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Current state of vulnerability reduction approaches on buildings subject to flooding

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SYNTHESIS

Current state of vulnerability reduction approaches on buildings subject to flooding

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ABSTRACT

River flooding is a permanent threat to goods and people in floodable areas. The 2007 European Framework Directive concerning flooding changes hazard management. A new direction was provided: live with water. It deals with vulnerability reduction and land resilience improvements. Instead of seeking to prevent flooding, it occurs and actions are taken to limit its impact on buildings. The key aspect is to minimize damage and the time required for re-occupation. Two contradictory and complementary solutions are the water exclusion and water entry strategies. Either or both solution can be implemented. This converts into technical measures on buildings. Recent measures have been put in place in France. There is currently no general feedback about the different approaches. However it appears that both are efficient but that the economic return varies considerably according to the frequency of flooding and hence the amount of avoided damages. Moreover there are many other constraints in respect of this new direction. Some people do not feel concerned or rely on financial compensation in the event of a natural disaster. People who do feel concerned and who wish to carry out works are assisted with grants but must first bear the brunt of paying in advance.

Key words:

Risk, hazard, critical issue, vulnerability, resilience, mitigation, flooding, dwelling

RÉSUMÉ

Les inondations liées aux crues de rivière sont une menace permanente qui plane sur les biens et les personnes. La directive européenne inondation de 2007 fait évoluer la notion de gestion du risque. Une nouvelle orientation est donnée afin de réduire la vulnérabilité et d'augmenter la résilience des territoires. Au lieu de limiter l'aléa en empêchant l'inondation, on laisse l'inondation se produire et des mesures sont prises pour limiter son impact sur le bâti. Réduire la vulnérabilité signifie minimiser les dommages sur le bâti et augmenter la résilience, améliorer la capacité à se relever d'un sinistre. Il existe trois approches. Il s'agit soit d'empêcher l'eau d'entrer donc éviter ou résister à l'eau soit de la laisser pénétrer dans le bâtiment et de prendre des dispositions pour limiter son impact. Ces approches sont à la fois contradictoires et complémentaires. Le choix d'adopter l'une ou l'autre des approches ou de les combiner se fait à partir d'un diagnostic de la vulnérabilité du bâti face au type de crue qui peut l'impacter. Plusieurs mesures techniques d'adaptation du bâti sont applicables en fonction de la stratégie adoptée. Il existe peu de retour sur expérience car peu de démarches ont été entreprises pour l'instant. Les freins à l'application de ces démarches sont nombreux : le manque de données pour établir un scénario de crue et un diagnostic réalistes, l'avance du coût des travaux avant de toucher les subventions, la part éventuelle des frais à la charge des particuliers. La rentabilité d'un tel investissement n'est pas facilement calculable dépendant de la fréquence imprévisible des inondations.

Mots clés :

Risque, aléa, enjeu, vulnérabilité, résilience, mitigation, inondation, habitation

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INTRODUCTION

In France flooding is the most widespread natural hazard. About one third of municipalities (of which 300 large cities) is threatened by floods (Les risques majeurs, 2011a). The annual amount of flood damages exceeds 250 million euros. It amounts to 80% of the damage cost incurred as a result of natural disasters (Techniques de l'ingénieur, 2013). Flood hazard management is called for. It is currently governed by: i) law number 2010-788 of 12 July 2010 and ii) decree number 2011-277 of March 2, 2011, translating the Floods Directive (FD) of October 23, 2011 into French law. The new strategy is based on the concepts of vulnerability reduction and land resilience improvements. These theoretical orientations are being adopted in France. They must be best suited to the local land characteristics (Parlement européen, 2007). Some pioneering lands implemented practical measures of vulnerability reduction such as the SMAGE (Syndicat Mixte d'Aménagement et de Gestion Equilibrée des Gardons). The SMAVD (Syndicat Mixte de la Vallée de la Durance) combines 78 municipalities spread over four French departments (named Alpes-de-Haute-Provence, Hautes-Alpes, Vaucluse & Bouches du Rhône) and the PACA region. This organization implements a river contract that incorporates a global approach for the Durance river management. This Alpine river in the Mediterranean basin is a tributary of the Rhône river strongly shaped by man and characterised by flash floods. One objective of the river contract targets flood hazard reduction. It comprises the old flood protection works restructuring in order to give back morphologic balance and mobility to the river (Doddoli et al., 2015). Nowadays the SMAVD engages in a PAPI procedure (Programme d'Actions de Prévention des Inondations) and thus will locally implement the Floods Directive. Instead of concentrating actions on flood hazard prevention, the idea now is to act on building issues too. This review has been written in the context of PAPI development. In the first instance, hazard, vulnerability and resilience are defined. The second part deals with three vulnerability reduction strategies, their efficiency and economic return. The third and last part details the constraints to vulnerability reduction measure implementation. The conclusion sets out to suggest an approach that may suit the Durance river basin.

DEFINITIONS

To properly understand the new flood risk management strategy, it is necessary to define risk, vulnerability, resilience and mitigation.

Risk is a combination of two factors (see figure 1). Natural hazard is the possibility that the phenomenon occurs. This review deals with river floods. Flooding consists of an overflow of water above the riverbed in usually dry lands (Gautier, s. d.). Every person, good, equipment or environment which could be affected by the consequences of flooding is considered as a critical issue. There is a risk when the hazard happens in an area with critical issues. In this review, a flood risk exists when water threatens people, their goods and economic activities by submerging anthropized land.

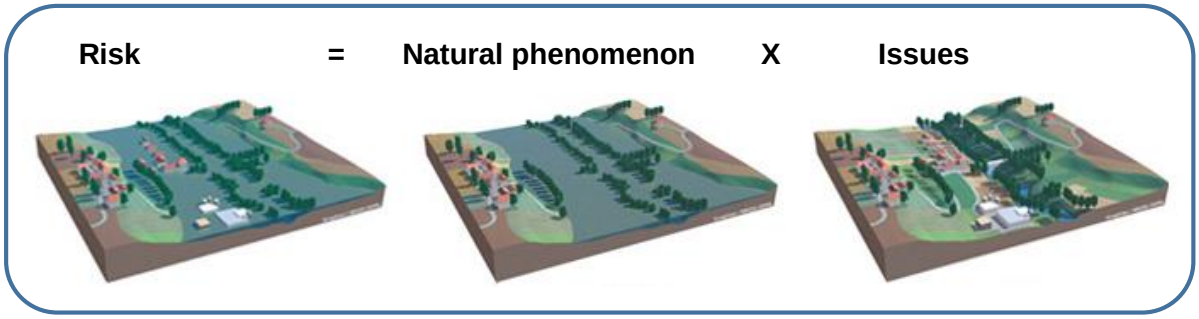

Figure 1 – Risk concept
Source: var.gouv.fr

Vulnerability is the more or less sensitive nature of what can be impacted by a phenomenon. Building vulnerability depends on building type, its location, its inherent resistance and technical equipment. The vulnerability of a person results from his or her risk awareness, behaviour, health and their ability to seek shelter. The level of risk exposure makes a person more or less vulnerable. It's different if the person is directly exposed, sheltered, a refugee, awake or asleep (Les risques majeurs, 2009). Vulnerability degree also varies with the type of flood (flash or gradual, wide or localised, light or serious).

Resilience is defined as the ability of quickly rebuilding after a disaster. For a company, it is the ability to restart the activity that was usual before flooding. For a building, it is the ability of returning to its usual role. For a person it's the ease of getting his or her health back. Land resilience affected by flooding can be slowed down by an insufficient number of companies capable of rehabilitation works and a staff, equipment and raw material shortage (CEPRI, 2010).

Mitigation is the implementation of measures designed to reduce damages due to natural hazard (Les risques majeurs, 2009).

To put it in a nutshell, to reduce land vulnerability is to make issues more prepared, stronger and equipped to deal with the phenomenon. To improve land resilience to flood risk is to increase its adjustment to the phenomenon and therefore its rapidity to re-establish its pre-crisis working.

THREE STRATEGIES OF VULNERABILITY REDUCTION

Current assumptions linked to climate change and urban growth lead to believe that there will be an increase of the frequency of floods: lands are more often exposed and more vulnerable than before.

Preventing land to be submerged at all costs is illusory. For many years the traditional approach was based on the layout of rivers through channeling and the building of embankments. It has been a long time that the classical and historical strategy was based on the layout of rivers by their channelling and the building of embankments. In reality, no one is protected from enduring a rise in the water level higher than the embankment's height. Protective structures are always designed for a given risk level that can be exceeded. Once a building is damaged, its rehabilitation has a steep cost and a long timeframe (CEPRI, 2010). The new strategy of risk management is to give space to water and accept its occasional presence. Because of this, reducing building vulnerability and increasing land resilience enables us to decrease the extent of the damage. Three major principles exist to reduce building vulnerability: keep the water out, let the water in or avoid water altogether (see figure 2).

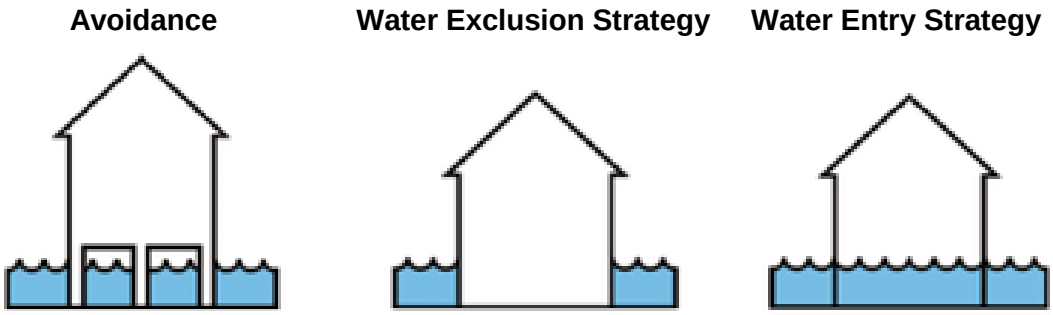

Figure 2 - Three strategies of vulnerability reduction
Source: fleuve-charente.net

AVOIDANCE

Avoiding water with a proper architectural style has proved its worth for new building construction and renovation (CEPRI, 2009). For instance, the low-level floor can be placed above the high water level by creating a crawl space or by building on poles or by raising land. In France, the touristic city of Noirmoutier-en-Ile has thought about the way to adopt a resilient urban planning. It launched the competition « Imaginer l'habitat noirmoutrin de demain » (which means: imagine the future noirmoutrin housing) with the CAUE of Vendée department (Conseil d'Architecture d'Urbanisme et de l'Environnement). Students and architects imagined resilient housing that could fit in with the island's architectural identity. The first prize was assigned to a project called « La Goiseuse a de bonnes bottes » (illustrated in figure 3). The idea of a house on piles allows hydraulic transparency in the event of marine submersion (Les risques majeurs, 2015).

Figure 3 – « La Goiseuse a de bonnes bottes »
Source: risquesmajeurs.fr

In the Netherlands, floating, amphibious or flood houses exist. Water forms a buildable area with districts of floating houses and footbridges. Dordrecht city, located at the confluence of four rivers and close to an estuary, chose an innovative solution. Amphibious houses allow to continue urban growth without making new buildings vulnerable to floods. These houses are tied to piles rooted in the earth. They rest sometimes on the floor sometimes on water during plain flooding (Eudes, 2008). In the United Kingdom, an amphibious house designed by the Baca architects agency (see figure 4) is floating in its concrete basin in the event of flooding (Galoffre, 2015).

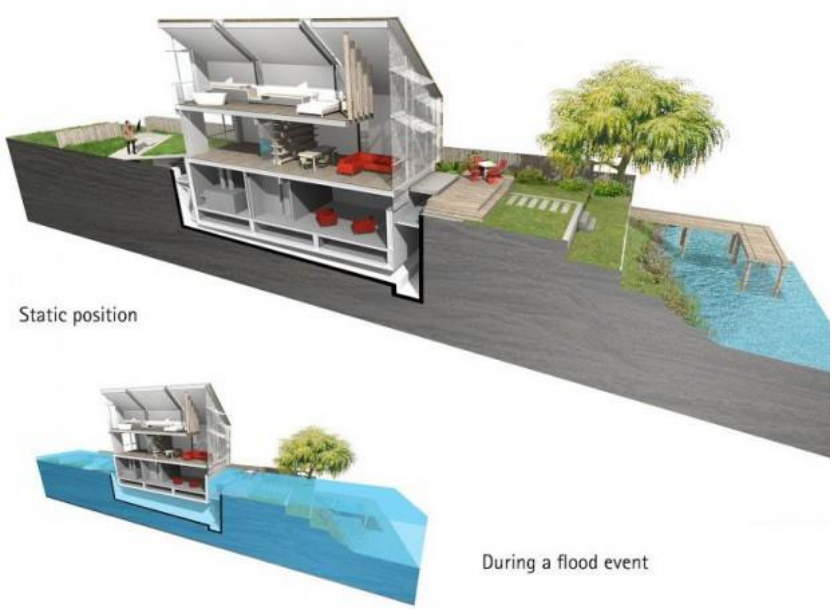

Figure 4 – Amphibious house of Baca architects agency
Source: batiactu.com

WATER EXCLUSION AND ENTRY STRATEGIES

Water exclusion or entry strategies seem to be the most relevant solutions for existing buildings.

Water exclusion strategy consists of attempting to keep water outside the building. Permanent or temporary measures can be used. Permanent measures would be to close water pathways through basements, openings, wastewater removal systems and walls. Temporary measures would be door boards or sand bags. For example, a watertight barrier that can be taken apart protects the headquaters of the AFD (Agence Française de Développement) from floods of the river Seine in Paris (see figure 5). It is made of aluminium, stretches for 300 meters and is tilted at 45 degrees. This system called K-system has been designed by the German company IBS (Chabreuil, 2010).

Figure 5 - K-system in front of AFD
Source: info.expoprotection.com

The water entry strategy allows water through property. It limits the damage and the period required to return to normal functioning. For example, a restaurant owner arranged his kitchen on the first floor in Laroque city which is frequently submerged by the river Hérault. In the dining room on the ground floor, the counter is in concrete, doors are in PVC and the electrical installation is raised. Thus activity recovery is fast post flooding (Carrere, 2015). In both strategies (water entry or exclusion), a shelter space upstairs is an efficient way to reduce peoples' and their goods' vulnerability (see figure 6). Its height must be sufficient to be safe. It has essential equipments available (drinking water supply, sanitation, heating, hot water supply) and allows for the potential storage of goods (CEPRI, 2010).

Figure 6 - Shelterspace
Source: developpement-durable.gouv.fr

According to the CEPRI (2010), the water exclusion strategy is suitable for a flood with a water height of less than one meter and lasting less than 48 hours. Beyond it, there is a risk of structural damage. It is therefore better to let the water in when the water height is over one meter and when the flood lasts for more than 48 hours. The CEPRI guide book (2010) draws up a list of measures of water exclusion and entry strategies. The efficiency of these measures

is given concerning resilience improvements and vulnerability reduction of people and goods. The flood characteristics for which the measures suit are also defined.

Regarding companies, the CEPRI (2012) classifies the practical measures in five categories. 40 to 60% of total damage cost due to flooding is related to economic activities (CEPRI, 2012). The organizational emergency and restart measures are efficient, inexpensive and not very demanding. The permanent raising height and relocation of goods have high costs, they are binding every day but are very efficient. Permanent adjustment of activity working leads to high confines and their efficiency is mixed. Moreover, measures intended to resist have a very fluctuating cost and their efficiency is limited to floods with a water height of less than one meter and lasting less than 48 hours.

VIABILITY OF THE THREE STRATEGIES

The viability of the three strategies can be ordered as follows: water avoidance is more frequently profitable than water exclusion strategy, which is itself more often profitable than the water entry strategy. For detached houses, the water exclusion strategy seems to be profitable in most cases: for frequent, middle or infrequent floods with a return period of less than 400 years. Beyond a return period of 400 years, flooding is so occasional that water avoidance becomes more expensive than the profits (avoided damage cost). The water exclusion strategy is interesting for floods with a return period of less than 50 to 100 years and water entry strategy for floods of a return period of less than 25 years (CEPRI, 2009). The CEPRI draws our attention to the United Kingdom and Netherlands' debatable results because indirect damages are not taken into account (for example the cost of rehousing). Using these results should be done with some caution because French buildings are different to those in the United Kingdom and the Netherlands.

REPORT ON THE FRENCH APPROACH ON EXISTING BUILDINGS

In France, vulnerability reduction strategies are in their early stages. Hardly any territories have any feedback on the topic. The SMAGE carried the first approach called ALABRI (Accompagnement à L'Adaptation de votre Bâti au Risque Inondation) which means accompanying the adaptation of your building to flood hazard that other lands took over the approach by adjusting it to their territory. The approach can be implemented on housing, public buildings and economic activities. First the buildings exposed to flood hazard must be identified. The team named by the project initiator convinces the owners to reduce the vulnerability of their goods, assesses it with a diagnosis, identifies the measures that can be taken and receives grants on behalf of the owner so that he can complete the adapted works (Le SMAGE des Gardons, 2015). In June 2015, the French department of the Gard prepared a map allowing to see the progress of the municipalities' activity with mitigation's obligation (Le Gard, 2015). However, it seems that no assessment listing the PAPI programs with a vulnerability reduction section exists and indicating the state of undertaken approaches at the national scale.

IDENTIFICATION OF VULNERABLE CONCERNS

Identifying issues exposed to a risk is possible by knowing the spatial intensity of hazard on the one hand and the issues' location on the other. In France, the mapping of the flood risk prevention plan (PPRI) shows three coloured zones depending on the level of risk exposure for the 100-year floodplain at least or the most negative historic flood. If the red area forbids any building, the blue area authorises it subject to the respect of rules demanding adaptation to flood risk. Finally, the white area represents building land without any restrictions concerning flood risk. The Local Town Planning (PLU) and the Land Use Plan (POS) which govern the construction remind the obligations written in the PPRI (Miget, 2010). The PPRI (official

document issued by the public authority) exists where urban growth must be strictly ruled. The areas with strong issues, significant urban pressure crossed by big rivers are systematically covered by a PPRI. On the other end, every submersible area just isn't known. It occurs that no PPRI exists in a small municipality without urban growth crossed by a small river even though buildings located along the river can be submerged (Olivier Sauron, 2015). It is then possible to use the Atlas of the flooded areas (AZI) although its spatial resolution is limited to 1/25000th against 1/10000th for the PPRI (below that scale, the map is no longer viewable). One or the other of these maps crossed with databases on construction enable experts to determine (with more or less accuracy) buildings threatened by flooding. The joint syndicate ABCèze (Syndicat Mixte d'Aménagement de la Cèze) thus identified 40 public buildings, 3500 housings and about 900 companies in submersible areas (Sauron, 2015). The SMBFH (Syndicat Mixte du Bassin du Fleuve Hérault) took an inventory of 20 000 buildings in submersible areas on its catchment area (Carrere, 2015). The SYBLE (Syndicat du Bassin du Lez) counted 9900 vulnerable buildings of which 5700 housings (Boursiac, 2015).

Once the vulnerable buildings are registered, different circumtances exist. In red and blue areas covered by a new generation PPRI established after 2002, the owners are subjected to mitigation obligation within 5 years after PPRI signature. In areas not covered by a PPRI or covered by an older PPRI, no obligation exists for owners. On the Hérault river's basin, 78 municipalities have a PPRI but only 26 of these have a recent PPRI including obligations on vulnerability reduction. None of the buildings of these 26 municipalities are located in submersible areas while the other 52 municipalities own buildings in submersible areas (Carrere, 2015). In the three cases (old generation PPRI, new generation PPRI or PPRI lack), the owners aren't very often aware of the risk and are certainly totally ignorant of the law.

OWNERS' AWARENESS

A vulnerability reduction approach cannot succeed without encouragement. The project initiator must firstly target its public to be efficient. The CEPRI (2012) listed the companies to canvass as a priority (including the ones accommodating sensitive persons, the ones contributing to crisis management, the ones that could be responsible for additional damage etc.). It recommends clear and succinct information which explains the objectives of damage amount's decrease and return on normal functioning period's shortening for the company, farming or housing. It is firstly necessary to convince councillors so that they transmit the idea themselves and implement the approach on public buildings. On the other hand, it is essential to raise awareness among owners and persuade them to benefit from this approach. The intervention's promotion can be carried out thanks to information brochures, in the municipality periodical or even during public meetings with councillors (Sauron, 2015 ; Garcia, 2015). A partnership with the chambers of commerce and industry can be built to reach as many companies as possible. The SMMAR (Syndicat Mixte des Milieux Aquatiques et des Rivières) of the Aude department already engaged in such a partnership (Mathieu-Subias, 2015). One can also alert through professional newspapers. Insurers and notaries are also able to work towards communication to owners (CEPRI, 2012). Risk memory and exposure levels make the arguments more or less easy.

ACCOMPANYING

Once the owners have been duly persuaded, it is necessary to guide them to go forward. The owners are supported by the team of the project initiator in order to draw up a diagnosis of vulnerability. This diagnosis leads to the choice of adapted measures for their situation, the evaluation of the works' cost, the acquisition of grants and the consultation of firms (Le SMAGE des Gardons, 2015).

Vulnerability diagnosis

A vulnerability diagnosis must firstly be undertaken. Vulnerability degree to flood risk is rarely known. There is currently no existing database on this parameter depending on many factors. One should resort to a diagnosis on a case-by-case basis. It is a real door-to-door task because every flood scenario is different in every place and each building has its own characteristics. The job is to draw up a list of compulsory and advised works, to estimate their cost, to determine the amount of grants to know how much the owner needs to invest.

The base flood in the PPRI gives basic information (water height and speed) of the diagnosis. Potential damage is then identified. Technical and organisational solutions need to be found to act on the building's weaknesses and therefore limit the damages.
At the end of the diagnosis, the owner can choose to implement the measures, to give up the building or even do nothing (CEPRI, 2010). If works aren't commissioned by the PPRI and the owner doesn't wish to invest, the approach often remains inactive.

Work phase

The next step consists of consulting companies so that they quote for the work. From their price, the ALABRI team writes the request for grant's file on behalf of the owner. Although grants exist, a part or the totality of work's cost must be borne by the owner. He must pay for the work beforehand and will receive grants afterwards (Le SMAGE des Gardons, 2015).

Two financing stages

The cost of vulnerability reduction approach is very variable depending on its extent, length and scope (CEPRI, 2012). 12,5 million euros were allocated to farming in the Rhône plan 2007-2013 (plan Rhône 2007-2013) against more than 20 million euros to economic activities in the Loire plan 2007-2013 (plan Loire 2007-2013). The CEPRI (2012) gives numerous examples of costs for economic activities. It particularly indicates the cost of intervention's promotion on companies in the range of thousands of euros. In order to handle the global cost of the intervention, several funding sources exist. One can distinguish two stages.

The first one concerns the project initiator (for example a municipality or river basin committee). The latter asks to mobilise the PAPI's fund dedicated to vulnerability reduction inside the flood risk prevention section for which several funders are engaged. In the Aude department for instance, the financial package foreseen by the PAPI 2 for diagnosis on companies and public buildings equals one million euros financed to 30% by Europe, 50% by the state and 20% by the SMMAR (Mathieu-Subias, 2015). In the Loire department, a financial package of 9 million euros financed to 50% by Europe and 50% by regional authorities is allocated to the achievement of 3000 diagnoses until the end of 2013 (CEPRI, 2012). Such a fund allows the project initiator to partly or totally finance the promotion and accompanying of owners depending on the financers' commitment. For example, a diagnosis of an economic activity is financed to a maximum of 50% by the Barnier fund (state fund) only if the project owner is a regional authority or a grouping of them and moreover only if the company is located on a municipality covered by a prescribed or approved PPRI (CEPRI, 2012). On the river Loire basin, the diagnosis is free for entrepreneurs in the framework of the Loire plan because the risk of economic loss is severe in the event of flooding (Les risques majeurs, 2011b). Thus, the diagnosis is most of the time free for building owners.

The second financing stage relates to works. Work grants vary from one land to another and so do the criteria for eligibility set by financers. The state finances the amount of works to 40% for housing with a financial ceiling equal to 10% of its market value whatever its location (Le SMAGE des Gardons, 2015). On the river Aude's basin, the PAPI 2 provides €500 000 for works on vulnerability reduction of companies with funding rates of 20% by the state and 40% by Europe. €500 000 are kept for works on public buildings financed to 20% by the state, 20%

by Europe, 20% by the department and 20% by the region (Mathieu-Subias, 2015). Maeva Carrère (2015) explains that only cases built by a grouping of municipalities are eligible for the European Regional Development Fund (ERDF) and that the region of Languedoc-Roussillon only finances works supported by public projects. One can thus become aware of the strong variability of grants that a building owner can claim depending on the building type (housing, economic activity, public building), on the compulsory or advised characteristic of the measure and on the building location. The regions and departments with the highest budgets are in fact those most exposed to flood damage.

VULNERABILITY REDUCTION BRAKES

The basin committees who put in place a vulnerability reduction approach are confronted with several problems.

AWARENESS DIFFICULTIES

During the promotion of vulnerability diagnoses, it is difficult to reach a majority of concerned people. The flooding of October 2014 in the Lez river basin affected around 700 private buildings in the municipalities of Grabels and Juvignac. The SYBLE deployed the ALABRI approach to these two municipalities as a priority. The diagnosis' promotion goes through public meetings. Although the inhabitants were personally invited, only 150 persons (about 20%) turned up (Boursiac, 2015). It is clearly hard to push someone to inquire even when the diagnosis is free. It is perhaps due to a psychological factor: the need to distance oneself from bad memories. Nevertheless, the SYBLE managed to convince the majority of the audience to make a diagnosis. Among the persons who attended the meeting, 120 requested a diagnosis for their property (wether 80%). Regarding economic activities, it is essential to fully understand the business world and the flood risk. A massive information campaign which is not adjusted to the distinctive feature of the economic activity is underperforming (CEPRI, 2012).

DISREGARD OF FLOOD HAZARD

The disregard of flood hazard arises during the diagnosis establishment while the choice of measures is precisely based on its characteristics (the water height of the flood, the current speed and the submersion time (CEPRI, 2009). The zoning of submersible areas in a PPRI is not always truly showing the current situation as a result of the delay required for its update. On the river Lez catchment, three quarters of the accommodation units of Juvignac and half of the accommodation units of Grabels subjected to the flooding of October 2014 were not situated in submersible areas (Boursiac, 2015). Even though the owners of buildings located in areas with no mitigation obligation want to carry out some works, they won't be eligible to subsidies - which is certainly not encouraging.

FINANCIAL RESOURCE AND ACCEPTABILITY

The project holders face a financial barrier too. Making owners directly pay the expenses of works is an inhibiting factor. Moreover, subsidies do not entirely cover the work cost of vulnerability reduction. Not all households have the financial means to invest. In reality, the housings that felt concerned already undertook works to reduce their vulnerability. For instance, the owners of two or three houses damaged by the flooding of October 2014 in Grabels decided to create a shelterspace themselves (Boursiac, 2015). Once the diagnosis is made, there are aesthetic and comfort concerns, attractive significant decrease in the likelihood of a sale and a refusal of risk memory.

UNCERTAIN RETURN ON INVESTMENT

The return on investment of measures designed to reduce the vulnerability of the property is by no means obvious for the building owner. The uncertainty about return is not helping the owner in decision-making in favour of such measures. The return on investment is even more important that the cost of avoided damages is high and that the flood frequency is high during the occupation time of the building by the owner. The measures to reduce the vulnerability are more easily set up if they fit within a renovation, reparation program after flooding or a rehabilitation program with a diluted cost in the mass. The ABI (Association of British Insurers) produced a table showing by accommodation unit the cost of each renovation, the additional cost of the vulnerability reduction measure and the avoided cost of damages in case of a flood up to five centimeters high and one-meter high. For example, according to the ABI, replacing a damaged boiler would cost £850, raise the existing boiler on the wall would cost £150 more and the benefit would therefore be £700 (equal to the equipment which must not be replaced minus the measure's cost of raising it). If the profitability is not guaranteed for a building owner, on the other hand it is even safer for the State and the local authorities who will be able to observe the benefits exceeding the costs in the long term (CEPRI, 2009).

DISSUASIVE FACTORS

Dissuasion by compensation

In France, the CatNat compensation system of owners covered by a natural disaster insurance in case of a flood recognised as such by an interministerial decree does not support mitigation. The goods covered by their insurance may be compensated for a refurbishment (Legifrance, 2015). The population isn't therefore motivated to implement works for vulnerability reduction as they know they can receive compensation. This insurance coverage reveals a kind of paradox. If insurance coverage allows resilience, it runs contrary to mitigation while mitigation improves the resilience as well. The ABI explains to insured parties that if their contract does not cover the standard repair costs it is however possible to get loans among creditors to finance measures of vulnerability reduction (Association of British Insurers, s. d.).

Dissuasion by the feeling of protection

The protection against flooding inhibits the prevention whereas the two strategies need to complement one another. For example, when a building is protected by embankments, reducing its vulnerability is less profitable as the flood frequency decreases.

Dissuasion by real estate market

When an owner wants to start the work, there seems to be resistance by building companies because of their disbelief at the flood risk or not to adapt their practices and know-how (CEPRI, 2012).

LACK OF LEGAL FRAMEWORK FOR SUBMERSIBLE CONSTRUCTION

It is hard to control that the mandatory measures were effectively undertaken on existing buildings subjected to an obligation. In new constructions, the CEPRI (2009) recommends changing mind-sets among policy-makers which would be essential to make urban planning evolve to the development of sustainable and submersible cities with 'damage zero' buildings.

The building adaptation to flooding is only partly addressed in several regulations (PPRI, SCOT, PLU, DTU, POS). The construction subjected to flood risk is not standardised in the same way as the one subjected to earthquake risk ruled by the earthquake-resistant norm. It seems more based on the consultation and the good will of the building stakeholders. Besides the mandatory measures of some PPRI, to rule the adaptation of new or renovated

accommodation units by a specific standard would allow to protect against their vulnerability. This obligation in the real-estate programs of renovation or new construction would make the approach more profitable than on existing buildings (CEPRI, 2009).

On the other hand, the measures to reduce building vulnerability are not enhanced in the real-estate market. The lack of construction market adjusted to flood risk doesn't promote the implementation of vulnerability reduction strategies. This can also be attributed to the little saleable nature of the submersible house's concept. Surely there is here a psychological barrier to overcome.

Making a territory resilient to flooding goes beyond the building scale. Reducing its own vulnerability is definitely needed but this is not sufficient. In order to fully perform its role, the proper functioning of the access, water, communication and energy networks must be secured (CEPRI, 2009). Some thinking as to how to make these networks less vulnerable too would also be welcome.

CONCLUSION

Risk is clearly the conjunction of a natural hazard and the vulnerability of stakes subjected to this risk. In order to decrease risk, it is necessary to address two fronts simultaneously: both on the hazard and on exposure. Therefore, the new strategy of risk management is focused on a multi-layered approach including the reduction of vulnerability. Today the approach to reduce the vulnerability to construction has just begun. Several basin committees on different French territories offer a free diagnosis for riparian owners. Many brakes and dissuasive factors have already been identified. For example, it is not easy to raise awareness among the population on flood risk and on its vulnerability to this risk and to convince the owners of the benefits they could reap after a future flooding by implementing some works. The profitability of measures to reduce this vulnerability is not established for sure. The dissuasive factors are including the potential compensation of damages in case of event recognised as natural disaster, the feeling of protection felt behind infrastructures.

On the Durance river territory, in determining the PAPI and allocating the budget to the different sections, the question is whether the priority of actions for flood control should be put on vulnerability reduction. The river Durance from its source in the Montgenèvre pass to the river Rhône is dammed going through several urban areas such as Avignon, Châteaurenard, Cavaillon and Pertuis. It is framed by highway lines and longitudinal and cross-ways embankments (Doddoli et al., 2015). These protection systems (for some of them precarious and unreliable) provide an uncertain protection level of anthropogenic areas. The hydraulic facilities with an unpredictable behaviour are subjected to a work program detailed in the river contract (reorganisation and strengthening). In certain locations there is a real danger of failure. It seems essential to ensure clear articulation of the vulnerability reduction approach and the rehabilitation policy of protection devices. The vulnerability reduction approach should not occur at the expense of protection systems maintenance, crucial to secure them. It is necessary to know the exposure scenario to carry out a good-quality diagnosis. The behaviour of the protection systems is still little known. Using too pessimistic basic assumptions would lead to recommend financially onerous measures for owners and maybe useless once the work intended in the river contract have been completed. Determining the water height and speed for the diagnosis depending on the characteristics of post-work facilities seems more appropriate. Therefore, these characteristics can only be approved once the stage of the work and its financing are authorized. Due to the known brakes of a vulnerability reduction approach, it seems wise to act on defective protection systems beforehand in order to give meaning to the approach. The implementation of the first approach to reduce the building vulnerability of the ALABRI type could be undertaken in a pilot area located behind an already rehabilitated protection system and with a controlled behaviour.

BIBLIOGRAPHY

Association of British Insurers, s.d. *Flood Resilient Homes : What homeowners can do to reduce flood damage*? National Flood Forum, 11p. Disponible sur Internet: https://www.westoxon.gov.uk/media/172419/Flood-resilient-homes-leaflet.pdf [Consulté le 23/10/2015]

Boursiac A., 2015. Chargée de mission PAPI du bassin du Lez au Syndicat du Bassin du Lez. Interview le 30/11/2015.

Carrere M., 2015. Chargée de mission inondations et gestion physique du Syndicat Mixte du Bassin du Fleuve Hérault. Interview le 17/11/2015.

CEPRI, 2009. *Un logement « zéro dommage » face au risque d'inondation est-il possible ?* Rapport, CEPRI, 56p.

CEPRI, 2010. *Le bâtiment face à l'inondation : Diagnostiquer et réduire sa vulnérabilité.* Guide méthodologique, CEPRI, 56p. Les guides du CEPRI.

CEPRI, 2012. *Impulser et conduire une démarche de réduction de la vulnérabilité des activités économiques : Les collectivités territoriales face au risque d'inondation.* Guide méthodologique, CEPRI, 60p. Les guides du CEPRI.

Chabreuil M., 2010. *Un système anti-crue original pour le siège parisien l'AFD*. Techniques de l'Ingénieur. Disponible sur Internet: http://www.techniques-ingenieur.fr/actualite/articles/un-systeme-anti-crue-original-pour-le-siege-parisien-lafd-3078/ [Consulté le 23/10/2015].

Doddoli C., Moreau L., Picon P., 2015. *Contrat de Rivière du Val de Durance. Avenant au contrat initial. Pièce n°1 : Rapport de présentation*. SMAVD. Rapport de présentation. pp. 1-155.

Eudes Y., 2008. *Villes amphibies, îles artificielles*. *Le Monde*,. Disponible sur Internet: http://www.lemonde.fr/vous/article/2008/02/02/villes-amphibies-iles-artificielles_1006677_3238.html [Consulté le 02/11/2015].

Galoffre C., 2015. *Une maison amphibie créée pour résister aux inondations*. Batiactu. Disponible sur Internet: http://batiactu.com/edito/id-42539 [Consulté le 04/12/2015].

Garcia S., 2015. Chargée de mission risques majeurs de la ville d'Alès. Interview le 03/12/2015.

Gautier Y., s.d. *Inondations*. Encyclopædia Universalisp. pp. 1-3. Disponible sur Internet: http://www.universalis-edu.com/encyclopedie/inondations/#titre-i_98671 [Consulté le 21/11/2015].

Le Gard, 2015. *Réduction de la vulnérabilité des logements - NOE - Prévention des risques inondations dans le Gard : tous acteurs !* Disponible sur Internet: http://www.noe.gard.fr/index.php/observatoire-du-risque-inondation/indicateurs?id=180 [Consulté le 10/01/2016].

Legifrance, 2015. *Version consolidée au 21 novembre 2015 du code des assurances*. Disponible sur Internet: http://www.legifrance.gouv.fr/affichCode.do?idArticle=LEGIARTI000006785969&idSe

ctionTA=LEGISCTA000006156960&cidTexte=LEGITEXT000006073984. [Consulté le 30/11/2015].

Le SMAGE des Gardons, 2015. *La démarche ALABRI en détail*. Disponible sur Internet: http://www.les-gardons.com/alabri/demarche-alabri [Consulté le 20/10/2015].

Les risques majeurs, 2009. *Comment réduire les risques : le concept de mitigation*. Disponible sur Internet: http://www.risquesmajeurs.fr/comment-reduire-les-risques-le-concept-de-mitigation [Consulté le 20/10/2015].

Les risques majeurs, 2011a. *8 et 9 novembre : Inondations majeures, quelle prévention et quelles réponses ?* Disponible sur Internet: http://www.risquesmajeurs.fr/8-et-9-novembre-inondations-majeures-quelle-pr%C3%A9vention-et-quelles-r%C3%A9ponses [Consulté le 21/11/2015].

Les risques majeurs, 2011b. *Plan Loire : diagnostic gratuit de vulnérabilité pour les entreprises situées en zone inondable*. Disponible sur Internet: http://www.risquesmajeurs.fr/plan-loire-diagnostic-gratuit-de-vuln%C3%A9rabilit%C3%A9-pour-les-entreprises-situ%C3%A9es-en-zone-inondable [Consulté le 03/12/2015].

Les risques majeurs, 2015. *Construire des résidences de qualité et adaptées au risque inondation*. Disponible sur Internet: http://www.risquesmajeurs.fr/construire-des-r%C3%A9sidences-de-qualit%C3%A9-et-adapt%C3%A9es-au-risque-inondation-0 [Consulté le 09/11/2015].

Mathieu-Subias H., 2015. *Responsable du pôle d'appui technique du Syndicat mixte des milieux aquatiques et des rivières*. Interview le 18/11/2015.

Miget S., 2010. *Construire en zone inondable, c'est techniquement possible ! - Qualité/Sécurité*. Disponible sur Internet: http://www.lemoniteur.fr/article/construire-en-zone-inondable-c-est-techniquement-possible-745439 [Consulté le 17/01/2016].

Parlement européen, 2007. *Directive 2007/60/CE du parlement européen et du conseil du 23 octobre 2007 relative à l'évaluation et à la gestion des risques d'inondation*.

Sauron O., 2015. Chargé de mission inondation au Syndicat Mixte d'aménagement du bassin versant de la Cèze. Interview le 18/11/2015.

Techniques de l'ingénieur, 2013. Prévention du risque inondation. *Techniques du bâtiment : La réglementation administrative et les contrats*, p. 1.

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LIST OF ABBREVIATIONS

ABI : Association of British Insurers
ALABRI : Accompagnement à L'Adaptation de votre Bâti au Risque Inondation
AZI : Atlas des Zones Inondables
CAUE : Conseil d'Architecture d'Urbanisme et de l'Environnement
CEPRI : Centre Européen de Prévention de Risque d'Inondation
DI : Directive Inondation
DTU : Document Technique Unifié
FEDER : Fonds Européen de Développement Régional
PAPI : Programme d'Actions de Prévention des Inondations
PLU : Plan Local d'Urbanisme
POS : Plan d'Occupation des Sols
PPRI : Plan de Prévention des Risques d'Inondation
SCOT : Schéma de Cohérence Territoriale
SMAGE : Syndicat Mixte d'Aménagement et de Gestion Equilibrée
SMAVD : Syndicat Mixte de la Vallée de la Durance
SMBFH : Syndicat Mixte du Bassin du Fleuve Hérault
SMMAR : Syndicat Mixte des Milieux Aquatiques et des Rivières
SYBLE : Syndicat du Bassin du Lez

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