecosystems, etc.

  This sector is meant to be filled with data at single asset level.

- HAZARD CHARACTERISTICS AND ACTORS

- PREVENTION-EMERGENCY-RESILIENCE

Post-disaster appraisal

PEOPLE

		number of people					
Direct damage	Deaths						
	Missing						
	Injured, sick						
	Affected						
	Homeless						
Second order damage	Evacuated						
	Displaced						
	Relocated						
Long term damage	People which abandoned their house permanently						

RESIDENTIAL

		typology of the building (single-family, condominium, townhouse, multi-family home, etc.)	location of the building (coordinates or municipality)	number of stores out of the ground level	volume of the building (m^3)	Presence of a basement (y/n)	is the building located in a flooding zone (PPRI)? (y/n)
Direct damage	Description of the damaged building						
		general description of the damage	Total cost of the recontruction (€)	Insured reconstruction cost (€)			
	Physical damage to buildings (e.g. the roof collapsed but the main walls are still standing)						
	Physical damage to content						
	Duration of the not availability in using the building due to degradation (days)						
	Physical damage to private vehicles (€)						
	Height of the water (m)						
	Duration of the submertion (hours)						
Second order damage	Value of the building before the event (€)						
	Value of the building after the event (€)						
Long term damage	Number of abandoned house						
Other information	Type of urban area						

PUBLIC FACILITIES

STRATEGIC SERVICES

		service typology (police station, fireman, municipality, health facility, educational facilities, etc.)	location fo the damaged facility (address)				
Direct damage	Strategic facilities						
	Redundancy (number of facilities with the same type of service in a radius of 5 km)						
		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
	Physical damage to buildings						
	Physical damage to equipment/vehicles						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Service interruption						
		municipality level (days, €)	Regional level (days, €)				
Long term damage	Loss of services						
Other information	Type of urban area (A,B,C...) (table at the right)						

NEIGHBORHOOD SERVICES

		service typology (police station, fireman, municipality, medical facility...)	location of the damaged facility (coordinates)				
Direct damage	Strategic facilities						
	Redundancy (number of facilities with the same type of service in a radius of 5 km)						
		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
	Physical damage to buildings						
	Physical damage to equipment						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Service interruption						
		municipality level (days, €)	Regional level (days, €)				
Long term damage	Loss of services						
Other information	Type of urban area (A,B,C...) (table at the right)						

CULTURAL HERITAGE

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to buildings						
	Physical damage to content						
Second order damage	Loss of intangible values						
		economical losses due to partial or total closure (€)	costs due to the measures for limiting or preventing damages (€)				
	Used restrictions						
Long term damage	Permanent loss of intangible values						
Other information	Type of urban area						

LIFELINES

POWER

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services (local, regional)						

TELECOMMUNICATION

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services (local, regional)						

WATER

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services						

TRASPORTATION

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)						
		type of transportation infrastructure (road, rails, airport..)	involved transportation infrastructures for networks (roads, rails, ...) (Km) and municipality involved. Coordinates for localised damages (airports...).	Total cost of the reconstruction (€)	Insured reconstruction cost (€)		
	Physical damage to networks (damage to critical infrastructure attributed to disasters)						
	Physical damage to operating systems						
		considered municipality	number of vehicles damaged in that municipality				
	Physical damage to vehicles						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		municipality level (days)	regional level (days)				
Long term damage	Prolongued loss of services						

ECONOMIC ACTIVITIES

AGRICOLTURE SECTOR

	(Agriculture is understood to include the crops, livestock, fisheries, apiculture, aquaculture and forest sectors as well as associated facilities and infrastructure)	general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to soil						
	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to infrastructures						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs (number of people)						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

INDUSTRIAL SECTOR

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to infrastructures						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
		y/n	location of the leakage (coordinates)	affected soil area (m^2)			
	Leakage of dangerous materials						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
	Loss of production in terms of non-produced items respect with the production of the average of the pervious years in the same period						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

COMMERCIAL SECTOR

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to the stockage						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
	Direct economic loss in the housing sector attributed to disasters (€)						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
	Loss of stokage products (number of items)						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

NATURAL SYSTEMS

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n for localised damage, percentage for spare damage)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to ecosystems						
Second order damage	Loss of biodiversity						
Long term damage	Loss of biodiversity						

HAZARD

HAZARD	Nature (flood, earthquake, landslide, etc.)	
	more details about the hazard's nature (e.g. runoff flood)	
	Has it been induced by another hazard? Specify which one	
	Kinetics (mean speed of the water, velocity of propagation of the flood) (m/s)	
	Has the territory been exposed to similar disasters (same hazard) in the past?	
	Has the territory been exposed to other disasters (different hazard) in the past?	
PERIMETER OF THE DISASTER	Regions involved	
	Departments involved	
	Municipalities involved	

ACTORS

Main actors that declare and store data	
State services	
Insurance	
Societies/NGO	
Research organizations	
Public organizations	
Private organizations	
Other actors	

PREVENTION - EMERGENCY - RESILIENCE

		Description	Cost (€)	Efficiency
PREVENTIVE PLANS AND MEASURES	Technical measures (structural measures			
	Organizational measures (non-structural measures)			
	human measures (in situ measures)			
EMERGENCY MANAGEME NT PLANS AND MEASURES	Technical measures			
	Organizational measures			
	human measures			
RESILIENCE PLANS AND MEASURES	Technical measures			
	Organizational measures			
	Human measures			

Disaster appraisal few years later

		number of people					
	Deaths						
	Missing						
	Injured, sick						
	Affected						
	Homeless						
	Evacuated						
	Displaced						
	Relocated						
	People which abandoned their house permanently						

		typology of the building (single-family, condominium, townhouse, multi-family home, etc.)	location of the building (coordinates or municipality)	number of stores out of the ground level	volume of the building (m^3)	Presence of a basement (y/n)	is the building located in a flooding zone (PPRI)? (y/n)
	Description of the damaged building						
		general description of the damage	Total cost of the recontruction (€)	Insured reconstruction cost (€)			
	Physical damage to buildings						
	Physical damage to content						
	Duration of the not availability in using the building due to degradation (days)						
	Physical damage to private vehicles (€)						
	Height of the water (m)						
	Duration of the submertion (hours)						
	Value of the building before the event (€)						
	Value of the building after the event (€)						
	Number of abandoned house						
	Type of urban area						

		service typology (police station, fireman, municipality, health facility, educational facilities, etc.)	location of the damaged facility (address)				
Direct damage	Strategic facilities						
	Redundancy (number of facilities with the same type of service in a radius of 5 km)						
		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
	Physical damage to buildings						
	Physical damage to equipment/vehicles						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Service interruption						
		municipality level (days, €)	Regional level (days, €)				
Long term damage	Loss of services						
Other information	Type of urban area (A,B,C...) (table at the right)						

		service typology (police station, fireman, municipality, medical facility...)	location fo the damaged facility (coordinates)				
Direct damage	Strategic facilities						
	Redundancy (number of facilities with the same type of service in a radius of 5 km)						
		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
	Physical damage to buildings						
	Physical damage to equipment						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Service interruption						
		municipality level (days, €)	Regional level (days, €)				
Long term damage	Loss of services						
Other information	Type of urban area (A,B,C...) (table at the right)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to buildings						
	Physical damage to content						
Second order damage	Loss of intangible values						
		economical losses due to partial or total closure (€)	costs due to the measures for limiting or preventing damages (€)				
	Used restrictions						
Long term damage	Permanent loss of intangible values						
Other information	Type of urban area						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services (local, regional)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services (local, regional)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to networks						
	Physical damage to operating systems						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		local level (days)	regional level (days)				
Long term damage	Prolongued loss of services						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the reconstruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)						
		type of transportation infrastructure (road, rails, airport..)	involved transportation infrastructures for networks (roads, rails, ...) (Km) and municipality involved. Coordinates for localised damages (airports...).	Total cost of the reconstruction (€)	Insured reconstruction cost (€)		
	Physical damage to networks (damage to critical infrastructure attributed to disasters)						
	Physical damage to operating systems						
		considered municipality	number of vehicles damaged in that municipality				
	Physical damage to vehicles						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Functional and systemic failures						
	Service interruption						
		municipality level (days)	regional level (days)				
Long term damage	Prolongued loss of services						

	(Agriculture is understood to include the crops, livestock, fisheries, apiculture, aquaculture and forest sectors as well as associated facilities and infrastructure)	general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to soil						
	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to infrastructures						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs (number of people)						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to infrastructures						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
		y/n	location of the leakage (coordinates)	affected soil area (m^2)			
	Leakage of dangerous materials						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
	Loss of production in terms of non-produced items respect with the production of the average of the pervious years in the same period						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to plants						
	Physical damage to equipment						
	Physical damage to machinery						
	Physical damage to the stockage						
	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters (€)						
	Direct economic loss in the housing sector attributed to disasters (€)						
		general description of the damage	loss due to the failure/interruption (€)	Insured loss (€)	duration of the interruption (hours/permanent)		
Second order damage	Business interruption						
		permanent loss of jobs (number of people)	temporary loss of jobs (number of people)				
	Loss of jobs						
	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period						
	Loss of stokage products (number of items)						
		municipality level	regional level				
Long term damage	Declining trend (preassessment of the losses 5 years from here) (€, %)						
Other information	Type of urban area (A, B, C...)						

		general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	Total cost of the recontruction (€)	Insured reconstruction cost (€)	is the damage located in a flooding zone (PPRI)? (y/n for localised damage, percentage for spare damage)	Presence of a prevention plan (y/n)
Direct damage	Physical damage to ecosystems						
Second order damage	Loss of biodiversity						
Long term damage	Loss of biodiversity						

Nature (flood, earthquake, landslide, etc.)	
more details about the hazard's nature (e.g. runoff flood)	
Has it been induced by another hazard? Specify which one	
Kinetics (mean speed of the water, velocity of propagation of the flood) (m/s)	
Has the territory been exposed to similar disasters (same hazard) in the past?	
Has the territory been exposed to other disasters (different hazard) in the past?	
Regions involved	
Departments involved	
Municipalities involved	

Main actors that declare and store data	
State services	
Insurance	
Societies/NGO	
Research organizations	
Public organizations	
Private organizations	
Other actors	

	Description	Cost (€)	Efficiency
Technical measures (structural measures			
Organizational measures (non-structural measures)			
human measures (in situ measures)			
Technical measures			
Organizational measures			
human measures			
Technical measures			
Organizational measures			
Human measures			

5 PACA flood in 2015

5.1 Description of the event

During the night between the 3rd and the 4th of October 2015 a flood devastated a large part of the Maritime Alps and Var regions (Figure 12 and Figure 13). This event brought to 1166 recognitions of CatNat (natural catastrophe state) distributed over 1005 municipalities.

Figure 13 (Provence-Alpes-Côte d'Azur) region

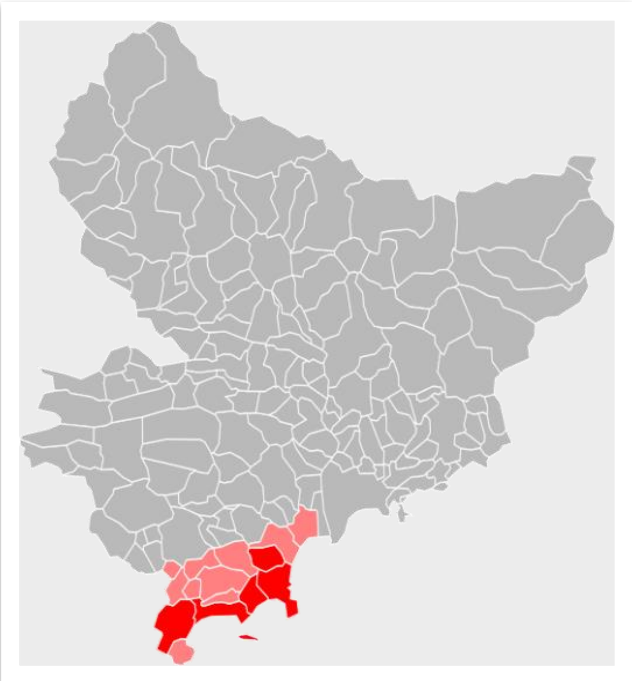


Figure 12 The most affected municipalities in Maritime Alps:

flooded municipalities

municipalities with fatalities

An extraordinary rainfall event (Table 3 and Figure 14) caused a fast rising of the waterways level and a significant runoff flow. This combination, aggravated by the steep morphology of the region, led consequently a high cost in terms of direct, indirect damages and life losses. The official reported number of fatalities is 20, so it represents one of the deadliest floods of the last 30 years in France. The abundant runoff flow seems to be a direct consequence of both the increasing urbanization of the area and a

	TOTAL [mm]	IN 2 HOURS [mm]	IN 1 HOUR [mm]
Cannes	196	175	106
Mandelieu-la-Napoule	159	152	99
Antibes	128	109	74
Nice Cote-d'Azur	109	89	74
Valbonne Sophia Antipolis	107	97	50
Chateauneuf-Grasse	90	86	74

Table 3 Pluviometric measures: 3th of October (Source: Keraunos, Observatoire français des tornades et orages violents

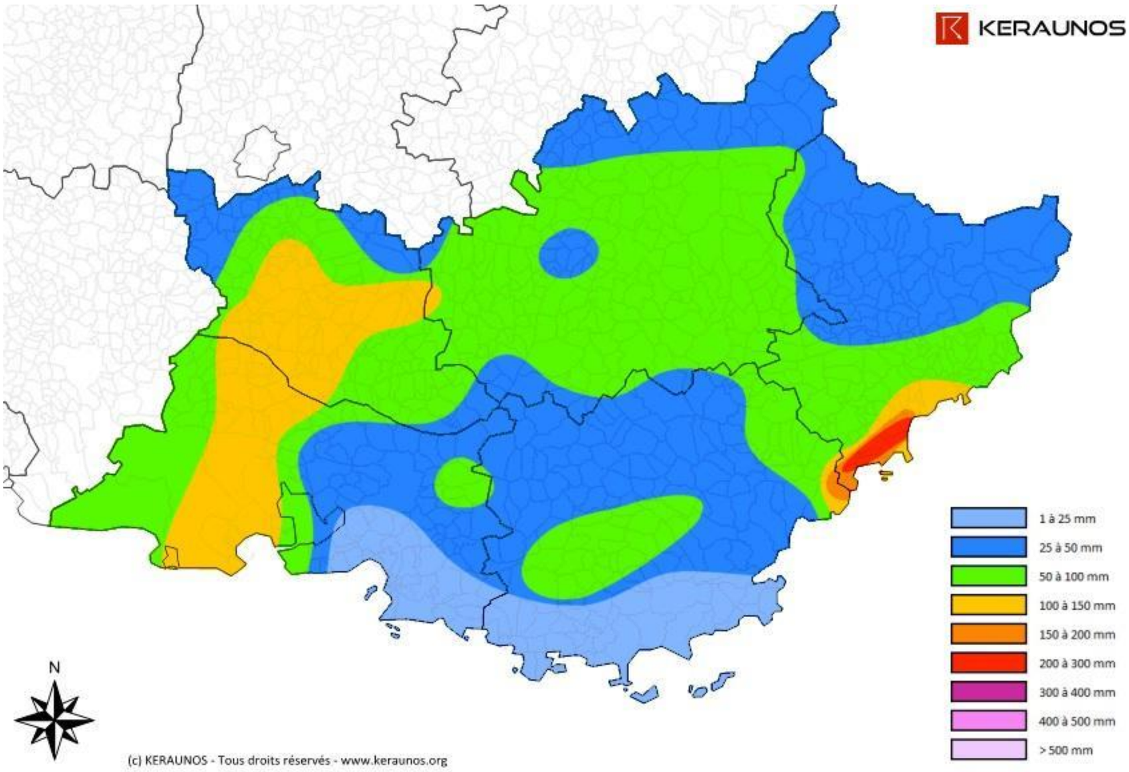


Figure 14 Cumulated rain in 24 h the 3rd October 2015 in PACA region

drizzle in the days before the major event that saturated the soil.

5.2 Affected area

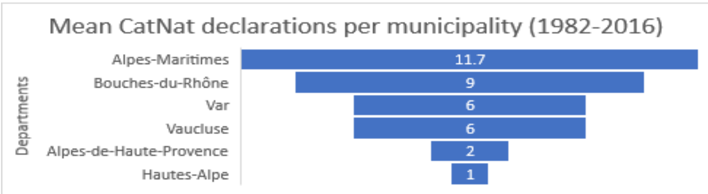
The heavy rains concerned a large part of PACA region, but the concentration of the damages occurred in the coastal municipalities such as: Cannes, Vallauris, Biot, Mandelieu-la-Napoule and Antibes.

In terms of regions, the four most affected (81% of the total CatNat declarations) were: Occitaine, Auvergne-Rhone-Alpes, Corse, Provence-Alpes-Cote d'Azur.

5.3 Historical events

The PACA region has a long experience with floods. In particular, the most affected area in October 2015 appears to be the same most affected zone from 1982 (Table 4), both in terms of number of CatNat declarations (Figure 15) and amount of cumulated damage (Figure 16) (Insee, October 2018).

Table 4 Mean CatNat declarations per municipality (1982-2016). Extracted from DREAL with CCR and ONRN (Insee, October 2018)



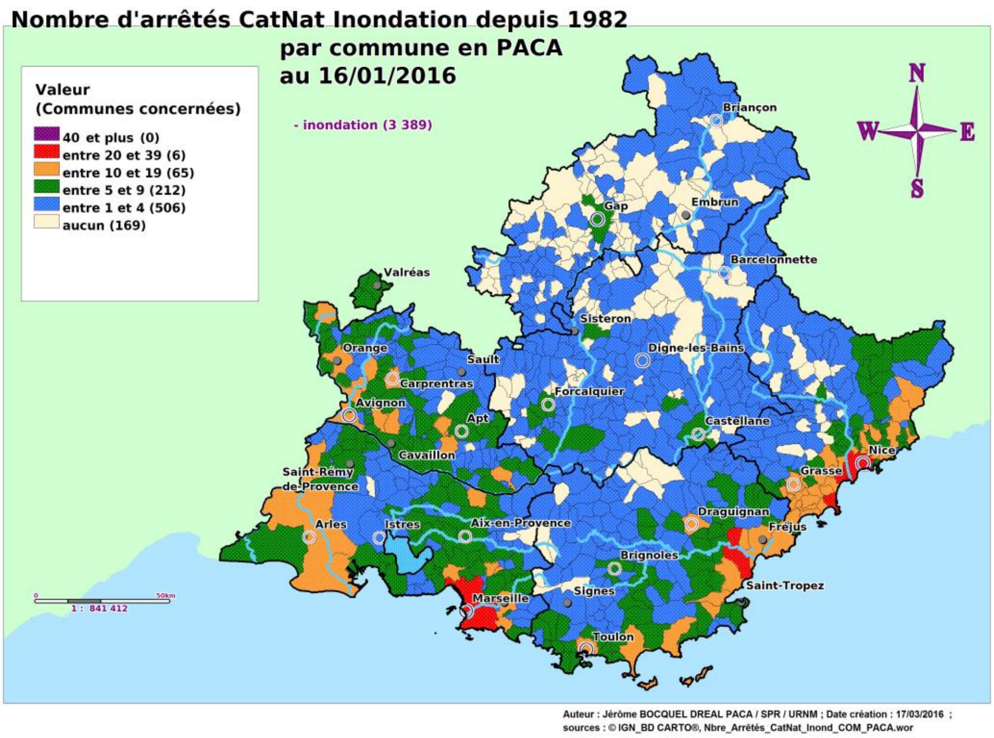


Figure 15 CatNat flood declarations from 1982 per municipality in PACA in 16/01/2016 (Insee, October 2018)

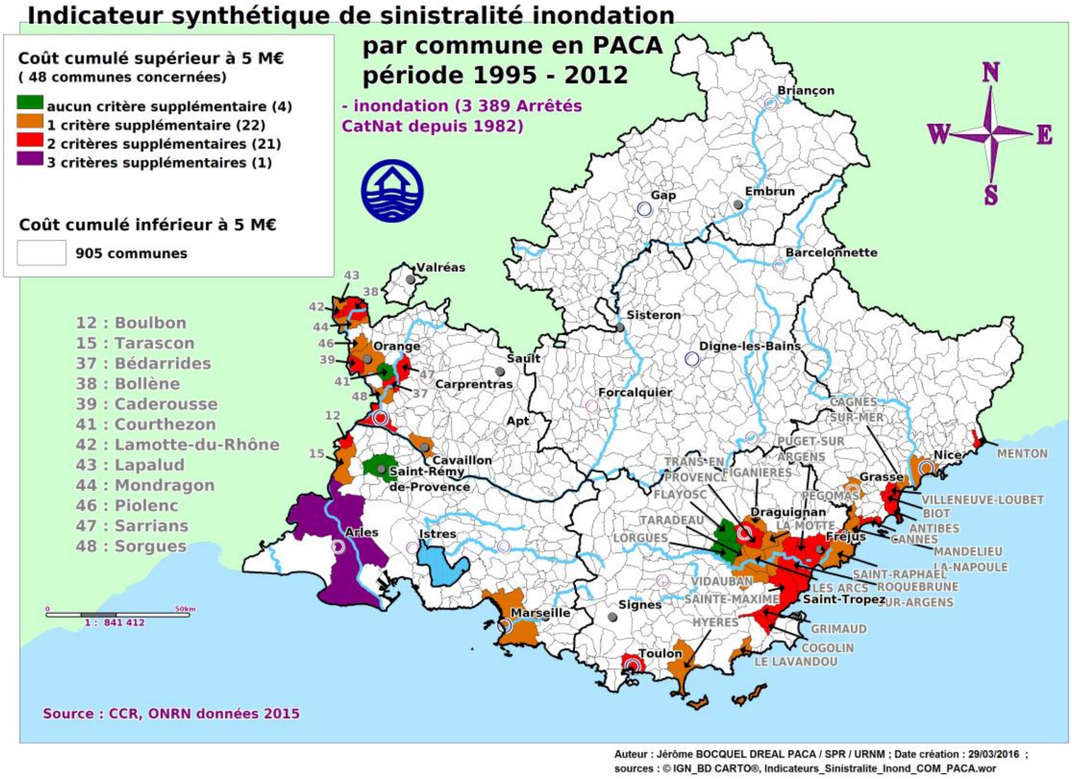


Figure 16 Indicators for flood damages per municipality in PACA in the period 1995-2012 (Insee, October 2018)

Considering only the coastal area in the last 30 years, the most relevant events are listed below.

DATE	AFFECTED AREA
03/10/1988	Nimes
05/11/1994	Low valley of Var, d'Allos à Annot, Nice
02/12/2005	Many municipalities of the department but mainly Nice
15/06/2010	Var centre between the Luc and Draguignan rivers, low valley of Argens river
2/11/2011 – 9/11/2011	Var + Maritime-Alps departments
17/09/2014 – 30/11/2014	Var, Argens, La Môle, l'Aille in the sector of Vidauban and the Narturby au Muy
03/10/2015	PACA region

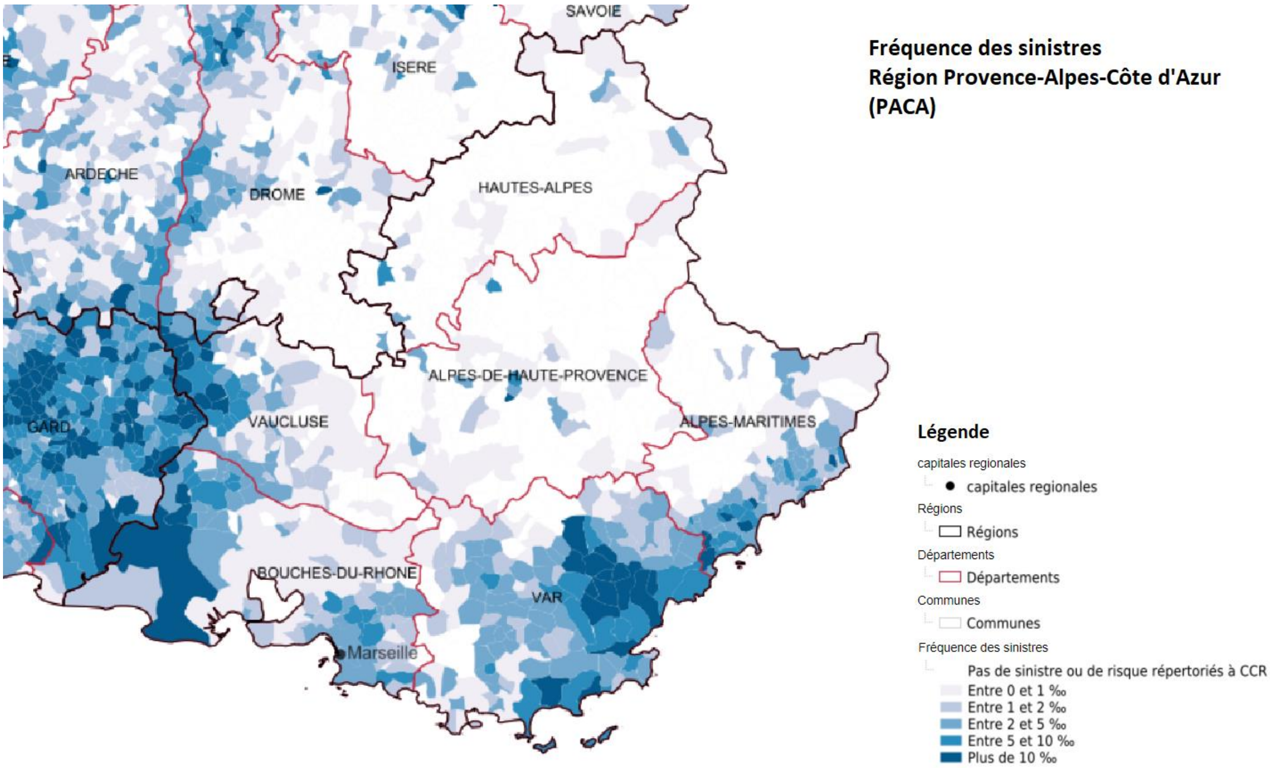


Figure 17 Frequency of damages in PACA region (Insee, October 2018)

As we can notice, the frequency of catastrophic events due to flooding in the area is high (Figure 17) and analysing the case of 2015, we can see how the damages are still huge.

5.4 Damages investigation

The flood of October 2015 is one of the most expensive events in terms of damages in the history of France as shown in Figure 18.

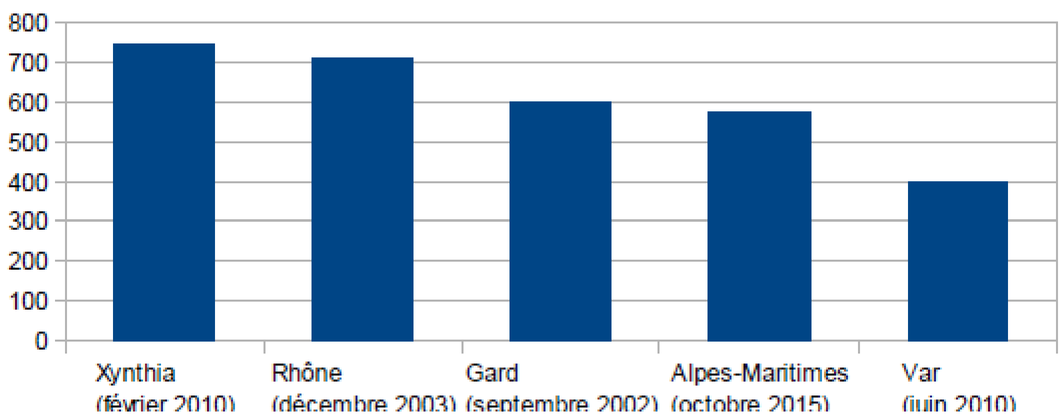


Figure 18 Intensity of total damages for the most catastrophic events in France (Insee, October 2018)

TOTAL DAMAGE ESTIMATED COST

Total damages estimated cost: 550 - 650 million euros for every type of ensured damage. Insurances received in total more than 60 000 claims, where the 60% is referred to private houses, 27% to vehicles and 13% to commercial activities (estimations of April 2016) (Figure 19). The amount of estimated cost for non-insurable direct and indirect damages is 130 million euros and for only the public domain (buildings, canals, highways) is 40 million euros (Prefect des Alpes-Maritime, May 2016).

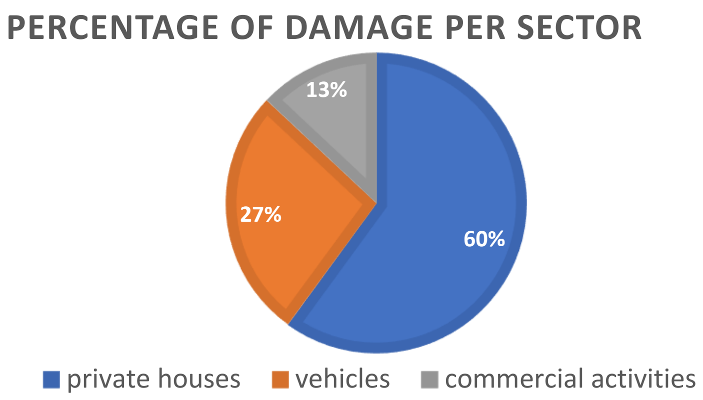


Figure 19 Scheme of the percentage of the total damage referred to each main sector (extracted from Prefect des Alpes-Maritime, May 2016)

AFFECTED PEOPLE

Victims: 20 (Prefect des Alpes-Maritime, May 2016)

- Antibes municipality: 1 fatality in pylône camping.
- Biot municipality: 3 fatalities in a retirement home.
- Cannes municipality: 3 fatalities (1 found on the beach, 1 in a souterrain parking, 1 in a basement).
- Cannet municipality: 1 fatality (Carimaï hamlet).
- Mandelieu municipality: 8 fatalities in the souterrain parking of 2 buildings (Riou de l'Argentière).
- Mougins municipality: 1 fatality in the car stuck under a bridge, the victim came out from his car and was taken by the flow.
- Vallauris municipality: 3 fatalities in cars in Golfe-Juan station.

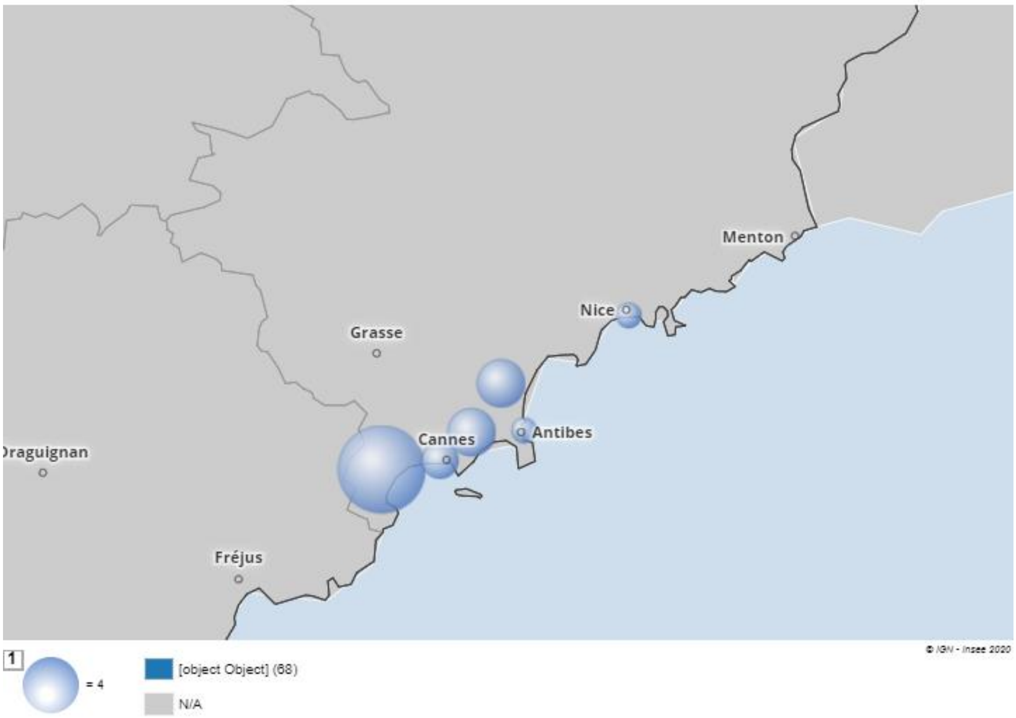


Figure 20 Deaths in 2015 flood (Merad, et al.)

<u>Displaced/evacuated:</u> 1200 people replaced from the most affected municipalities (Prefect des Alpes-Maritime, May 2016).

Table 5 Affected people. Extracted from (Prefect des Alpes-Maritime, May 2016)

			number of people
PEOPLE	Direct damage	Deaths	20
	Second order damage	Evacuated	1200
		Displaced	1200

RESIDENTIAL BUILDINGS

Table 6 Affected residential buildings. Extracted from (Prefect des Alpes-Maritime, May 2016)

			Number of flooded houses	Location of the building (coordinates or communes)	Total cost of the reconstruction (€)
RESIDENTIAL	Direct damage	Description of the damaged building	7000	Alpes-Maritime	60% of the total reconstruction cost

LIFELINES

Table 7 Transportation damages. Extracted from (Prefect des Alpes-Maritime, May 2016)

TRANSPORTATION	Direct damage		Type of transportation infrastructure (road, rails, airport…)	Involved transportation infrastructures for networks (roads, rails, ...) (Km) and communes involved. Coordinates for localised damages (airports...).	
		Physical damage to networks (damage to critical infrastructure attributed to disasters)	8 departmental roads blocked for some hours	Var Prefecture	
			considered municipality	number of vehicles damaged in that municipality	Total damage cost (€)
		Physical damage to vehicles	Alpes-Maritime	8000	30% of the total reconstruction cost
			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)	
	Second order damage	Service interruption	Interruption of the train and plane traffic for one day	Alpes-Maritime	

Table 8 Telecommunication damages. Extracted from (Prefect des Alpes-Maritime, May 2016)

TELECOMMUNICATION			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	40.000 fix lines and 33 mobile phones have been affected	Alpes-Maritime

Table 9 Power damages. Extracted from (Prefect des Alpes-Maritime, May 2016)

POWER			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
	Direct damage	Physical damage to plants	70.000 houses without electricity at the peak of the crisis	Alpes-Maritime

Table 10 Water infrastructure damages. Extracted from (Prefect des Alpes-Maritime, May 2016)

			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
WATER	Direct damage	Physical damage to plants	The rain collector network has been highly damaged due to the transport of soil and debris	Alpes-Maritime

ECONOMIC ACTIVITIES

Table 11 Commercial sector damages. Extracted from (Prefect des Alpes-Maritime, May 2016)

			General description of the damage	Location of the damage (coordinates for localised damages, extension (m^2) and communes for spared damages)	Total cost of the reconstruction (€)
COMMERCIAL SECTOR	Direct damage	Physical damage to plants	1000 reportedly damaged companies	Alpes-Maritime	10% of the total reconstruction cost
			90% of the technical installations were devastated with many animals' lives losses or disappearance	Marineland park (in Antibes)	

5.5 Main causes of damage

DIRECT CAUSES OF DAMAGES

- Extraordinary rainfall event. Large quantity of water not only from the river overflow but also from the runoff due to the heavy rainfall itself.
- Steep morphology of the region, which increases the runoff speed concentrating the flow in certain parts of the town.
- The increasing urbanization of the area, which increases the runoff speed and the runoff flow.
- A drizzle in the days before the major event that saturated the soil (Keraunos, 2015). The only few permeable areas of the city (green areas), due to saturation of the soil, were not able to hold the heavy rainfall becoming the equivalent of an impermeable soil, contributing to the runoff intensity.
- Obstructions in correspondence of bridges due to sediments and debris transported by the river. This phenomenon can have as a consequences the flooding of the area upstream the bridges and at the same time affect the

bridge’s stability, causing in case of a sudden collapse of it, a devastating water wave (dam break).

INDIRECT CAUSES OF DAMAGES

- Bad land planning, with many constructions in flooding areas. Having a look to the PPRI of the involved municipalities we can see that in all red (high risk), orange (medium risk) and yellow zones (low risk) buildings are present (Figure 21 and Figure 22 show PPRI of Cannes). It means that a lack of strategic urbanization, planned without a study of the present hazard such as flood, has been perpetrated over the years.

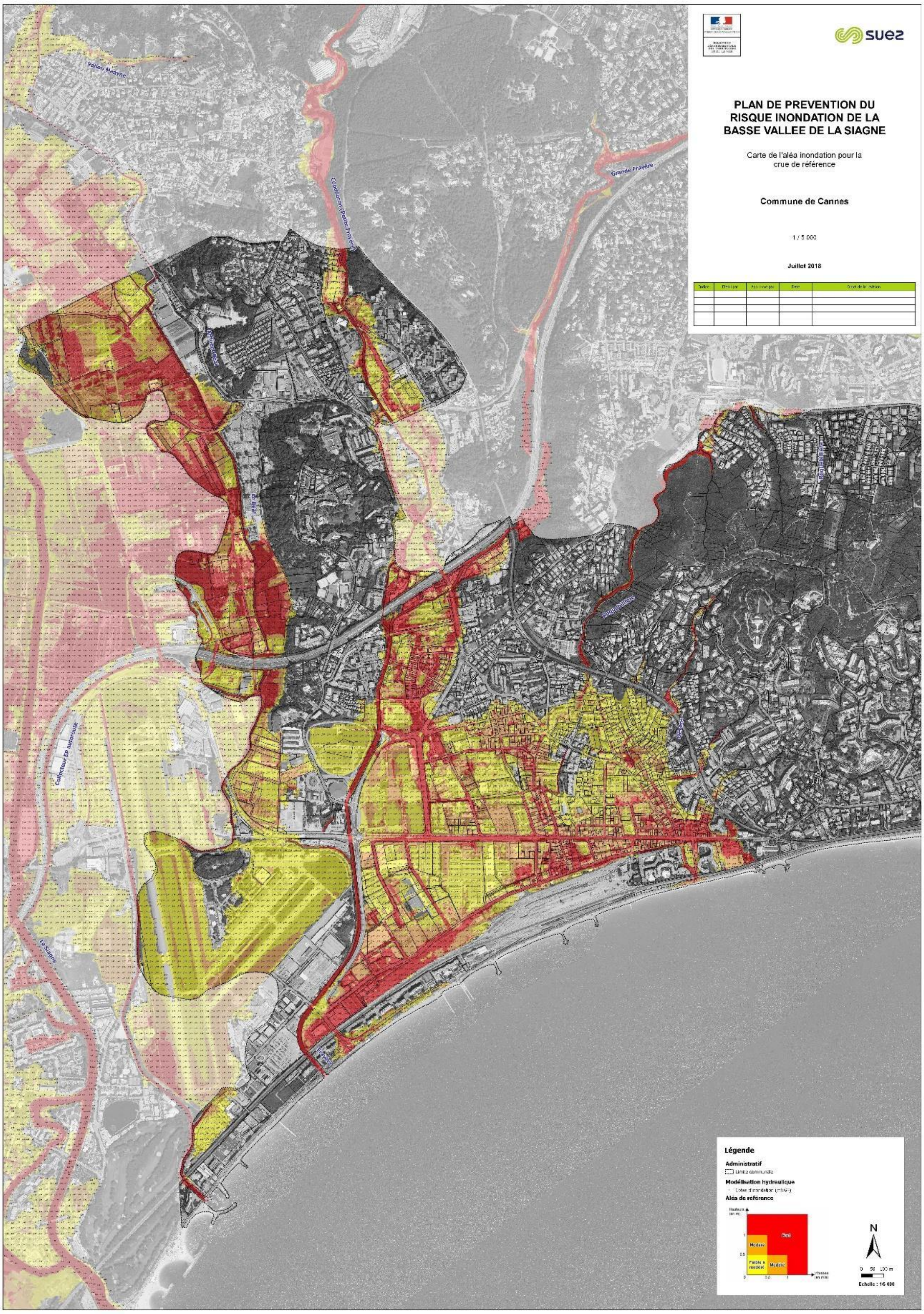


Figure 21 PPRI Cannes - west zone (Source: https://www.alpes-maritimes.gouv.fr/Politiques-publiques/Environnement-risques-naturels-et-technologiques/Les-risques-naturels-et-technologiques/Les-projets-de-plans-de-prevention-des-risques-PPR/Cannes/PPR-inondations)

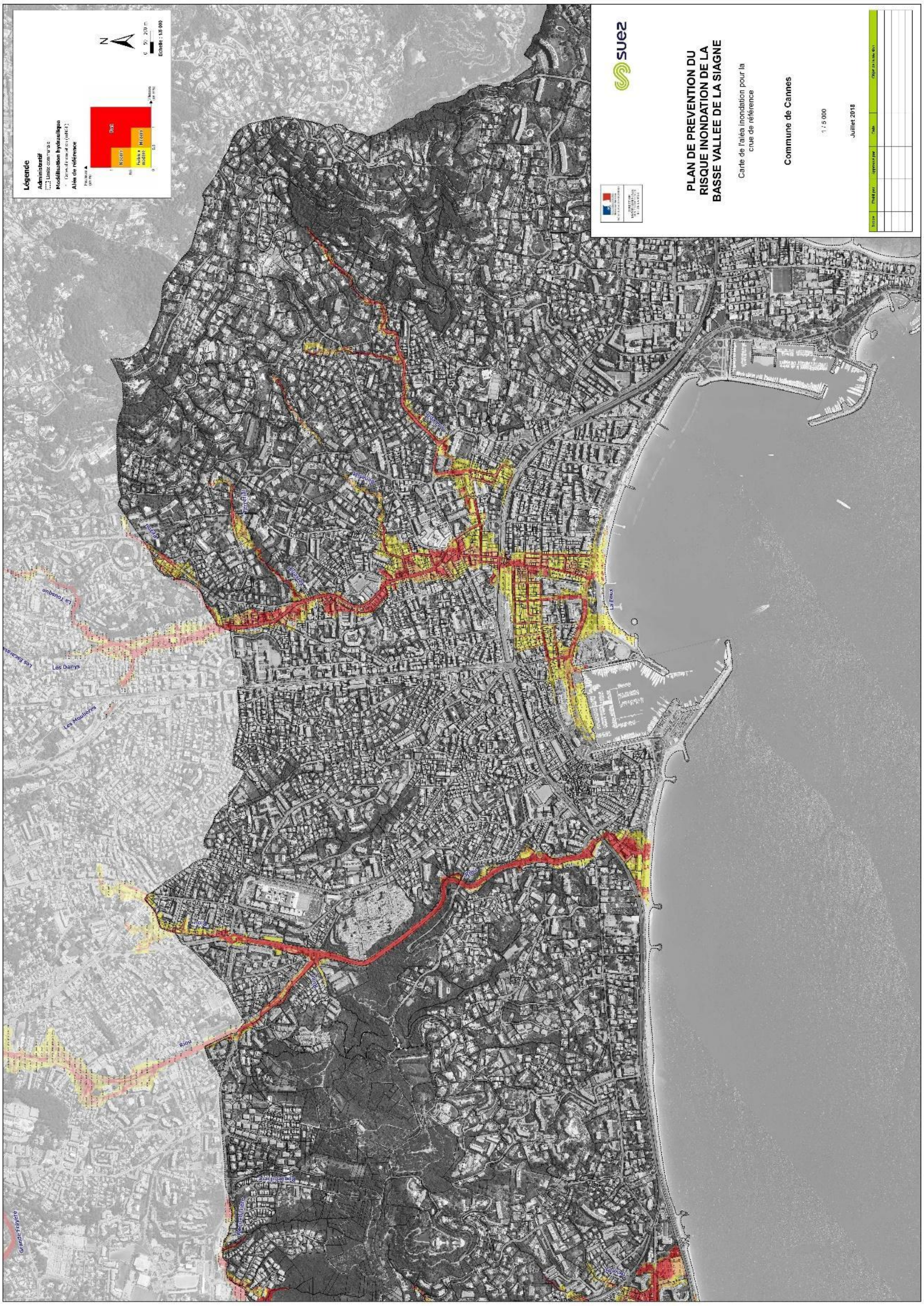


Figure 22 PPRI Cannes - central zone (Source : https://www.alpes-maritimes.gouv.fr/Politiques-publiques/Environnement-risques-naturels-et-technologiques/Les-risques-naturels-et-technologiques/Les-projets-de-plans-de-prevention-des-risques-PPR/Cannes/PPR-inondations)

- Absence of adequate Prevention Plans. As we can see in Figure 23, the PPRI progress in October 2015 in Alpes Maritimes shows a situation where the majority of the municipalities in Alps Maritimes region lack of a PPRI.

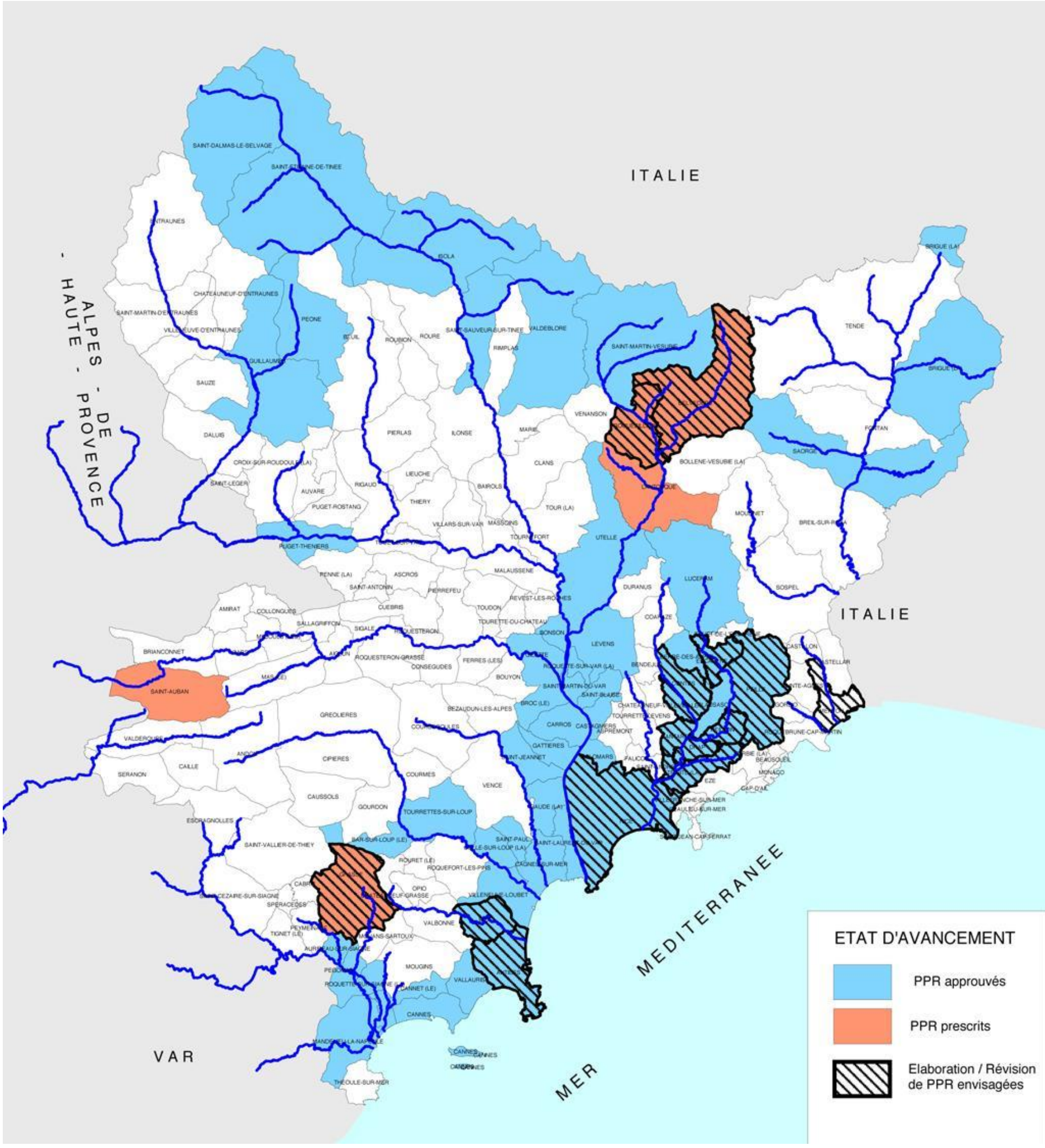


Figure 23 PPRI situation in October 2015 in Alpes Maritimes department

- Inadequate warning system which put both rescuers and citizens in the condition to have a shortened time (a few hours) to organize and move out from the flooded areas (Prefect des Alpes-Maritime, May 2016).

- Inadequate emergency calls for help system (the maximum amount of possible simultaneous calls was 20) (Prefect des Alpes-Maritime, May 2016).

- Inadequate acknowledgement of the population on the warning system (colours codes) and on the right behaviour during the crisis (Prefect des Alpes-Maritime, May 2016).

- Actual incapacity of models to forecast the rain quantities in certain configurations (Prefect des Alpes-Maritime, May 2016). In fact, this catastrophe occurred as a consequence of a particular meteorological event: combination of cold wind coming from north-west and the warm winds convergence from the sea (Figure 24). This gap in temperature caused a difference in atmospheric pressure that caused the fast formation of rainy clouds and the consequent heavy rainfall. This phenomenon happens fast and with the nowadays technology is still hard to forecast considerably in advance.

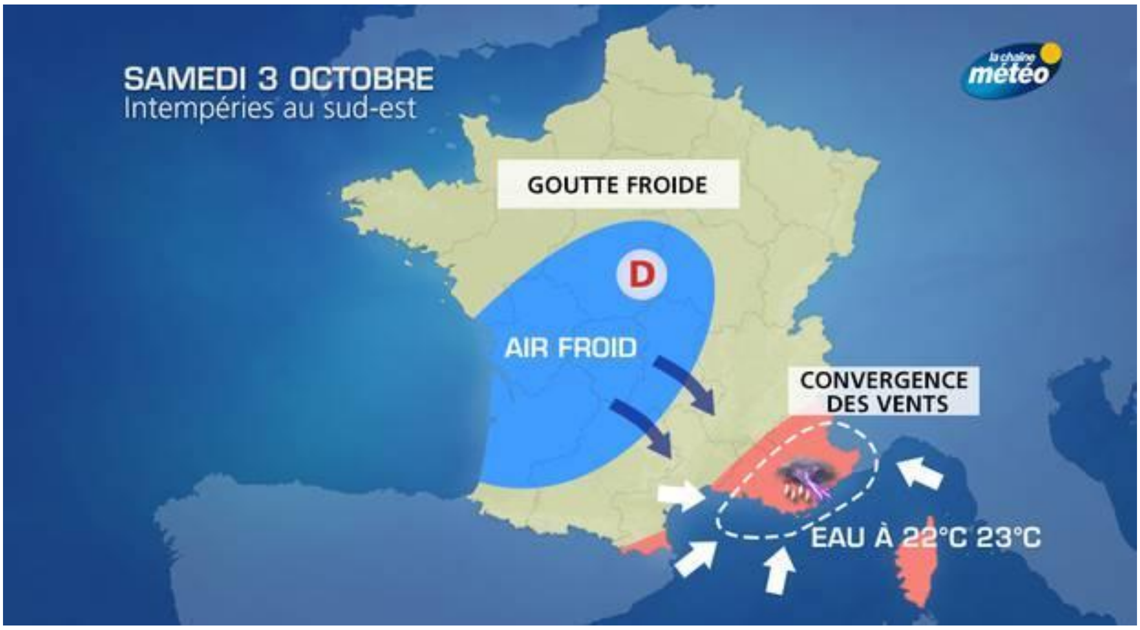


Figure 24 Meteorological scheme of the events anticipating the disaster

- Weak operational connection among vigilance and operational teams at Prefecture and municipalities level (Prefect des Alpes-Maritime, May 2016).

- Absence or shortage of roads cartography (Prefect des Alpes-Maritime, May 2016).

5.5 Main references

MAIN OFFICIAL/SCIENTIFIC DOCUMENTS AND REPORTS

Prefect des Alpes-Maritime. (4th May 2016). ***« Inondations des 3 et 4 Octobre 2015 dans les Alpes-Maritimes. Retour d'expérience. Rapport final. »***

The *retour d'experience* (return on operating experience (REX)) is an official document made by the Prefect in case of a particular event. In this case, REX collects all the data that are shared with the population about the cause, the evolution and the consequences of the flooding. The creation steps are shown in Figure 25.

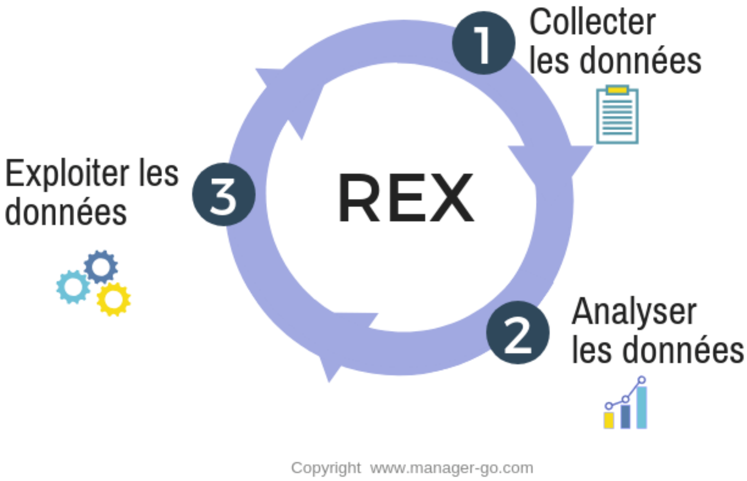


Figure 25 Creation steps for a REX: (i) Data collection, (ii) Data analysis, (iii) Data management

Insee. (October 2018). *« Un million d'habitants vivent en zone inondable »*

INSEE was created by the Budget Law of 27 April 1946. It is a Directorate-General of the Ministries for the Economy and for Finances and is located in offices throughout the French territory (Insee, 2019). They share statistics and data extrapolations.

Groupe interdisciplinaire de réflexion sur les traversées sud-Alpines et l'aménagement du territoire maralpin (GIR Maralpin). (18th October 2015). *« Les inondations azuréennes catastrophiques du 3 octobre 2015. Quelques clés de lecture »*

GIR Maralpin was born in 1996, with the goal of gathering professors, researchers, and experts, French and foreigners, from many branches of knowledge, and to deeply analyse the land planning and management.

Keraunos. *« Orage diluvien exceptionnel sur la Côte-d'Azur le 3 octobre »*
Keraunos (or Observatoire Français des Tornades et des Orages Violents) is the first french research unit specialized in risks forecast and management connected with storms.

Pîerre Carrega. (9th October 2015) *« Les inondations azuréennes du 3 octobre 2015 : une catastrophe annoncée ? Premières considérations »*.
Pîerre Carrega. (January- March 2016) *« Les inondations azuréennes du 3 octobre 2015 : un lourd bilan lié à un risque composite ».*
Pîerre Carrega is a full professor at University of Nice Sophia Antipolis and is part of the lab ESPACE (Étude des Structures et des Processus d’Adaptation et des Changements de l’Espace), which is a mixed research unit (UMR 7300) made in 1997. It was born from a collaboration of CNRS and three universities of the Provence-Alpes-Côte-d’Azur region: Aix-Marseille University, Avignon University and University of Côte d’Azur (ESPACE Laboratoire de recherche, 1997).

NEWSPAPERS

Newspapers from local to national level talked about the disaster in Alpes-Maritimes, with different level of detail and providing very different data. The main analysed journals are: Ouest-France, Le Monde, Le Parisien, Reuters, Rue89, AFP, La Gazette, News Press, La Tribune, Le moniteur, L’Humanité, Local Cannes, Local Nice, L’Indipèndant, Nice-Matin.

Actors which made declarations in the news about the flood:

- *About the flood crisis management*: François Hollande, RSI Cote d'Azur, le Conseil Départemental, the State on behalf of Fonds d'Aide au Relogement d'Urgence (FARU), the Ministerial Decree, Council of ministers, les Services de la

Ville, Directorate General of Social Cohesion, Franck Chikli (deputy with the mayor of Cannes), Jean-Clause Babize (President of RSI Cote d'Azur), Michel Ribero (vice-president of RSI Cote d'Azur), Chamber of Commerce and Industry, Chamber of Trade and Crafts, Chamber of Agriculture, Territorial Unit of Regional Directorate of companies, of consumptions, of work and employment, Communauté d'Agglomération de Sophia-Antipolis, Eric Ciotti (the department's boss), Centre National pour le Développement du Sport (CNDS), the Water Agency (l'Agence de l'Eau), Cabinet Mayane.

- *About the damages*: President of the Departmental Council of Alpes-Maritimes Éric Ciotti, mayor of Cannes David Lisnard, President of the French Insurance Association Bernard Spitz, Var Prefecture, Covéa Insurance, Franck Chikli (deputy with the mayor of Cannes), Jean-Clause Babize (President of RSI Cote d'Azur), Michel Ribero (vice-president of RSI Cote d'Azur), Territorial Unit of Regional Directorate of companies, of consumptions, of work and employment, Departmental Directorate of Territories and Sea.

5.6 Prevention measures applied after the event of October 2015

- Works on the Font de Gallou which will last 7 months over 100 metres between the highway and the bridge: realisation of a hydraulic model and stabilization of riversides. The aim is to reduce the risk of obstructions (Varitto, 2018).
- The Roubine and Frayère dams in Cannes are being rehabilitated. Seals reworked, waterproofing renovated, cracking indicators installed, and damaged structures repaired. Realised by the SMIAGE and co-financed by the *Communauté d'Agglomération des Pays de Lérins* (90%) and the *Conseil Général* (10%) (Burlot, 2019).
- 9 new projects in PAPI 2 (e.g. construction of a retention basin in Biot) (M.-C. A., 2019).
- Improvement of the alert system. It makes group calls related to 12 lists. It became a free service with 1400 numbers (Dasque, 2018).

- Distribution of 2000 flyers in the riskiest areas of the municipality of Nice (J.O., 2016).
- Since the 3rd October, every year, a day for the education and awareness of the population is organized, in order to develop a culture of risk (S. C., 2016).
- App #MyPredict for the estimation of risk from weather forecast and the management of flood warnings (from Cannes municipality website).
- Cannes bought a 3D cartographic tool in order to simulate, analyse and manage the crises. In addition, some satellite telephones were taken in case of interruption of the classical resources (from Cannes municipality website).
- Floodgates have been installed in 3 municipal buildings in Cannes (the municipal police post office, the mediatic-library Romain Gary and a bar (6-8 place Commandant Maria)) (from Cannes municipality website).
- 25 specialized agents in hydraulics, 46 zones and 32 works maintained by the CACPL in 5 cities, 208 km of the valley and waterways cleaned, 50 tonnes of natural and anthropogenic waste taken from the valley and waterways, 400645 m^2 of riverbanks cleaned, 3 prefectural decrees of DIG (Déclaration d'Intérêt Général) (from Cannes municipality website).
- Revision of PPRI: 3 types of zones distinguished according to the hazard (M.-C. A., 2019).

5.7 Historical background and conclusion

Analysing the history line in PACA region, we can find some correspondence in the promulgation of new legislations about flood prevention and crisis management with the different catastrophic experiences (Figure 26).

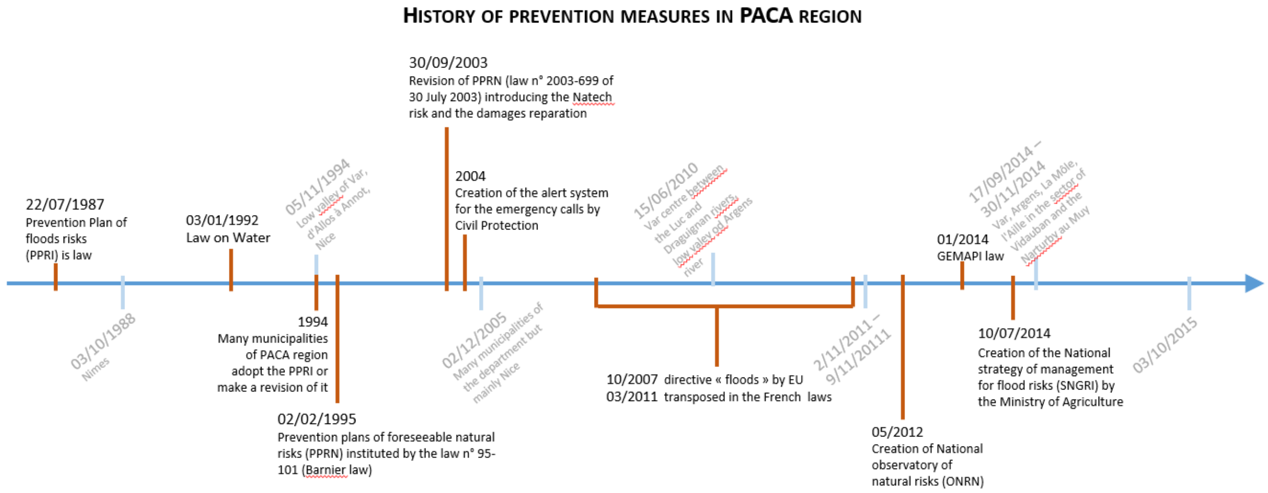


Figure 26 History of prevention measures and catastrophic floods in PACA region (Extracted from https://www.gouvernement.fr/risques/inondation)

This means that the regulation is reactive to the main challenges faced during each crisis and it adapts the legislative system in order to increase preparedness and resilience in future events.

Anyhow, even though there is a large amount of laws and documentation about risk reduction and prevention, it seems to remain distance between the prescriptions and the operative application in crisis management, prevention and post-disaster recovery and reconstruction. This could be due to several reasons and constraints such as the fragmentation of state bodies and actors involved in this field, the lack of connection between the legislative system and the operative one that impede the correct crisis management or the downward trend in public sector spent on prevention and inspection (Merad, et al.).

6 Flooding events in Seine and Lorraine basins in 2016

6.1 Description of the event

Between the 25th May and the 6th June 2016, heavy rains caused numerous floods in the north of France. As shown in Figure 27, the peak of the rain was the 30th May.

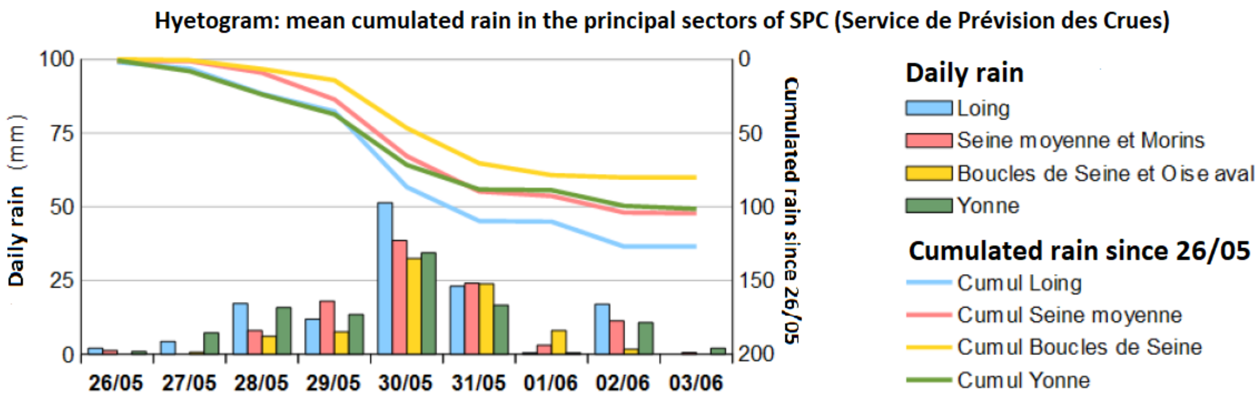


Figure 27 Hyetogram: mean cumulated rain in the principal sectors of SPC (Service de Prévision des Crues) (Direction régionale et interdépartementale de l'environnement et de l'énergie d'Île-de-France, 10/2016)

This extended-in-time event introduces a *Culture of slow flooding* (Perrin, et al., 2017), which can induce excessive confidence that corrections and repairs on the network could be made without major difficulties during the event. In this case, the crucial values are not only referred to the daily rainfall but mostly to the cumulated one.

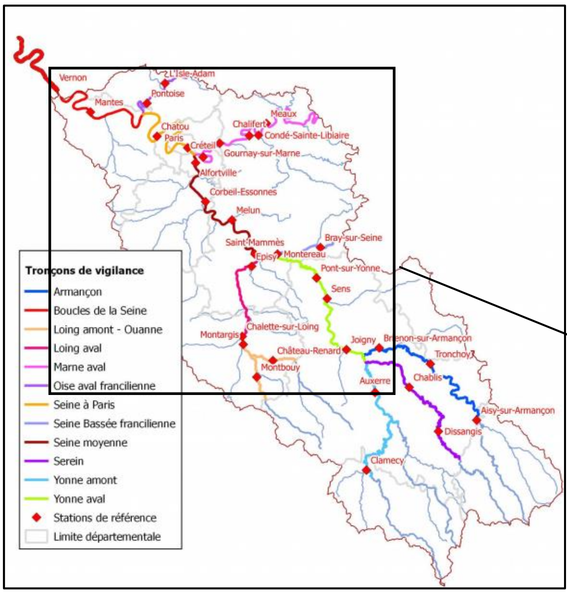


Figure 29 area interested by the heavy rainfall (Direction régionale et interdépartementale de l'environnement et de l'énergie d'Île-de-France, 10/2016)

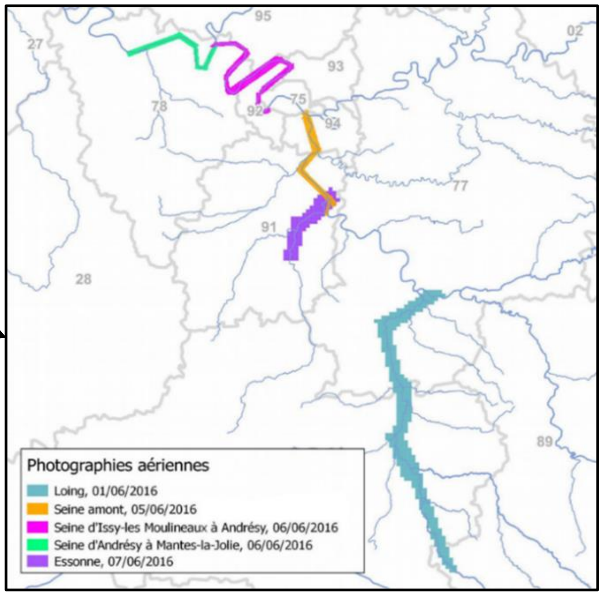


Figure 28 rivers where a flood occurred (Direction régionale et interdépartementale de l'environnement et de l'énergie d'Île-de-France, 10/2016)

The temporal and spatial extension of the event, as shown in Figure 28 and Figure 29, made it the most costly disaster after the creation of a compensation scheme (Ministère de la Transition écologique et solidaire - République Francaise, 2017). A total of 1148 municipalities (1500 according to (Ministère de la Transition écologique et solidaire - République Francaise, 2017)) have been declared at *Natural Catastrophe* (CatNat) state (see Figure 30) along the 3 consequent sessions of 7th, 13th and 21st June (Perrin, et al., 2017).

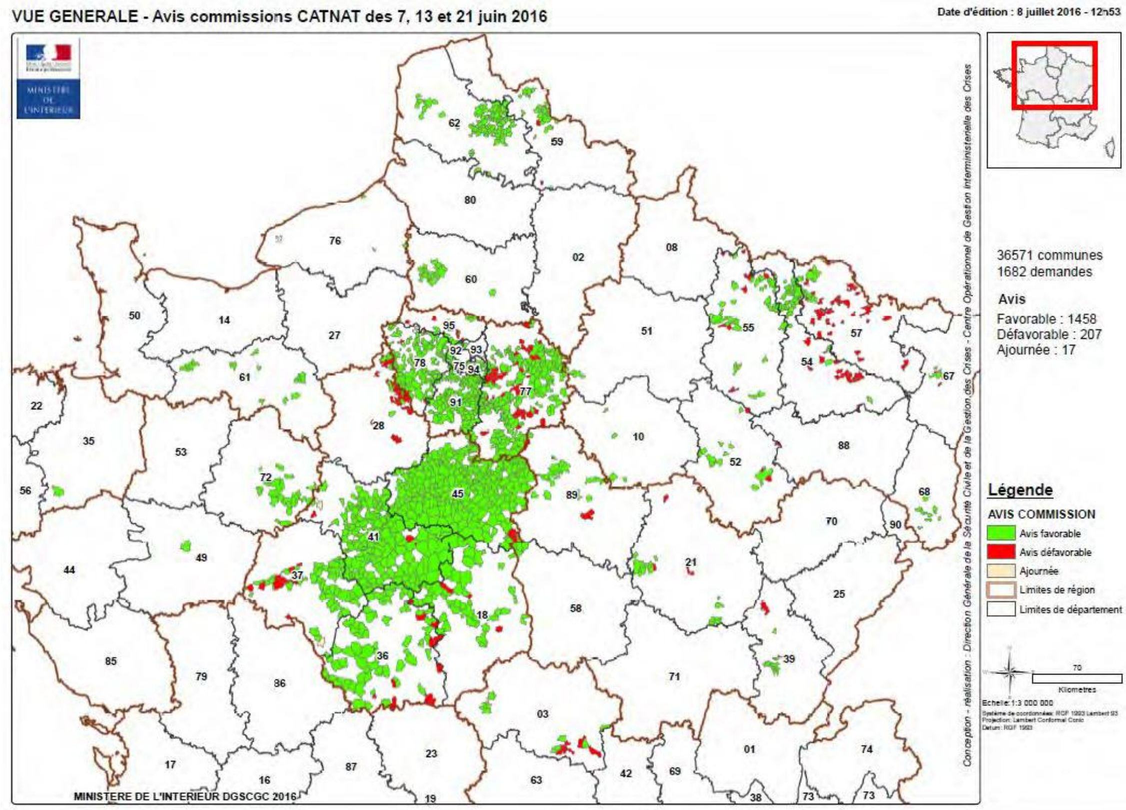


Figure 30 municipalities in CatNat state (Source:Ministère de l'Intérieur DGSCGC 2016)

6.2 Affected area

Involved departments:

- Essonne
- Loir-et-Cher
- Loiret
- Seine-et-Marne
- Paris
- Yvelines
- Cher
- Yonne

Most damaged municipalities (Mission Risques Naturels, 06/2016):

- Villeneuve-Saint-Georges
- Montargis
- Moret- Sur-Loing
- Nemours

- Montrichard
- Melun
- Longjumeau
- Romorantin-Lanthenay

These municipalities are shown below in Figure 31 and Figure 32.

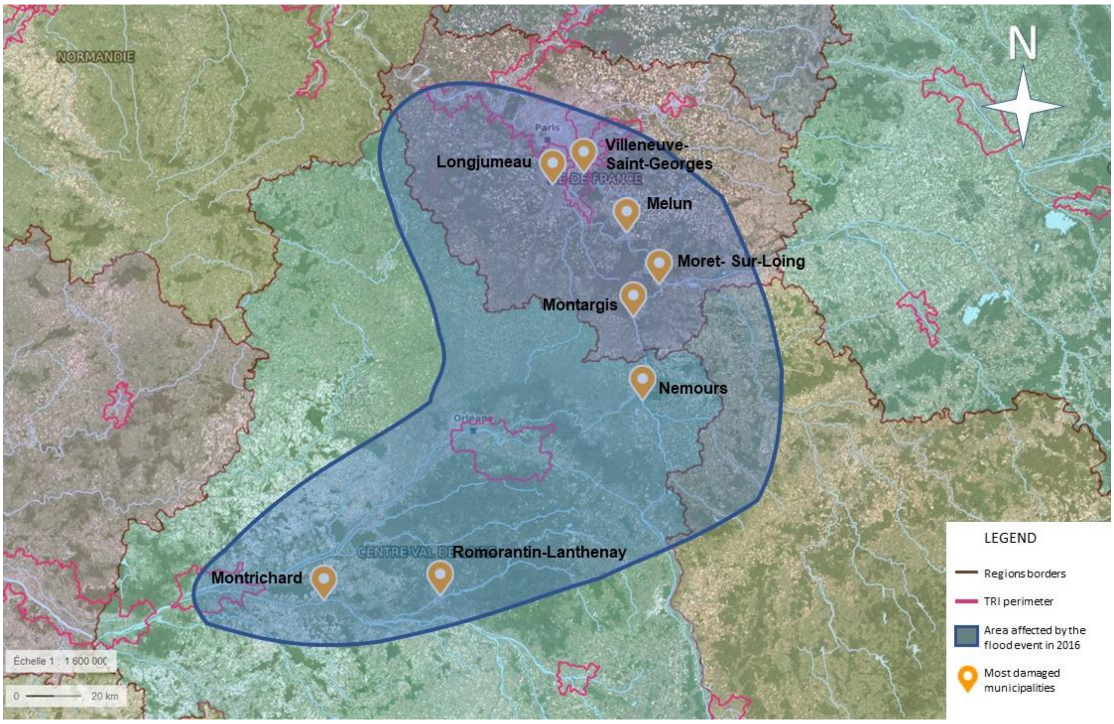


Figure 31 Area of the event, most affected municipalities and TRI perimeter (Source: extracted from https://www.geoportail.gouv.fr/)

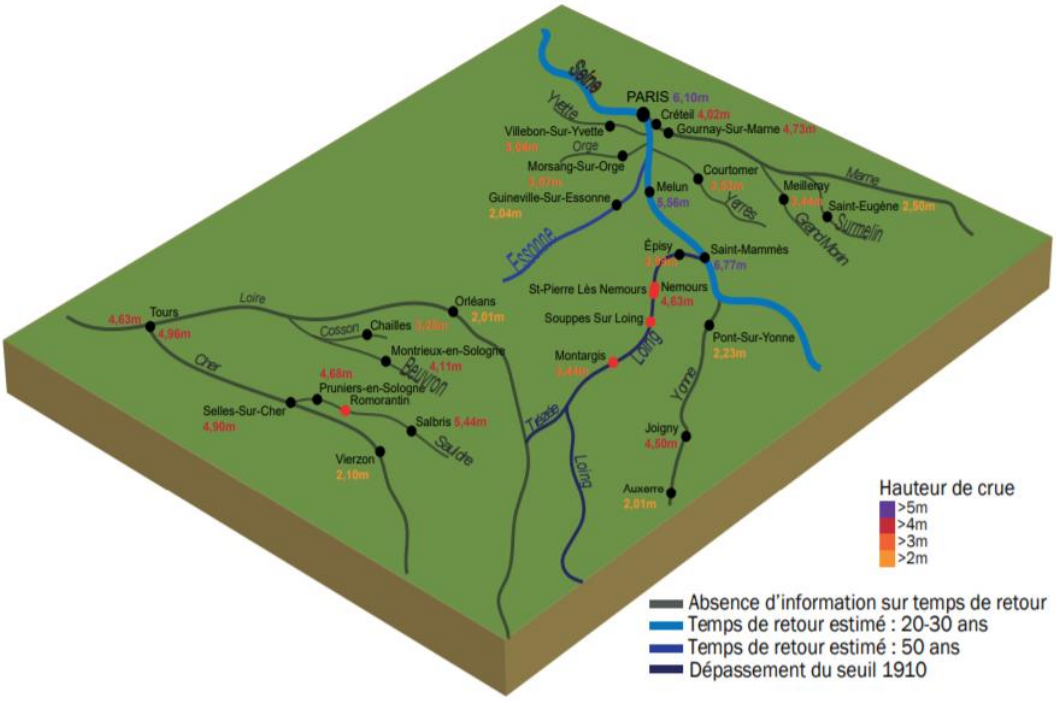


Figure 32 Schema of most exposed territories to flooding in 2016 and recorded water heights (Infographic MRN)

6.3 Description of the sequence of events in Seine and Loire River Basins from 30th May to 6th June 2016

(Service R&D modélisation – Direction des Réassurances & Fonds Publics CCR, 06/2016)

Concerned departments: 18, 28, 36, 37, 41, 45, 89, 75, 77, 78, 91, 92, 93, 94, 95.

Most affected municipalities: Montargis (45), Nemours (77), Melun (77), Moret-sur-Loing (77) and Longjumeau (91), Villeneuve-Saint-Georges (94).

Overflowing rivers: Seine, Loing, Yvette, Yerres, Bièvre.

Sequence of storm events that caused the subsequent flooding events:

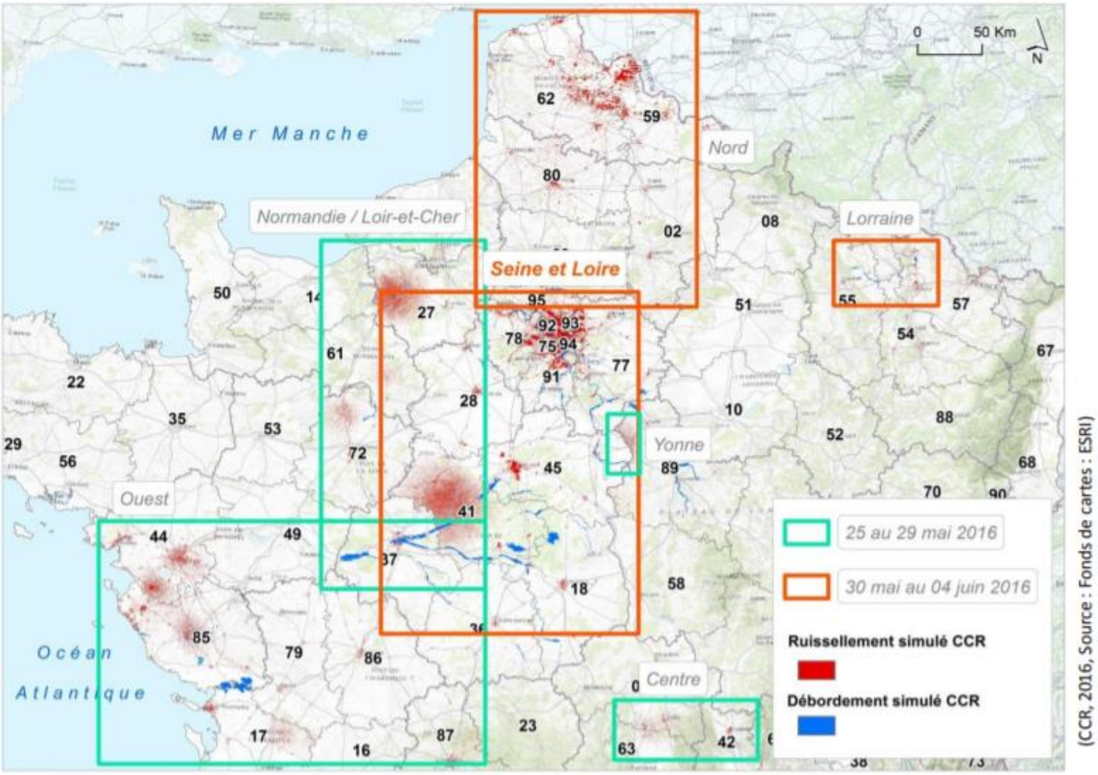


Figure 33 Storms episodes from 25th May to 4th June 2016 - Event localisation and simulated hazard by CCR

- NORTHERN STORMS FROM 30th MAY TO 31st MAY 2016

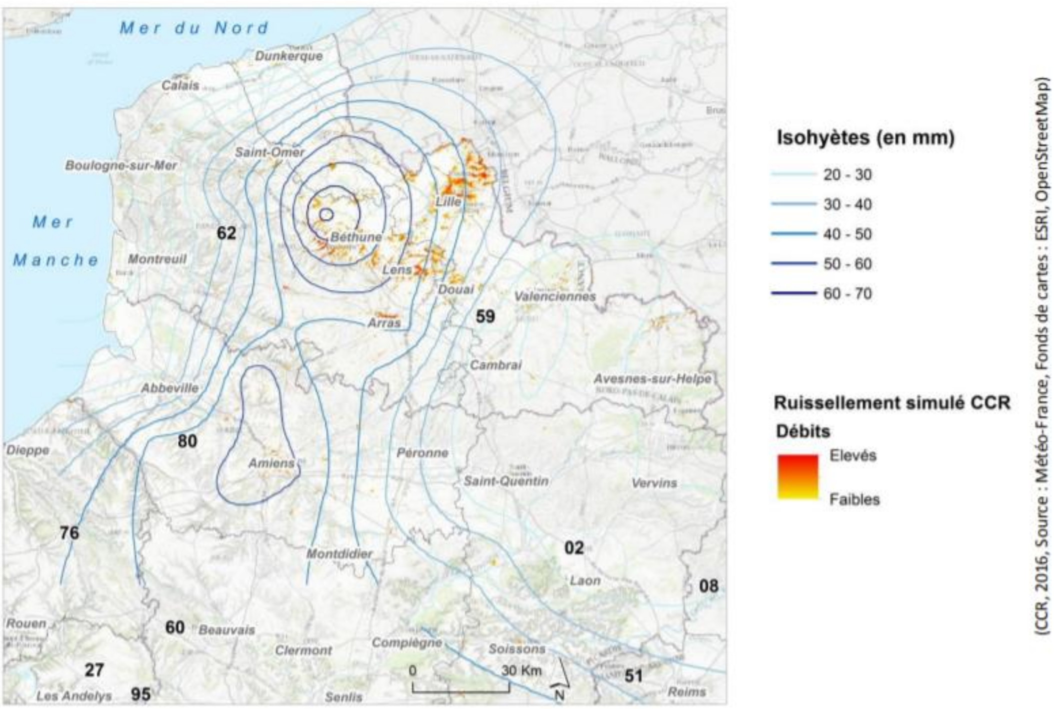


Figure 34 Northern storms 30th-31st May 2016

Damages:

			Number of flooded houses	Location of the building (coordinates or communes)
RESIDENTIAL	Direct damage	Description of the damaged building	40	Doullens (80)
		Height of the water (m)	0.8	

			General description of the damage	Location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
TRANSPORTATION	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	Part of the metro line was paralysed, and SNCF traffic was interrupted	Lille
			Flooding of streets	Nord-Pas-de-Calais

Concerned departments: Nord (59), Pas-de-Calais (62), Somme (80).

Most affected municipalities: Béthune (62), Merville (59), Bruay-la-Buissière (62).

Overflowing rivers: Lawe and Clarence rivers.

- FLOODS IN LORRAINE FROM 31st MAY TO 1st JUNE 2016

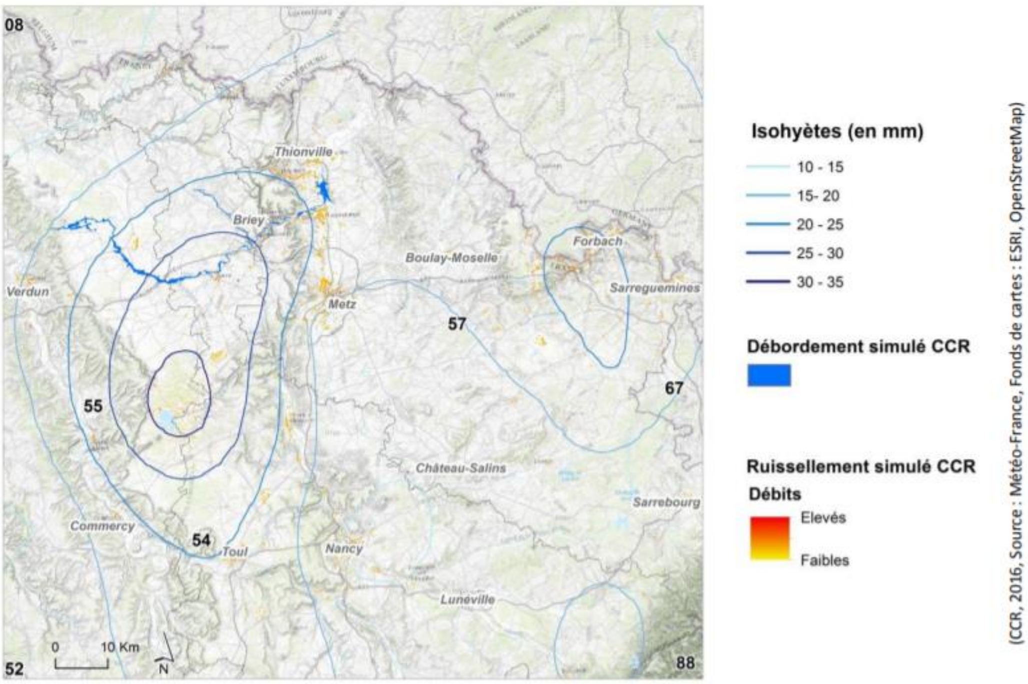


Figure 35 Floods in Lorraine from 31st May to 1st June 2016

Damages:

			number of houses	location of the building (coordinates or communes)
RESIDENTIAL	Direct damage	Description of the damaged building	Some houses flooded	in Meuse department, in Briey municipality (55)
			numerous houses flooded	Meurthe-et-Moselle (54),

			number of houses	location of the building (coordinates or communes)
LIFELINES TRANSPORTATION	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	Train traffic was severely disrupted between Thionville and Luxembourg in Moselle (57).	Moselle (57)
			type of transportation infrastructure (road, rails, airport..)	involved transportation infrastructures for networks (roads, rails, ...) (Km) and communes involved. Coordinates for localised damages (airports...).
		Physical damage to networks (damage to critical infrastructure attributed to disasters)	The road network was not spared with many roads in the region cut during the event	Moselle (57)

Concerned departments: Meuse (55), Meurthe-et-Moselle (54), Moselle (57).

Most affected municipalities: Trieux (54), Briey (55).

Overflowing rivers: Orne.

- CENTRAL STORMS OF 27th MAY 2016

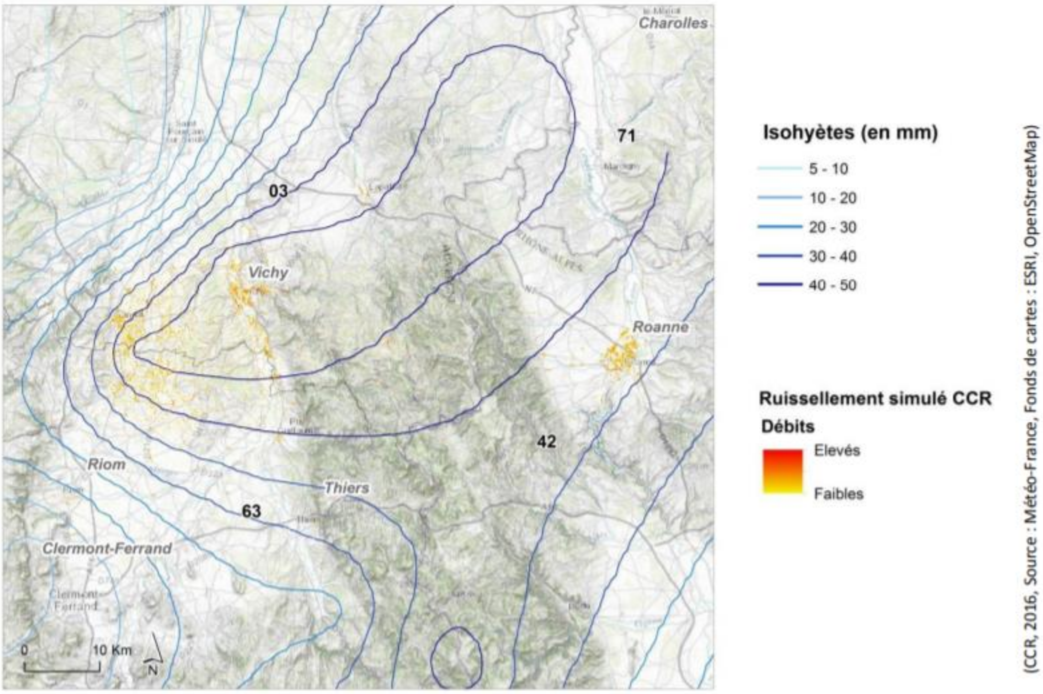


Figure 36 Central storms of 27th May 2016

Damages: Firefighters intervened almost 200 times to the flooding of houses and cellars.

			number of houses	location of the building (coordinates or communes)
RESIDENTIAL	Direct damage	Description of the damaged building	several houses flooded	Allier (03)
			several houses flooded	Puy-de-Dôme (63)
			several houses flooded	Loire (42)

Concerned departments: Allier (03), Puy-de-Dôme (63), Loire (42).

Most affected municipalities: Vichy (03), Cusset (03) and Bellerive (03).

- WESTERN STORMS FROM 27th TO 29th MAY 2016

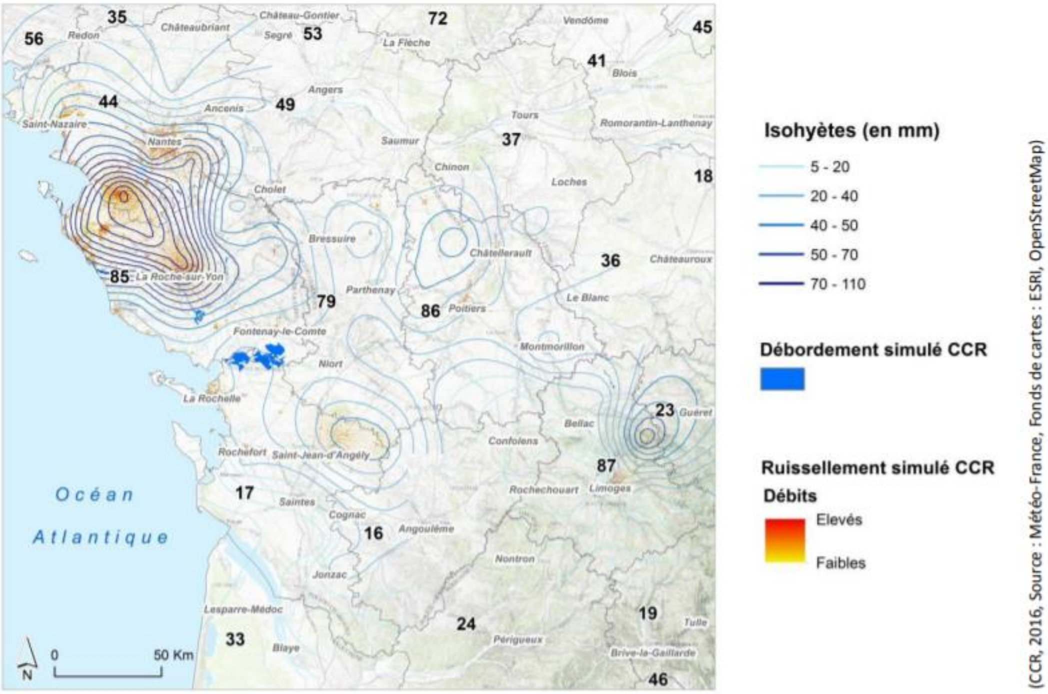


Figure 37 Western storms from 27th to 29th May 2016

Damages: The main damages are concentrated in the departments of Loire-Atlantique (44) and Vendée (85).

			general description of the damage	location of the damage (coordinates for localised damages, extention (m^2) and municipality for spared damages)
TRANSPORTATION	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	the streets of the city centre were flooded with 10 to 20 cm of water	La Baule
			the streets of the Penhoët district were flooded	Penhoët district, in Saint-Nazaire

Concerned departments: Loire-Atlantique (44), Charente-Maritime (17), Vendée (85), Deux-Sèvres (79), Vienne (86), Haute-Vienne (87).

Most affected municipalities: Saint-Nazaire (44), Saint-Cyr (86), La Baule (44).

- STORMS IN NORMANDY AND LOIR-ET-CHER FROM 27th TO 29th MAY 2016

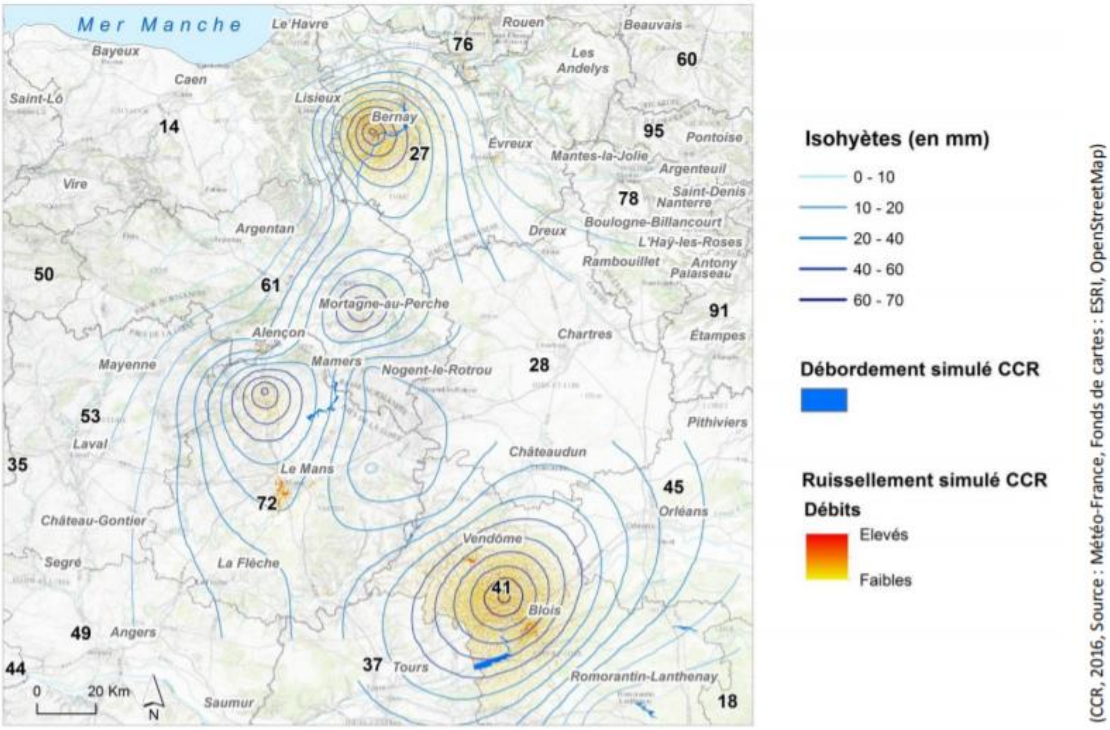


Figure 38 Storms in Normandy and Loir-et-Cher from 27th to 29th May 2016

Damages: The heavy runoff caused the flooding of roads and several houses, particularly in Orne (61). In Baigneaux (41), several houses were flooded by 20 cm of water. In Grand-Quevilly (76), several stores in the commercial area had to be evacuated due to flooding. The streets of Rouen (76) and Bernay (27) were also flooded.

			number of houses	location of the building (coordinates or communes)
RESIDENTIAL	Direct damage	Description of the damaged building	several houses	Orne (61)
		Description of the damaged building	several houses	Baigneaux (41)
		Height of the water (m)	0.2	

			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
TRANSPORTATION	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	streets flooded	Rouen (76)
			streets flooded	Bernay (27)
			streets flooded	Orne (61)

Concerned departments: Orne (61), Eure (27), Seine-Maritime (76), Sarthe (72), Loir-et-Cher (41).

Most affected municipalities: Rouen (76), Bernay (27).

Overflowing rivers: Iton.

- STORMS IN YONNE FROM 27th TO 29th MAY 2016

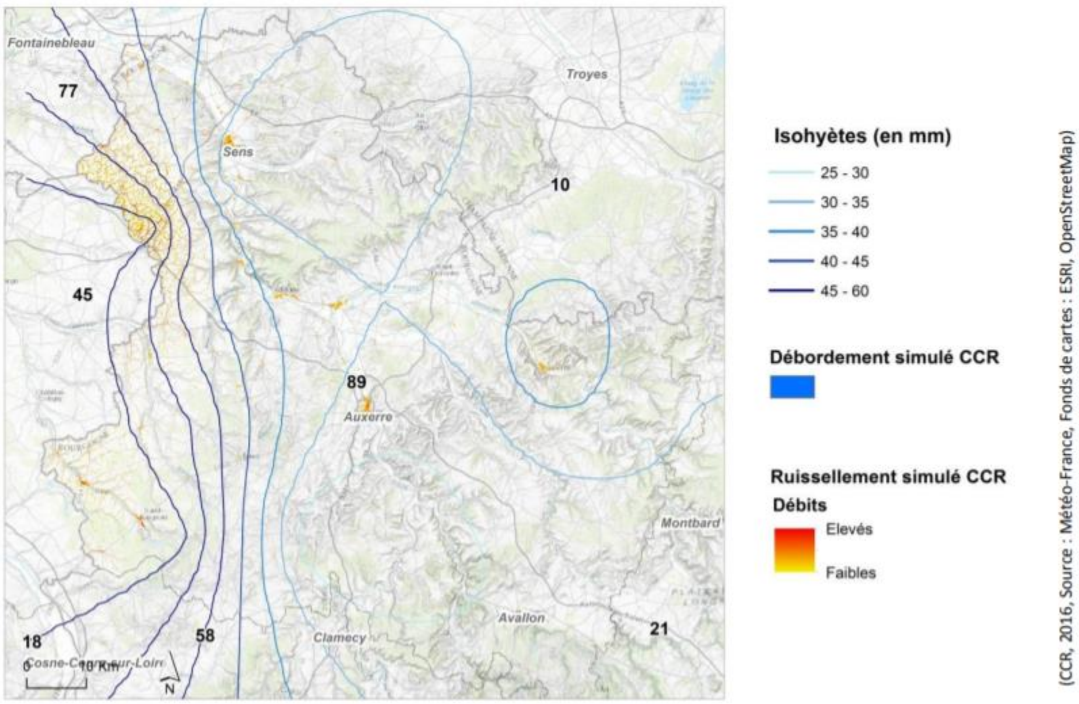


Figure 39 Storms in Yonne from 27th to 29th May 2016

Damages:

RESIDENTIAL	Direct damage		Number of houses	Location of the building (coordinates or communes)
		Description of the damaged building	flooding several houses and causing the evacuation of the inhabitants	Chemilly-sur-Yonne (89)

LIFELINES	TELECOMMUNICATION	Direct damage		General description of the damage	Location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
			Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	Many communication lines have been cut off	Chemilly-sur-Yonne (89)

Concerned departments: Yonne (89).

Most affected municipalities: Chemilly-sur-Yonne (89).

6.5 Historical events

As we can see in **Figure 40**, the area has already been affected by numerous flood events with a large percentage with considerably cumulated damages.

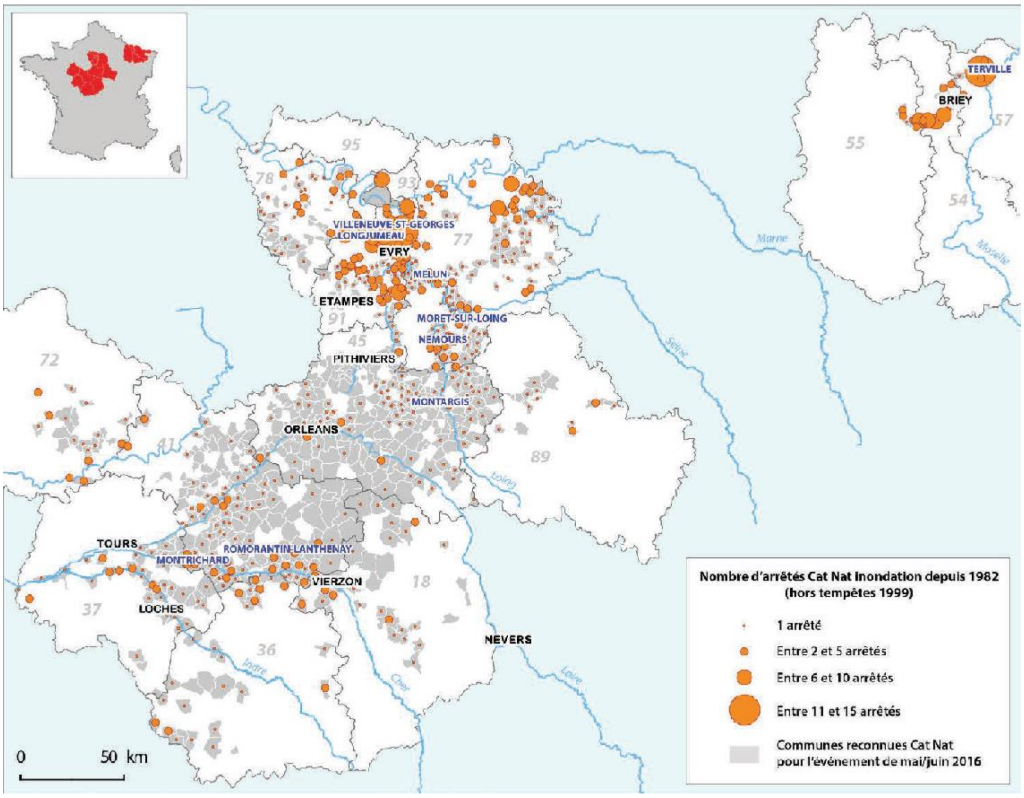


Figure 40 Number of CatNat floods since 1982 at municipality level (Mission Risques Naturels, 06/2016)

Fortunately, the majority of the events are negligible in terms of damage cost, but a very considerable part of them, it is shown in **Figure 41**, represent a high cost for the society.

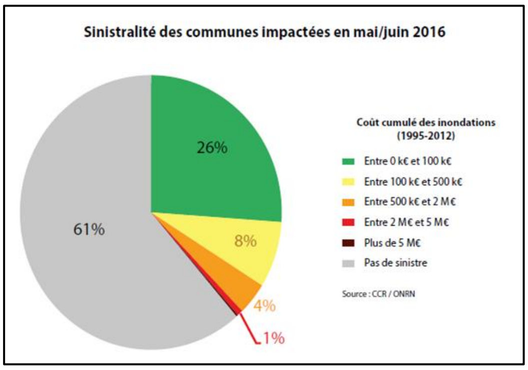


Figure 41 Cumulated cost caused by flood between 1995 and 2012 in the affected municipalities in 2016 (Mission Risques Naturels, 06/2016)

6.6 Damages investigation

TOTAL DAMAGE ESTIMATED COST

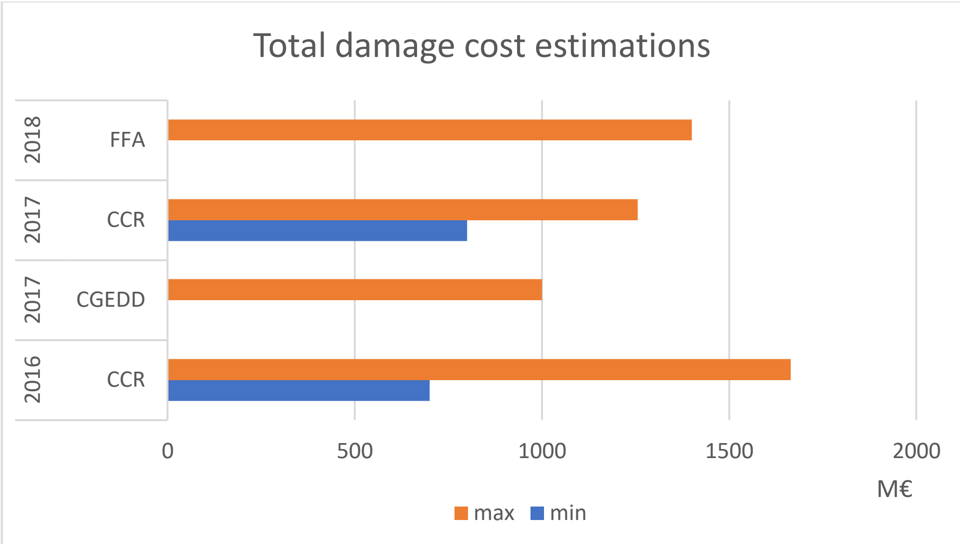


Figure 42 total damage cost estimations from different sources (extracted from (Perrin, et al., 2017), (Mission Risques Naturels, 04/2018), (Service R&D modélisation – Direction des Réassurances & Fonds Publics CCR, 06/2016))

Different total damage cost estimations have been done after the event. As we can see in Figure 42, the final appraisals are very different. This is due to the fact that defining a complete damage cost is very relative and changes a lot depending, for example, on taking into consideration only insured damages or all of them.

Focusing at departmental asset, in Figure 43 we can see the repartition of the damages among the most affected ones and in Table 12 the related data used for the graph.

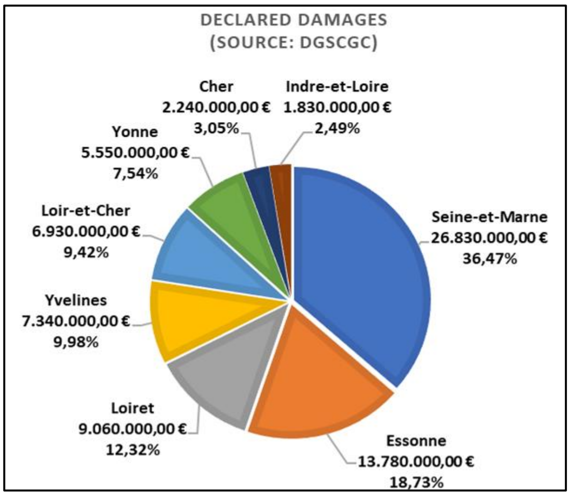


Figure 43 Comparison of damage declarations among the 8 most affected departments (extracted from Perrin, Sauzey, Menoret, & Roche, 2017)

Table 12 (Perrin, et al., 2017)

DECLARED DAMAGED TO THE STATE				
Department	number of collectivity and groups	declared damages	declared damages / number of collectivity	Percentage
Seine-et-Marne	98	26,830,000.00 €	273,775.51 €	18.86%
Essonne	36	13,780,000.00 €	382,777.78 €	28.19%
Loiret	89	9,060,000.00 €	101,797.75 €	10.44%
Yvelines	35	7,340,000.00 €	209,714.29 €	24.02%
Loir-et-Cher	55	6,930,000.00 €	126,000.00 €	18.99%
Yonne	39	5,550,000.00 €	142,307.69 €	26.48%
Cher	13	2,240,000.00 €	172,307.69 €	43.60%
Indre-et-Loire	43	1,830,000.00 €	42,558.14 €	19.10%
Total	408	73,560,000.00 €	180,294.12 €	100.00%

As we can notice, the majority of the damage cost is concentrated in few departments.

Descending to municipal level, according to data provided by (Mission Risques Naturels, 04/2018), a comparison between the number or damage declarations made by the most affected municipalities and the estimated total damage cost based on MRN studies. As we can see in Figure 44 there is some correspondence in the two types of data.

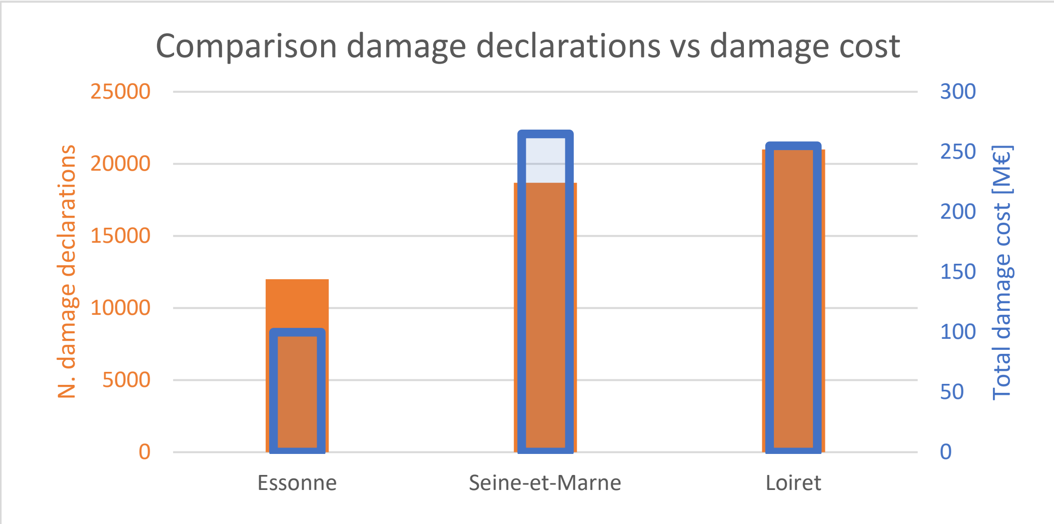


Figure 44 Comparison damage declarations vs damage cost (extracted from (Mission Risques Naturels, 04/2018))

In addition, a parallel between declared damage and estimated aid both weighted on the number of municipalities per department has been done and displayed in the graph in Figure 45. Only the eight most affected ones have been taken into consideration.

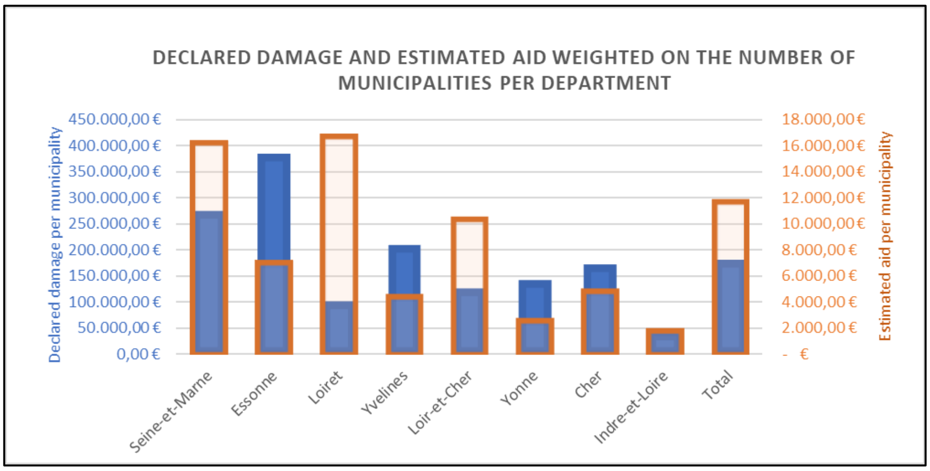


Figure 45 Comparison between the declared damage and the estimated necessary aid per municipality in the 8 most affected departments (extracted from Perrin, Sauzey, Menoret, & Roche, 2017)

In this case, the difference in the most part of the cases is evident. This makes us question on the real correctness of placements of funding and aids. In fact, the damage considered eligible represents in general only about one third of the damage declared by the local authorities (Perrin, et al., 2017).

The distribution of costs by municipality (within the special risks segment) shows that 9% of the municipalities corresponds to the 80% of the total claims (Figure 46). The 5 most affected municipalities cumulated approximately the 20% of the total cost of the event: Montargis, Nemours, Saint-Pierre-Lès-Nemours and Souppes-Sur-Loing (located along the Loing), Romorantin (located along the Sauldre) (Mission Risques Naturels, 04/2018).

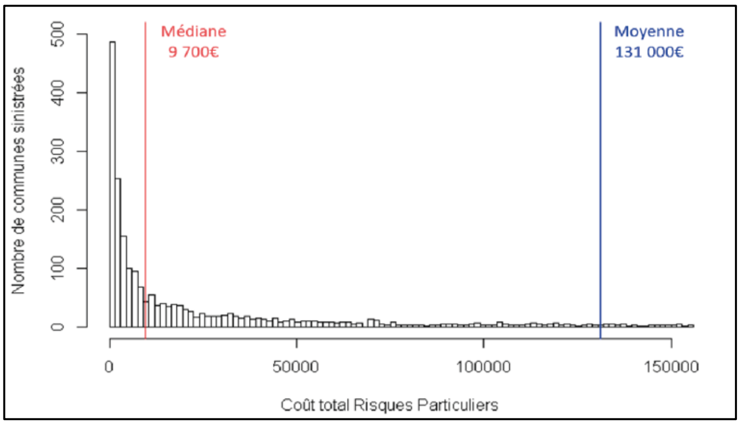


Figure 46 Number of cumulated damages VS Total cost of Particular risk (Mission Risques Naturels, 04/2018)

AFFECTED PEOPLE

Table 13 (Ministère de la Transition écologique et solidaire - République Francaise, 2017)

			number of people
PEOPLE	Direct damage	Deaths	6
	Second order damage	Evacuated	20000
		Displaced	20000

RESIDENTIAL BUILDINGS

An analysis of the damage on residential building has been performed depending on the building typology:

Table 14 (Mission Risques Naturels, 04/2018)

	Cost	Damages	Municipalities	Characteristics
Zone A	39%	25%	Saint-Pierre-Lès-Nemours and Souppes-Sur-Loing)	An individual residential housing, built at the end of the 20th century
Zone B	61%	75%	Nemours, Montargis, Romorantin	A dwelling located in the historic centre and of smaller size, such as a semi-detached apartment built before 1945

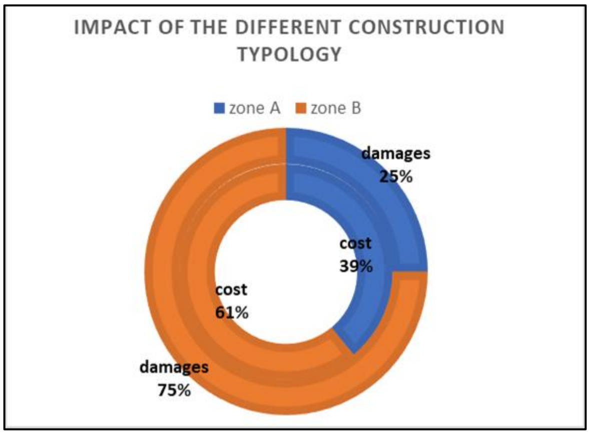


Figure 48 Percentage of damages and relatively costs for different construction typology (extracted from Mission Risques Naturels, 04/2018).

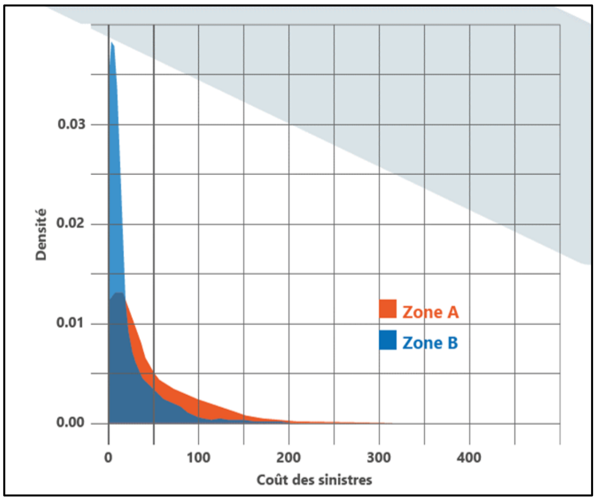


Figure 47 Frequency density of damages costs in function of the building typology (Mission Risques Naturels, 04/2018).

As expected, the older constructions suffered the higher level of damage and the cost of their reconstructions is consequently greater. In Figure 47 and Figure 48, we can see that the higher density of damage is related to B type buildings since they are the majority of nowadays constructions. Anyhow, the greater cost remains characteristic of the A zone.

As we can see in Figure 49, a research done by MRN put in evidence the fact that the single houses are much more affected than the apartments. This can be due to the fact that single houses are generally developed in one or two floors so the percentage of the houses which would be flooded is higher.

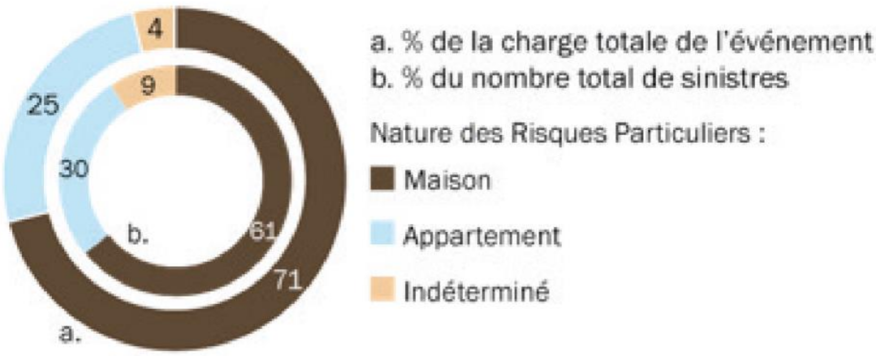


Figure 49 Quantity of damaged elements and costs per category (Mission Risques Naturels, 04/2018)

LIFELINES

Data describing the main consequences of the floods on lifelines, divided by sector, are presented in the following tables (Table 15, Table 16, Table 17)

Table 15 Transportation sector damages. Extracted from (Boizard, et al., 12/2016)

TRANSPORTATION			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	the streets of the Penhoët district were flooded	Penhoët district, in Saint-Nazaire
			the streets of the city centre were flooded with 10 to 20 cm of water	La Baule
			streets flooded	Rouen (76)
			streets flooded	Bernay (27)
			streets flooded	Orne (61)
			part of the metro line was paralysed, and SNCF traffic was interrupted	Lille
			streets flooded	Nord-Pas-de-Calais
			The motorway A10 was gradually flooded during the night until water invades all the lanes and the motorway is physically cut off at around 9am. Back into service from the 10th June	Access ramps and lanes of the A10 motorway in Loir-et-Cher
			Train traffic was severely disrupted between Thionville and Luxembourg in Moselle (57).	Moselle (57)
			flooded road	Orléans bypass (RD 520 and RD 2701) , western tangential part in the Saint-Jean - de - Ruelle hopper
			flooded road	East-West axis (RD 2060).
			flooded road	North-South axis: RD 2020 (ex-RN 20), and RD 2152 RD 2007, RD 97, RD 921
			flooded road	access to cluster 45 in Saran: RD 557
			Type of transportation infrastructure (road, rails, airport...)	Involved transportation infrastructures for networks (roads, rails, ...) (Km) and communes involved. Coordinates for localised damages (airports...).
		Physical damage to networks (damage to critical infrastructure attributed to disasters)	road	115 roads, 230 sections, 347 km
			The road network was not spared with many roads in the region cut during the event	Moselle (57)
			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)

Second order damage	Service interruption	The helicopters were unable to fly on the first day	
	Functional and systemic failures	Impossible to set up a deviation for A10 or to divert from one road to the other	Loir-et-Cher
		Difficulty for companies' employees in the 45-pole zone or Laboratoires Servier Industrie to go to or leave their work	45 pole zone or Laboratoires Servier Industrie
		SDIS encountered great difficulties in providing assistance to residents or companies	Loir-et-Cher

Table 16 Telecommunication sector damages. Extracted from (Boizard, et al., 12/2016)

TELECOMMUNICATION			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
	Direct damage	Physical damage to plants (destroyed or damaged critical infrastructure units and facilities attributed to disasters)	Many communication lines have been cut off	Yonne (89)

Table 17 Power sector damages. Extracted from (Boizard, et al., 12/2016)

POWER			general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and municipality for spared damages)
	Direct damage	Physical damage to plants	18000 houses suffered a lack of electricity	Loiret, Loir-et-Cher, Ile-de-France

ECONOMIC ACTIVITIES

Data about the effect of the floods on the economic sector are presented below in Table 18 and Table 19.

Table 18 Damages to economic activities. Extracted from (Service R&D modélisation – Direction des Réassurances & Fonds Publics CCR, 06/2016) for direct damage and from (Duranthon, et al., 11/2016) for second order damage

COMMERCIAL SECTOR			Location of the damage (coordinates for localised damages, extension (m^2) and communes for spared damages)	General description of the damage
	Direct damage	Physical damage to plants	Quevilly (76)	Several stores in the commercial area had to be evacuated due to flooding
			General description	Sector

	Second order damage	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period	Significant decrease in the number of tourists for several weeks. According to the Committee of River Owners - CAF - the tourist attendance of its members felt by 35% between the first half of 2015 and the first half of 2016.	Tourism (restaurant boats, cruise ships, etc.)
			the poor harvest and the lower quality of production led to a reduction in the transported tonnage	freight transport

Table 19 extracted from (Boizard, et al., 12/2016)

INDUSTRIAL SECTOR			General description of the damage	Location of the damage (coordinates for localised damages, extension (m^2) and communes for spared damages)	Total cost of the reconstruction (€)
	Direct damage	Physical damage to infrastructures	The flood damaged many river structures under the responsibility of Voies navigables de France (VNF) or the Port Autonome de Paris (PAP): dikes, dams, locks, quays, etc.		€7.6 million (only urgent works)

The total damage to businesses has been estimated for 4 million euros (Inondations, les leçons à tirer de la crue de 2016 - n 69, 2017). Considering now the different sectors, we can see the average cost per claim according to MRN in Figure 50.

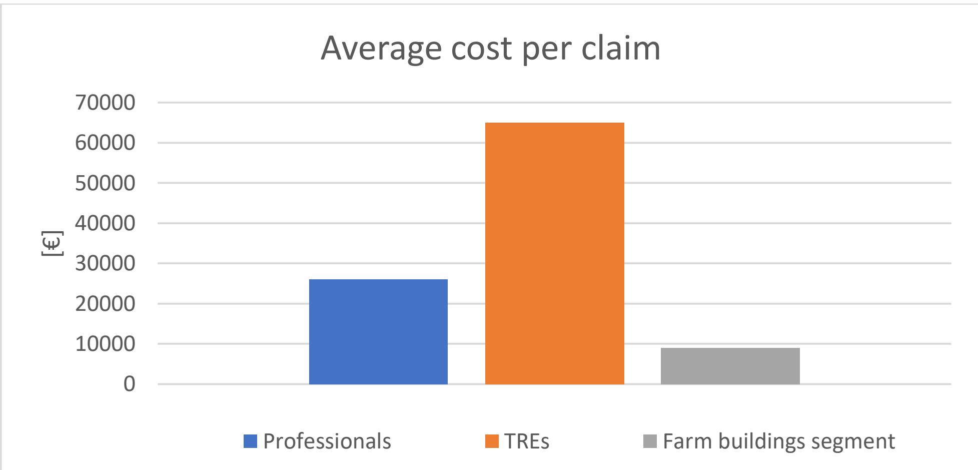


Figure 50 extracted from (Mission Risques Naturels, 04/2018)

The farm buildings segment is not very well represented with 1% of the overall loss ratio (Mission Risques Naturels, 04/2018).

In the six most affected departments (Seine-et-Marne, Loiret, Loir-et-Cher, Essonne, Yonne, Indre-et-Loire), it can be estimated that around 650 companies were directly affected in their activity. In Seine-et-Marne, 179 companies had to reduce their activity, but 625 companies, with nearly 2,500 employees, were supported by the public services with several procedures (Perrin, et al., 2017).

The most damaged activities during the 2016 event are listed below in Table 20, with the relative damage costs.

Table 20 (Boizard, et al., 12/2016)

COFIROUTE	revenue loss (tollbooth)	4 955 000 €
	costs incurred (related to customer care, drying and refurbishment operations)	4 049 000 €
	TOT	9 004 000 €
ORVADE (UTOM)	work to be done on the incineration plant	3 000 000 €
	operating loss	2 000 000 €
	TOT	5 000 000 €
Sorting centre	work to be done	100 000 €
	operating loss	200 000 €
	post-cruise waste	150 000 €
	TOT	450 000 €
Laboratoires Servier Industrie	work to be done	250 000 €
	wages and non-production	2 000 000 €
	TOT	2 250 000 €

One of the economic fields which has been severely hit by the event and which is a good representative of the impact of the indirect damages on commercial activities is the freight transport sector. In the graph below (Figure 51), extracted from data provided by Voies Navigables de France (VNF), we can see the percentage of business losses in respect to the previous season and to the mean of the 5 previous years. The loss percentage depends a lot on the type of transported good but, in general, it is always a negative trend.

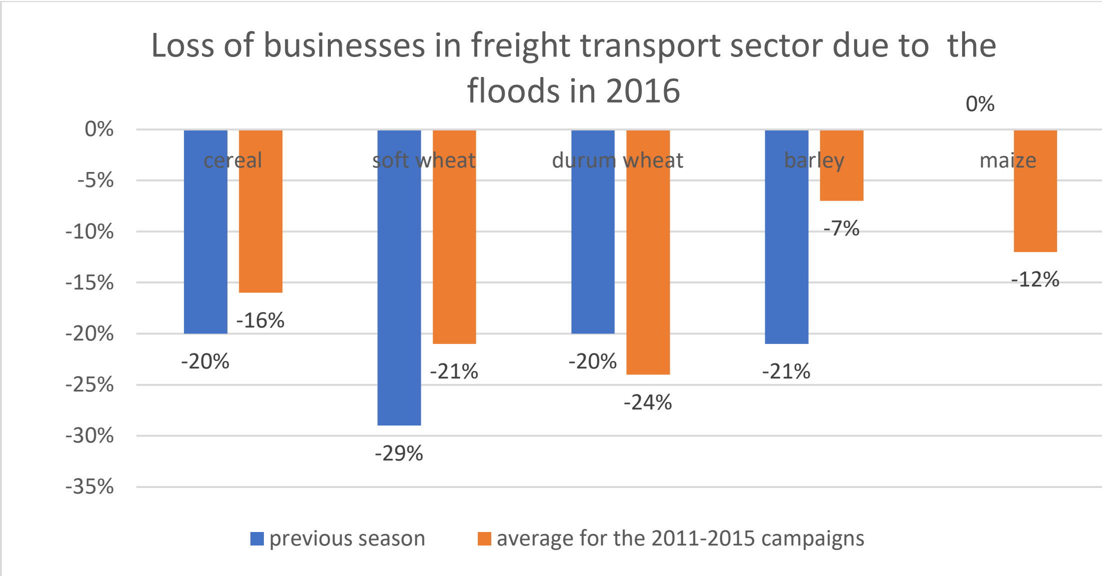


Figure 51 extracted from VNF, September 2016

However, the transport of cereals represents an important part of the activity of inland navigation: about 27% of boat trips on the Seine. VNF estimates that in 2016, the tonnages of cereals lost, compared to previous years, will be 2 350 000 t. If the tonne is valued at €10, this represents a loss of €23.5 million in turnover for the industry (Duranthon, et al., 11/2016).

Table 21 Indirect damages. Extracted from Duranthon, et al., 11/2016

			general description of the damage	Sector	Difference in respect to the previous years
COMMERCIAL SECTOR	Second order damage	Loss of revenue (€) due to the interruption respect with the average of the previous years in the same period	Tonnages of cereals lost, compared to previous years	Cereal freight transport	2 350 000 t equivalent to €23.5 million
			Freight traffic on the Seine basin	Freight transport	22.7 million t-km in 6 months correspondents to a turnover of 2M€
			Estimation of loss of revenue resulting from the flood from data in files requested by the PAP for the granting of assistance	Freight transport	13 M€ (approximately 6% of the annual turnover)
			Estimation done by CAF	tourism sector	10 M€
			Estimation done by CAF	construction sector	4 M€
			Paris Port Community (CPP) assessment	Port industry	15 M€

According to the report drawn up by the Ile-de-France interdepartmental chamber of agriculture:

Table 22 Acricultural sector damages. Extracted from (Inondations, les leçons à tirer de la crue de 2016 - n 69, 2017)

AGRICULTURAL SECTOR		*(Agriculture is understood to include the crops, livestock, fisheries, apiculture, aquaculture and forest sectors as well as associated facilities and infrastructure)*	general description of the damage	location of the damage (coordinates for localised damages, extension (m^2) and communes for spared damages)	Total cost of the reconstruction (€)
	First order damage	Physical damage to soil	190 field crop farms	Ile-de-France region	
		Physical damage to plants	100 specialised farms (market gardening, arboriculture, nursery, etc.)	Ile-de-France region	
			70 livestock farms	Ile-de-France region	
		Generic	Total damage cost for 3800 affected hectares	Ile-de-France region	5.5 M€

To sustain the commercial activities facing the catastrophe, different aids were established.

From public institutions, the main ones for which we have some quantified data are listed in the table below (Table 23).

Table 23 Main aids from institutions. Extracted from (Boizard, et al., 12/2016)

PROVIDING INSTITUTION	TYPE OF AID	AMOUNT [€]
the Regional Directorate for enterprise, competition, labour and employment (DIRECTTE)	A subsidy given for the 4 days of closure	70 000 €
	An exceptional "flood" aid to 32 companies	97 500 €
	Aid for the partial activity to 61 companies	191 138 €
Departmental Council	Repair costs (excluding tax)	1 485 000 €

From private sector instead, based on the information provided by the various actors, the amounts of mobilised aid are listed below (Figure 52).

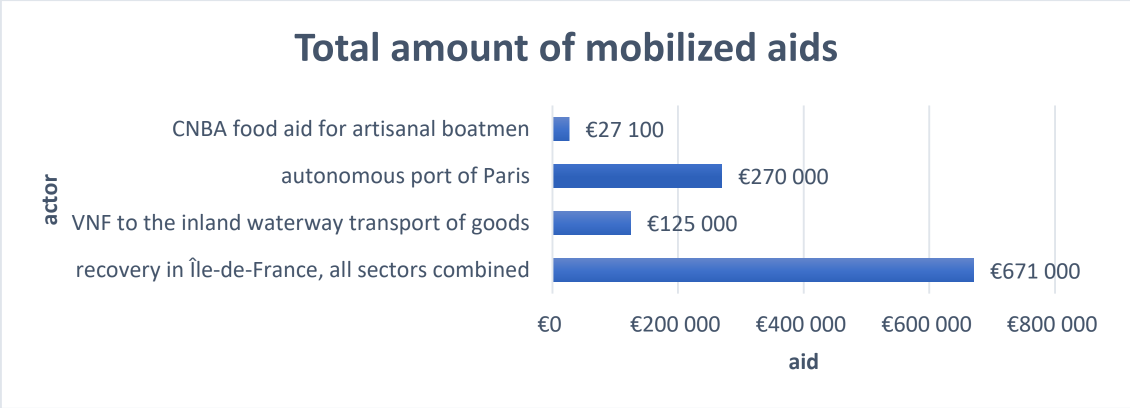


Figure 52 Total amount of mobilized aids from private sector (Duranthon, et al., 11/2016)

CULTURAL HERITAGE

Table 24 shows the main mitigation measures applied in Louvre museum and the negative trend of tickets selling and attendance in the months of the event.

*Table 24 Damages and losses to Cultural heritage sector. Extracted from *(Crue de la Seine, declenchement du plan de prevention des risques inondation du musée du Louvre), **(Duranthon, et al., 11/2016), ***(economic continuity unit set up by the financial ministries, 06/2016).*

			General description	economical losses due to partial or total closure (€)	costs due to the measures for limiting or preventing damages (€)
CULTURAL HERITAGE	Second order damage	Used restrictions	Louvre Museum decided to close to the public to implement, as a preventive measure, the evacuation of works located in floodplains to the upper floors*		Closed from Friday 3rd June 2016 until Tuesday 7th June 2016 included
			Decrement in the attendance at national heritage sites and major museums**	- 16% in the first nine months of 2016 compared to the same period in 2015	
			during the month of May tourist attendance felt in Île-de-France***	-19.2%	
			the number of tickets sold for cultural events or places felt ***	-20 to -30%	

OTHER AGGRAVATING FACTORS

Current events do not stop when a major crisis occurs. Accidents, illnesses, and delinquency continue to occur. They may even be aggravated by the crisis (for example, preventing acts of looting in flooded houses in Gidy or Cercottes required patrols by the gendarmerie) (Direction régionale et interdépartementale de l'environnement et de l'énergie d'Île-de-France, 10/2016).

In addition, it has sometimes been difficult to replace people (Direction régionale et interdépartementale de l'environnement et de l'énergie d'Île-de-France, 10/2016).

5.6 Exposure

The main cause of post-disaster damage is generally related to wrong urban planning. As we can see in Figure 53, most of the inhabitants and industries of the affected area

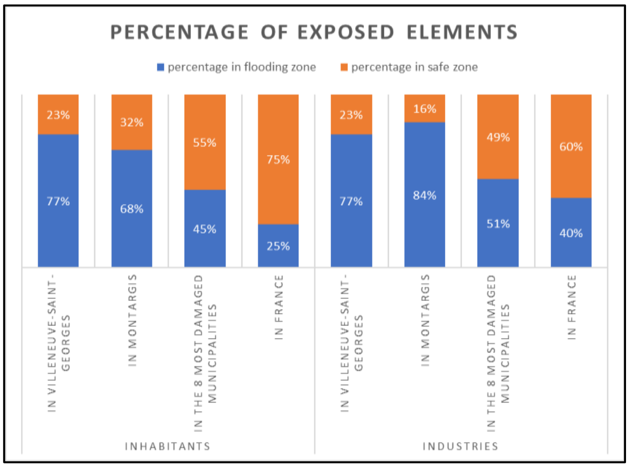


Figure 53 Percentage of exposed elements in the most affected municipalities (Mission Risques Naturels, 04/2018)

are located in flooding zones.

A very important factor to consider is the presence or absence of a PPRI in the damaged municipalities. In fact, the planning of interventions during an emergency can actually have a direct and immediate impact on the damage entity. As we can notice from Figure 54 and Figure 55, most of the municipality lack of PPRI. This has a direct impact in the preparedness of the inverventions and the consequent effects of the disasters.

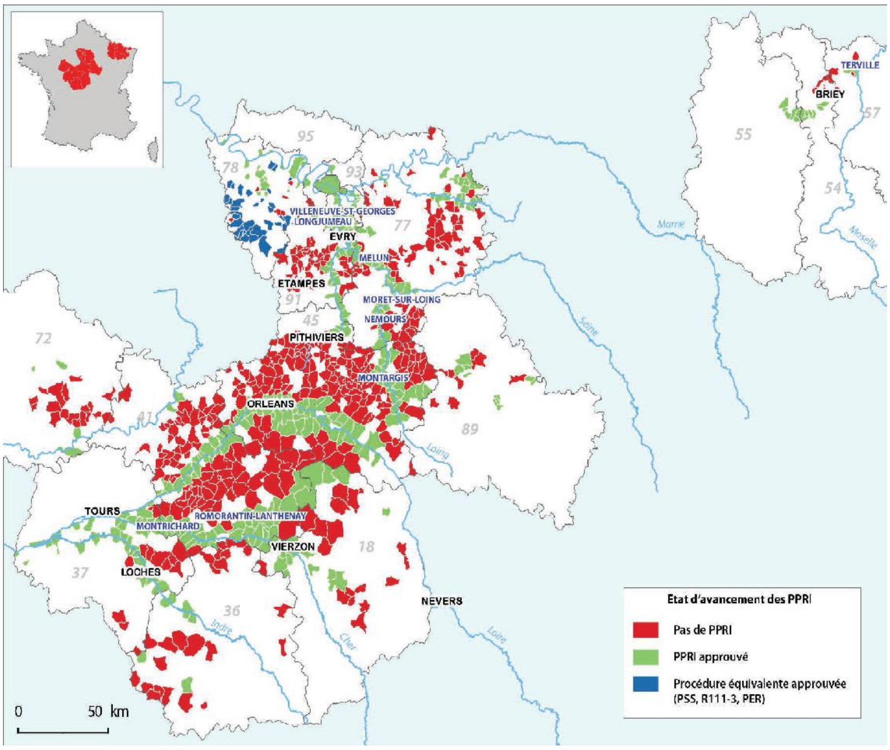


Figure 54 Municipalities' regulations situation when the event occurred (Mission Risques Naturels, 06/2016)

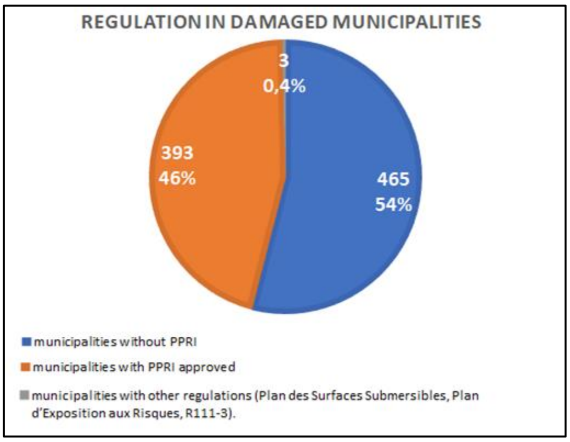


Figure 55 Percentage of damaged municipalities with and without a PPRI at the time of the event (Mission Risques Naturels, 06/2016)

6.7 Prevention measures applied after the event of 2016

BEFORE THE EVENT

- Presence of lake-reservoir.

  Therefore, the estimated benefits of the lake-reservoirs appear limited in relation to the overall cost of the flood. This is due to the fact that most of the damage was observed on tributaries not protected by the lake-reservoirs. In addition, the flooding occurred downstream of these structures, which were consequently unable to fully play their role at the flood peak (Service R&D modélisation – Direction des Réassurances & Fonds Publics CCR, 06/2016).

AFTER THE EVENT

- After the flood, the restarting of the installations required a lot of additional resources. The mobilization of external service providers cost 800 000 euros, including 500 000 euros for the installation of protection elements, barriers or cofferdams, and 300 000 euros for the cleaning of the medians (Inondations, les leçons à tirer de la crue de 2016 - n 69, 2017).
- At the end of 2016, Ségolène Royal asked to prefects to organize some crisis management exercises in three regions particularly exposed to flood risk: Strasburg, Dunkerque, Bordeaux (Ministère de la Transition écologique et solidaire - République Francaise, 2017).
- The flood departmental reference mission, established in 2011, has been enlarged to all the departmental directions of the territory (DDT), giving an additional local technical support to prefects for the crisis management (Ministère de la Transition écologique et solidaire - République Francaise, 2017).
- The flood in May-June 2016 was the first event in which the maps showing the potentially flooded zones were used as an operational tool in support of decision making. After that, maps representing flood risk have been improved and implemented with more detailed data (Ministère de la Transition écologique et solidaire - République Francaise, 2017).
- "Vigicrues Flesh" was activated in March 2017. It is a free Alert Service whose goal is to inform in real time the local authorities potentially involved in a flood (Ministère de la Transition écologique et solidaire - République Francaise, 2017).
- Installation of a measurement station in Pont d'Austerlitz in Paris to monitor the level of the Seine river (Ministère de la Transition écologique et solidaire - République Francaise, 2017).
- Adoption of strategic local measures to better manage flood risk (SLGRI) in territories with high level of hazard due to flood (Ministère de la Transition écologique et solidaire - République Francaise, 2017).

6.8 Focus on Paris

Since Paris is the capital city of France, much more data are available. In particular, in the French geoportal there are available layers with spatial data. Some maps for almost all the faced macro-topics have been extracted.

RESIDENTIAL BUILDINGS

As it is visible in Figure 56, the map of public housing in Paris has been overlapped with the flooding zones according to PPRI. The presence of public housing generally means a high density of the population, that is why it is interesting to understand where this construction typology is more common. According to the extracted data, the higher density is outside the exposed area except for the south-west area.

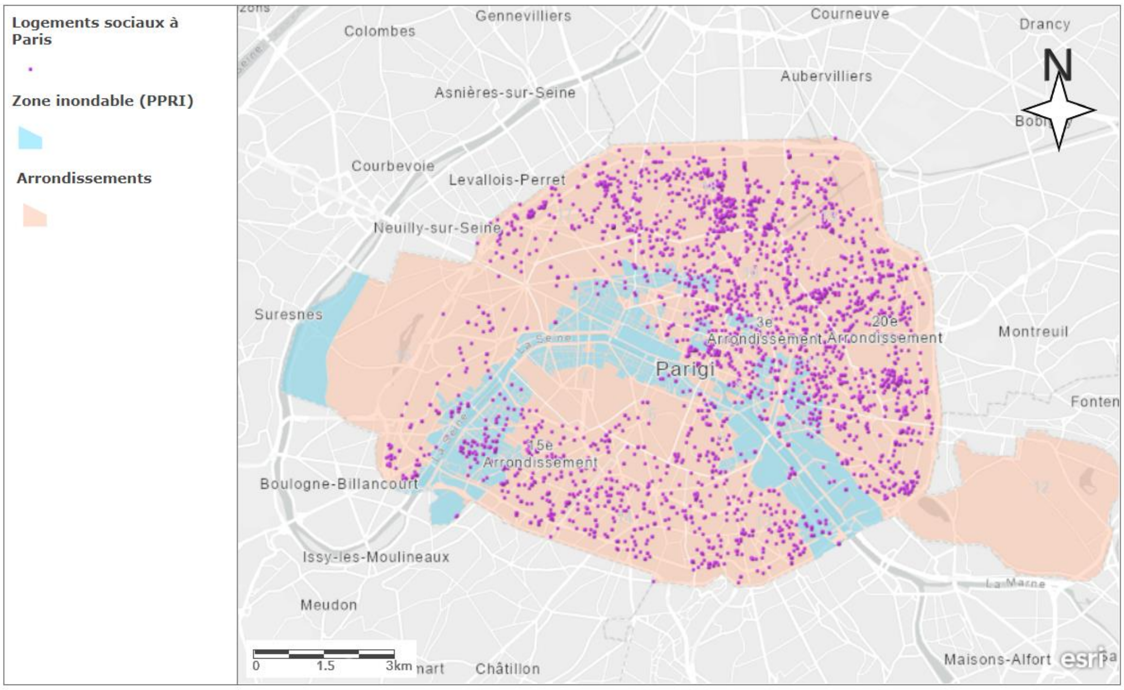


Figure 56 Public housing in Paris and flooding area (extracted from: https://www.geoportail.gouv.fr)

LIFELINES

In Figure 57 the subway lines and stops map is overlapped to the PPRI. As expected, considering the huge subway network of Paris, most of the stops are present in the flooding area. So, the risk for stops to be flooded and cause worse systemic consequences to the entire network is quite elevate.

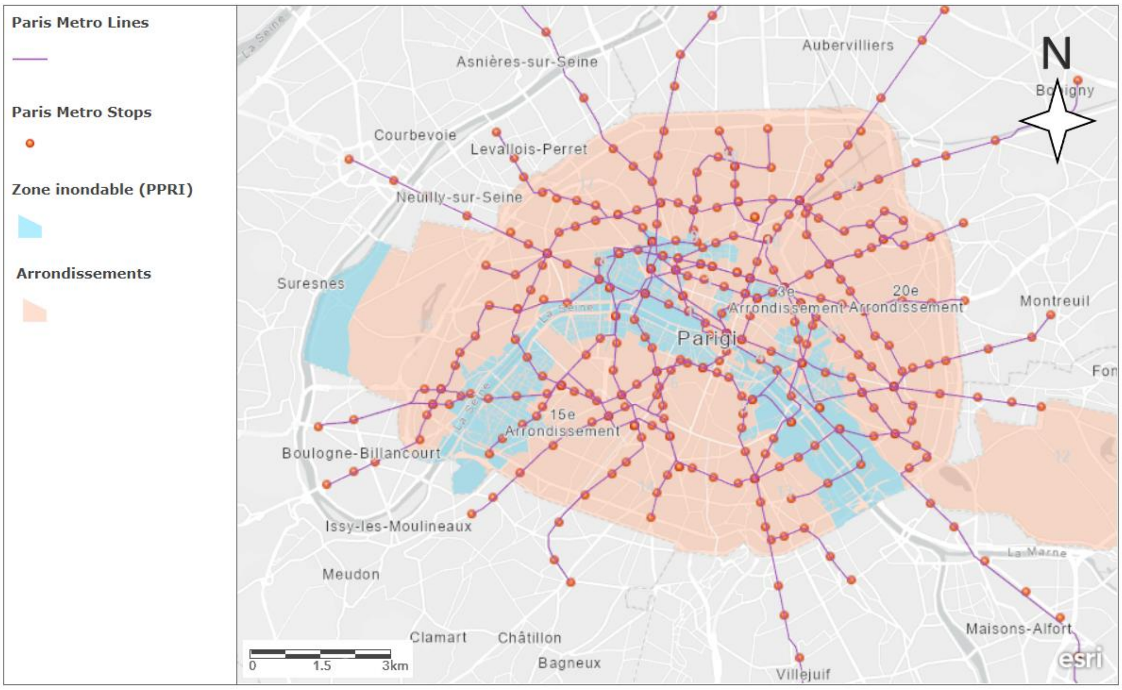


Figure 57 Subway lines and stops in Paris overlapped to the flooding zone according to PPRI (extracted from: https://www.geoportail.gouv.fr)

In Figure 58, a map of the area where the electric supply system would be weakened by the flood is shown. As we can wee, the area almost corresponds to the PPRI, it means that probably the city is equipped with good redundancy in supply network and not a strong interdependency.

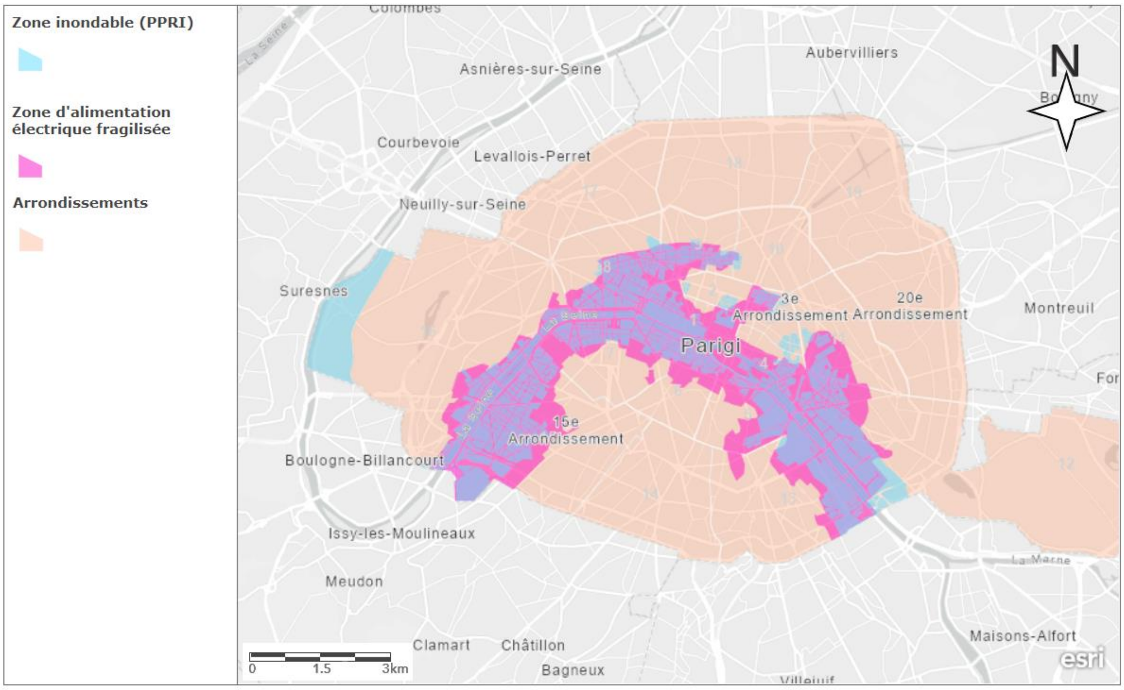


Figure 58 Area where the electric supply network would be weakened by the flood compared to the PPRI (extracted from: https://www.geoportail.gouv.fr)

PUBLIC CRITICAL FACILITIES

In Figure 59 we can see that only a very small part and in particular in the south-west area close to Seine river, schools are exposed to flood risk according to PPRI.

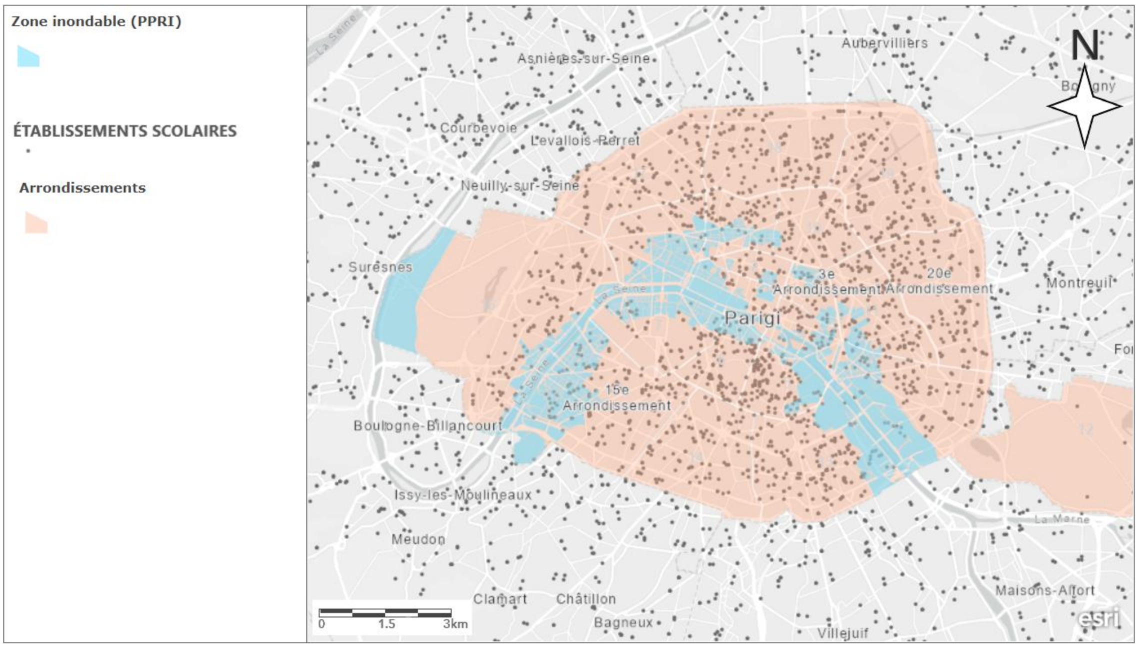


Figure 59 Schools and educational facilities in Paris overlapped to PPRI map (extracted from: https://www.geoportail.gouv.fr)

In Figure 60, the location of police stations is shown. In this case a large part of these critical facilities, fundamental for crisis management, is located in risky zone. This factor can cause several systemic problems in rescuers activities in case of a huge flooding.

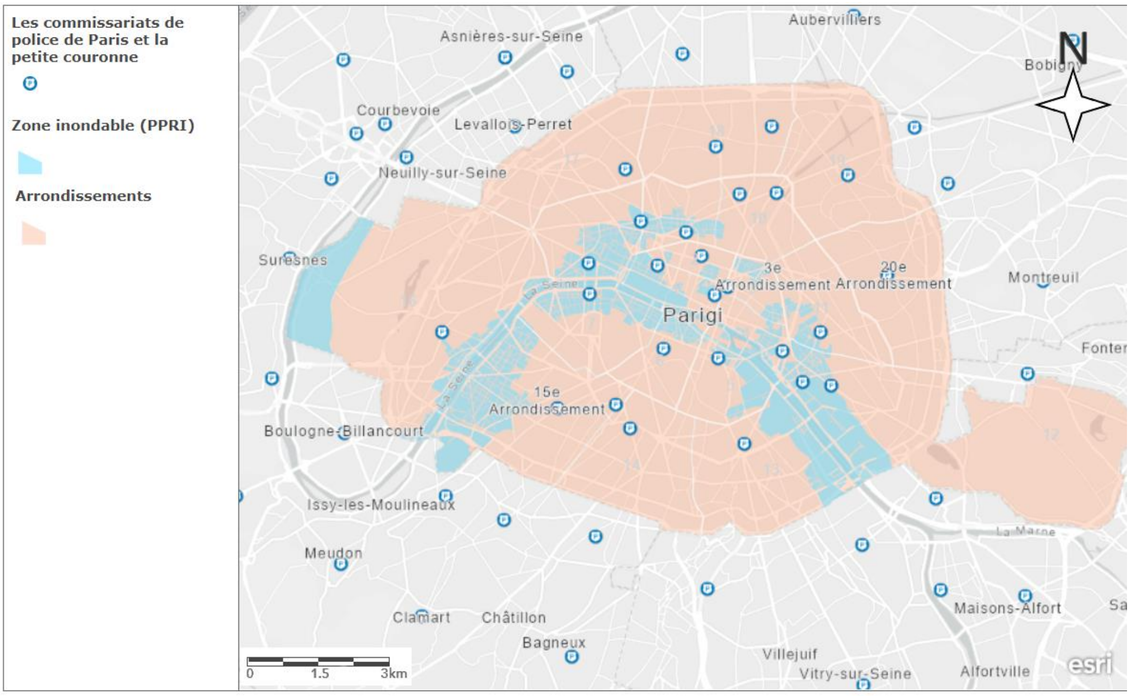


Figure 60 Police stations location in Paris overlapped to PPRI map (extracted from: https://www.geoportail.gouv.fr)

In Figure 61 health centres facilities locations are shown. There is a huge redundancy and except for the south-west area (same for schools and public housing), they are almost all outside the risky area.

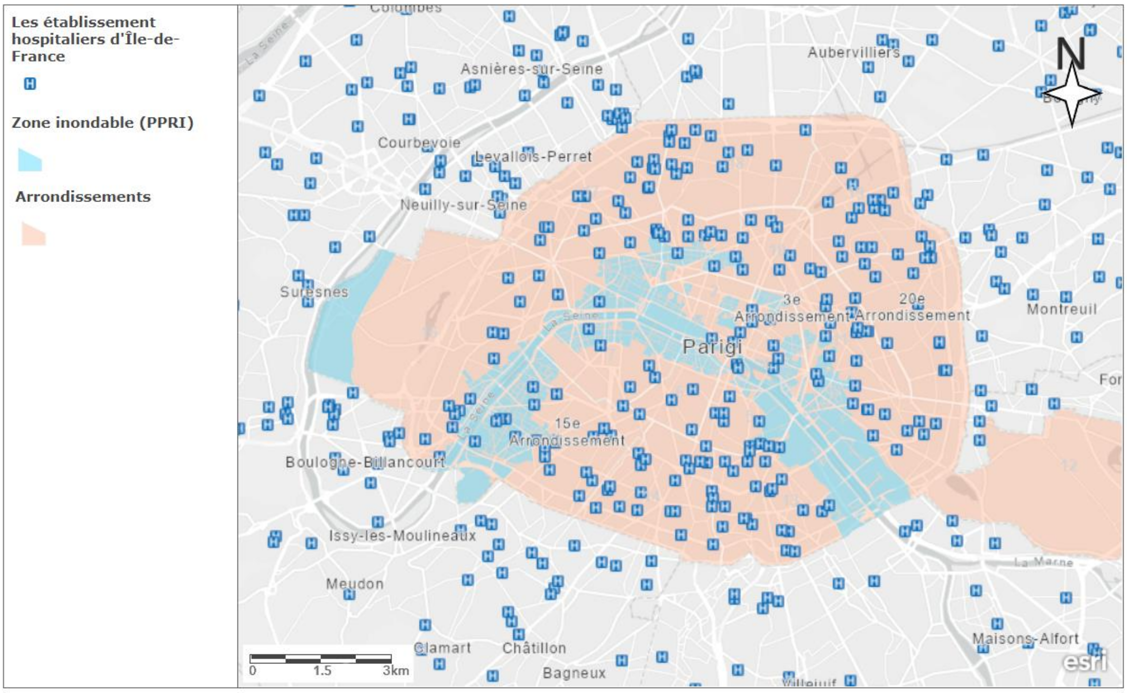


Figure 61 hospitals and health facilities in Paris overlapped to PPRI map (extracted from: https://www.geoportail.gouv.fr)

CULTURAL HERITAGE

In Figure 62, we can see that the most part of the historical attractions are in risky area. This is mainly due to the fact that the flooding zone according to PPRI is coincident with a large part of the historical city centre. In fact, Paris was originally born from Ile de la Cité, the small island in the middle of the Seine, and developed initially along the river and only later enlarging its area to zones farer from the Seine.

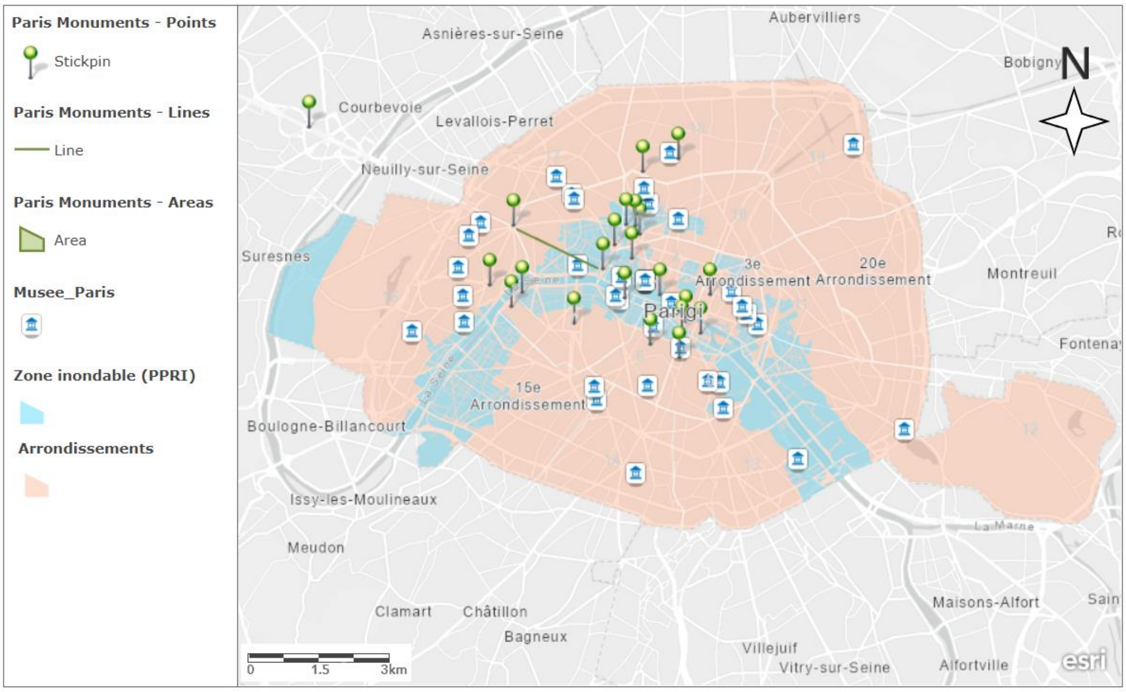


Figure 62 Cultural heritage exposure in Paris (extracted from: https://www.geoportail.gouv.fr)

NATURAL SYSTEM

In Figure 63, natural areas exposed to flood risk are shown. As we can see the green areas at risk are only a few. This is due to the fact that Paris is poorly equipped with gardens and green area, especially in the central area which is heavily urbanised. The only bigger garden which is present in the risky zone is “The Garden”, where the Tour Eiffel is located.

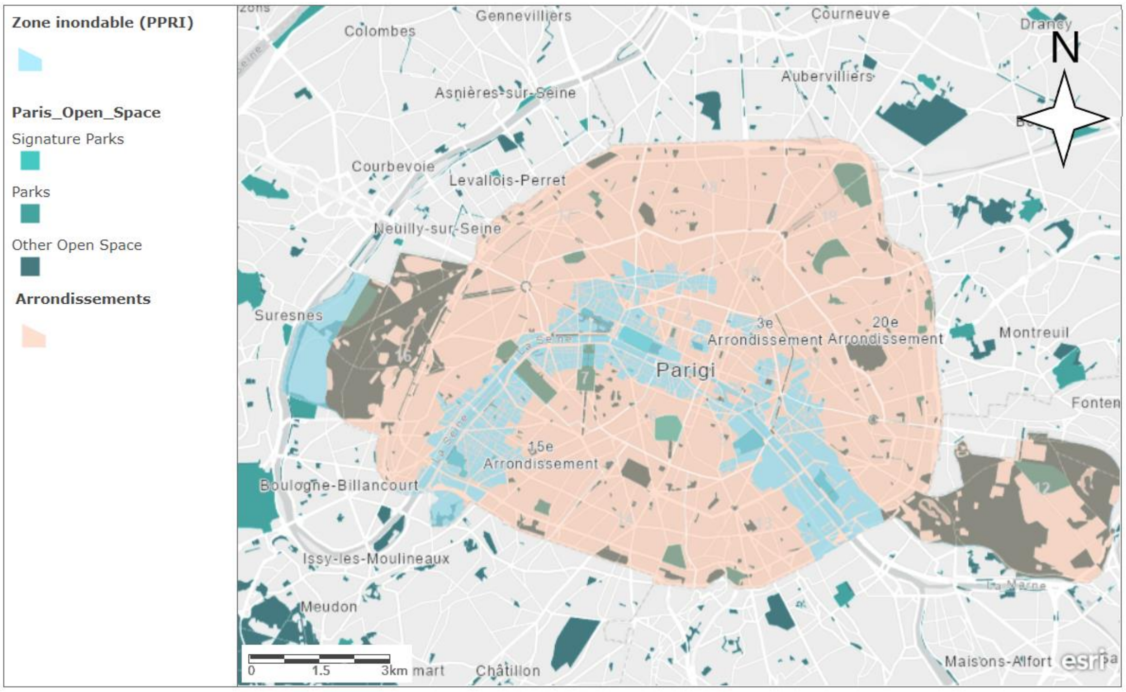


Figure 63 Natural areas exposed to flood risk in Paris (extracted from: https://www.geoportail.gouv.fr)

6.9 Conclusion

France put much funding in the prevention from flood consequences, but the post-disaster results still remain very costly and they affect a large number of people. It means that once again there is a lack of correspondence between prevention "on paper" and prevention "in real".

7. Final considerations

The analyses of the two study cases showed that France is not new to natural disaster and in particular flooding, and the institutions put in place several mitigation measures, regulations and funding to face this kind of crises. The reactiveness to these challenges is anyway still not enough to avoid the significant amount of damages affecting private and public sectors. In particular, the gap between legislation and operative applications is significant and quite evident in situations, such as flooding, when a correct crisis management could make a different in the cumulation of post-event damages.
The collection of detailed data about direct and indirect damages at both short and long term can become a basis for innovative mitigation strategies and a compass to focus efforts in the most effective fields.

7.1 Faced challenges

To achieve its goals, Lode project is facing many challenges that drive countercurrent.

Challenges about partners and stakeholders:

- There is will a lack of trust from stakeholders in sharing sensible data. The main data holders about post-disaster damages in France are private insurances which are not so collaborative in sharing information. For example, a collaboration was asked to MRN but they refused to share the part of their database concerning the study cases.

  The reasons for such a reluctance in sharing could be:
  - fear of how data could be used by concurrencies against their interest in case they would obtain them.
  - not fully comprehension of their advantages in sharing such a big amount of valuable information.
  - luck of trust in the confidentiality of partners in holding sensible data.
- Difficulties in stimulating the stakeholders' interest if their profit is not direct and immediate.
- Difficulties in organising a European project with members spread around Europe. Meetings in person are complicated to organize and online meetings can be a deficit for a good communication.

- Language limits during project discussions due to a majority of partners, especially stakeholders, non-native English speakers.

Challenges about data:

- Data provided to public are extremely general and only in aggregated form. There are detailed data about the event itself (mainly precipitation data) but only rough estimations about the post-event phase, damages and losses.
- The delineation of the perimeter of the affected areas becomes a complex task due to the severe lack of information.
- In data referring to damages cost, it is rarely specified if the numbers are referred to the total amount or only to the insured assets.
- Data from different countries often not comparable due to different languages, unit of measure, IT systems for data recording, loss indicators, terminologies for peril classification and data aggregation methods (De Groeve, et al., 2014).
- Lack of guidelines and standards at local, national and international levels for loss data collection and recording, especially for human and economic losses (De Groeve, et al., 2014).
- Some data are detectable from newspapers, but often different articles are mutually contradictory. In addition, the references of those data are not generally specified, and they are said by public authorities not always directly involved in the disaster recovery process.

7.2 Future challenges

LODE project is ambitious and will require surely further elaborations and efforts. One of the most important ambition is the idea of constructing a common structured database for all EU Member States, consultable from each state and meant to shearing information and data. With a better structured framework, also the collection of future data can be optimized and can help Civil Protection or local authorities in this process. Enlarging the horizon to new partners and stakeholders, with at least one for each European Country, would be a big first step toward a future were data are more easily available for implementing research and decision-making strategies.

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Appendix 1: Definitions

Definitions

- RISK

  It is a function of Hazard, Vulnerability and Exposure

- HAZARD (2018)

  characteristics of the dangerous agent (phenomena)

- VULNERABILITY

  propensity to damage, fragility

- EXPOSURE

- DISASTER (Source: UNISDR, 2009)

  A disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope with using its own resources.

- DISASTER RISK (Source: UNISDR, 2009)

  The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.

- DISASTER IMPACT (Source: NRC, 19993)

  The impact of a disaster represents the overall effects, including positive and negative effects, of the disaster.

- DISASTER DAMAGE (Source: ECLAC, 20034)

  Total or partial destruction of physical assets existing in the affected area.

- DISASTER LOSS (Source: NRC, 1999)

  The losses of a disaster represent marked-based negative economic impact. These consist of direct and indirect losses.

Appendix 2: *Sendai Framework for Disaster Risk Reduction 2015-2030*

Global target A: Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality between 2020-2030 compared with 2005-2015.	
A-1 (compound)	Number of deaths and missing persons attributed to disasters, per 100,000 population.
A-2	Number of deaths attributed to disasters, per 100,000 population.
A-3	Number of missing persons attributed to disasters, per 100,000 population. *The scope of disaster in this and subsequent targets is defined in paragraph 15 of the Sendai Framework for Disaster Risk Reduction 2015-2030 and applies to small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters caused by natural or man-made hazards, as well as related environmental, technological and biological hazards and risk.*

Global target B: Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020-2030 compared with 2005-2015.	
B-1 (compound)	Number of directly affected people attributed to disasters, per 100,000 population.
B-2	Number of injured or ill people attributed to disasters, per 100,000 population.
B-3	Number of people whose damaged dwellings were attributed to disasters.

B-4	Number of people whose destroyed dwellings were attributed to disasters.
B-5	Number of people whose livelihoods were disrupted or destroyed, attributed to disasters.

Global target C: Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030.	
C-1 (compound)	Direct economic loss attributed to disasters in relation to global gross domestic product.
C-2	Direct agricultural loss attributed to disasters. *Agriculture is understood to include the crops, livestock, fisheries, apiculture, aquaculture and forest sectors as well as associated facilities and infrastructure.*
C-3	Direct economic loss to all other damaged or destroyed productive assets attributed to disasters. *Productive assets would be disaggregated by economic sector, including services, according to standard international classifications. Countries would report against those economic sectors relevant to their economies. This would be described in the associated metadata.*
C-4	Direct economic loss in the housing sector attributed to disasters. *Data would be disaggregated according to damaged and destroyed dwellings.*
C-5	Direct economic loss resulting from damaged or destroyed critical infrastructure attributed to disasters. *The decision regarding those elements of critical*

	infrastructure to be included in the calculation will be left to the Member States and described in the accompanying metadata. Protective infrastructure and green infrastructure should be included where relevant.
C-6	Direct economic loss to cultural heritage damaged or destroyed attributed to disasters.

Global target D: Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030	
D-1 (compound)	Damage to critical infrastructure attributed to disasters.
D-2	Number of destroyed or damaged health facilities attributed to disasters.
D-3	Number of destroyed or damaged educational facilities attributed to disasters.
D-4	Number of other destroyed or damaged critical infrastructure units and facilities attributed to disasters. *The decision regarding those elements of critical infrastructure to be included in the calculation will be left to the Member States and described in the accompanying metadata. Protective infrastructure and green infrastructure should be included where relevant.*
D-5 (compound)	Number of disruptions to basic services attributed to disasters.
D-6	Number of disruptions to educational services attributed to disasters.
D-7	Number of disruptions to health services attributed to disasters.
D-8	Number of disruptions to other basic services attributed to

	disasters. *The decision regarding those elements of basic services to be included in the calculation will be left to the Member States and described in the accompanying metadata.*

Global target E: Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020.	
E-1	Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030.
E-2	Percentage of local governments that adopt and implement local disaster risk reduction strategies in line with national strategies. *Information should be provided on the appropriate levels of government below the national level with responsibility for disaster risk reduction.*

Global target F: Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030.	
F-1	Total official international support, (official development assistance (ODA) plus other official flows), for national disaster risk reduction actions. *Reporting of the provision or receipt of international cooperation for disaster risk reduction shall be done in accordance with the modalities applied in respective countries. Recipient countries are encouraged to provide information on the estimated amount*

	of national disaster risk reduction expenditure.
F-2	Total official international support (ODA plus other official flows) for national disaster risk reduction actions provided by multilateral agencies.
F-3	Total official international support (ODA plus other official flows) for national disaster risk reduction actions provided bilaterally.
F-4	Total official international support (ODA plus other official flows) for the transfer and exchange of disaster risk reduction-related technology.
F-5	Number of international, regional and bilateral programmes and initiatives for the transfer and exchange of science, technology and innovation in disaster risk reduction for developing countries.
F-6	Total official international support (ODA plus other official flows) for disaster risk reduction capacity-building.
F-7	Number of international, regional and bilateral programmes and initiatives for disaster risk reduction-related capacity-building in developing countries.
F-8	Number of developing countries supported by international, regional and bilateral initiatives to strengthen their disaster risk reduction-related statistical capacity.

Global target G: Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.	
G-1 (compound G2-G5)	Number of countries that have multi-hazard early warning systems.
G-2	Number of countries that have multi-hazard monitoring and forecasting systems.

G-3	Number of people per 100,000 that are covered by early warning information through local governments or through national dissemination mechanisms.
G-4	Percentage of local governments having a plan to act on early warnings.
G-5	Number of countries that have accessible, understandable, usable and relevant disaster risk information and assessment available to the people at the national and local levels.
G-6	Percentage of population exposed to or at risk from disasters protected through pre-emptive evacuation following early warning. *Member States in a position to do so are encouraged to provide information on the number of evacuated people.*