

# **The Contribution of GIS in The Management of Natural risks And Urban Planning**

## **Case Study: Management of Floods in the Region of Mohammedia**

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**Abstract:** Morocco, due to its geographical location, is exposed to different types of phenomena: climatic, meteorological, geological, etc. We also distinguish so-called major risks such as earthquakes, landslides, droughts, floods, and tsunamis.

Natural hazards have experienced impressive increases (1950: 24 occurrences, 2015: 377 occurrences), resulting mainly from the density of risk areas occupancy, likely to hazards or disastrous events. These zones with potential risks lead to dramatic disasters, caused damage to goods, combine fatal losses to human lives, and eventually cripple the socio-economic development of the regions.

In particular, the phenomenon of floods in Morocco began to be felt more strongly during the last two decades, due on the one hand to population growth, economic growth and urban development, agricultural, industrial and tourism which entail a growing occupation of vulnerable areas and on the other hand, the worsening of extreme phenomena (drought and floods) due to climate change resulting in severe localized storms causing rapid and violent floods.

Given that the Human is the central core of territorial development, and taking into account the rapid growth of the population in Morocco (20.4 million inhab in 1982 to 33.8 million inhab in 2014 is an evolution of 65.7%), the strong geographic mobility and the immigration toward urban centres as a result of different constraints (climate change, exacerbation of precariousness, lack of equipment, impairment of a local approach for the development and planning of the Territory,...), urban planners, who must follow an advanced regionalization logic, are led to properly manage their territory and develop local strategies and regional policies in order to cope with this evolution.

The management and control of the Territory are able by the knowledge of the different underlying issues (land use map, vulnerability map, migration flow...). As well, the increase of the population without a proper planning and a necessary knowledge of the Territory, will be exposed to increasing major and sometimes disastrous risks; and subsequently will generate social and political consequences not to mention the considerable cost of the damage caused and the restitution and the relocation of companies.

It is in this framework that the territorial development and its interaction with the environmental risks are of interest to any manager or planner. Thus, an in-depth study of the dynamics of the land use is important in urbanization and urban planning.

**Keywords:** GIS, mapping, flood, urban planning, management of natural risks, ArcGIS, HEC-RAS, Hec-GeoRAS.

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### **I. INTRODUCTION**

Urban planning or the opening of new sites to urbanization is strongly correlated to land use constraints. As a result, the main objective of my thesis is entitled " **The contribution of GIS in the management of natural risks and Urban Planning - Case Study: Management of floods in the region of Mohammedia** ", which of course, fits within the framework of the national strategy for management of natural risks in Morocco, to develop instruments for the management and prevention of natural disasters through effective tools to aid in decision-making.

The said thesis finds its origin from studies launched between 2008 and 2012 in partnership with the World Bank and the Ministry of General Affairs and governance in order to assess the exposure of Morocco to risks related to natural hazards, in the framework of the implementation of a national strategy for the integrated management of risks for the kingdom.

Assuch, the planner, through a geo-decision making system, will have a complete analysis tool and will therefore develop a global vision on its territory in order to take the right decisions and shape to retrofit the forecastmaster plan of land use forecasting.

Floods are a natural phenomenon marked by undetermined frequency. The Coastline of Mohammedia is included and will no longer play the exception and so the question that arises is the following:

**Is the city of Mohammedia, known by his strategic and only national tanker port, under continuous and unforeseen flood threat ? (Reminder: 25-26 November 2002).**

The new geo-spatial technologies, in particular Geographic Information Systems (GIS) are an important tool for analysis and decision support. The strength of this tool lies in its ability to integrate, combine, process and analyse information and alphanumeric data and space. In fact, the ultimate outcome of these crosses is returned on synthesise maps in order to describe and understand the territorial dynamics.

## II. STUDY AREA

Fédala (*as it was called in the past*) or the city of Mohammedia is a prefecture belonging to the region of the Great Casablanca. Its geographical coordinates are: 33° 41' 23" North 7° 23' 23" West. It is limited to the north by the Atlantic Ocean to the east and to the south by the Province of Ben-Slimane and to the west by the prefecture of Sidi-Bernoussi.

The city of Mohammedia is part of Corridor Strategic Coastline " Kenitra - Casablanca " presenting for the Kingdom a dynamic focus to multiple economic and political issues. At 70 km from Rabat and 24 km from Casablanca, the urban perimeter of the city extends on an area of 35 km<sup>2</sup>. The population of the municipality has increased from 187.708 inhab in 2004 at 208.612 inhab in 2014. A rate of increase of **1.12%**. This relatively low growth is mainly due to the intra-city saturation and increasing change of mentality, which has led to a shift of the population toward the periphery duetothe increased environmental pollution giving decision makers other problematic to solve.

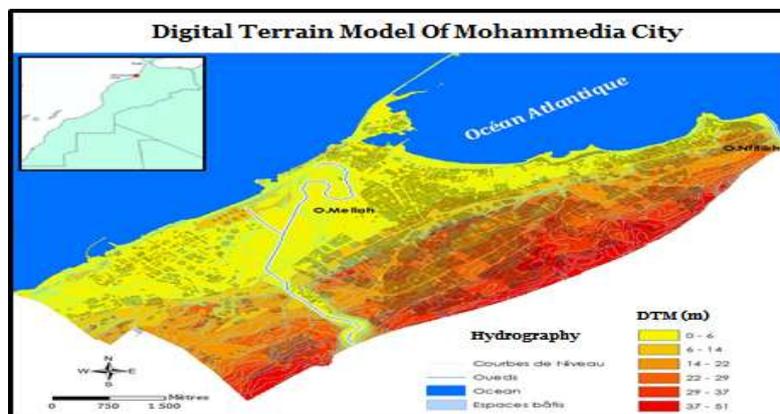
Among other things, this evolution is mainly due to the industrial growth that it has started since independence, the increasingoil and port activities, and to its advantageous location between the two capitals : economic and administrative.

The city of flowers and stylish sports, as some like to call it, houses the main oil refinery in Morocco, SAMIR. On its outskirts, there is, the largestthermal power plant of the country, which supplies a large part of the Great Casablanca region. It also hosts the main tanker port of the kingdom, which refuels the SAMIR.

The study area belongs to the western part of the coastal Meseta of Morocco also called Northern Morocco. It is distinguished by a low topography low, ranging below sea level at the level of the wet zone, sandy beaches and rocky flats.

Hydrologically, there are two mouths that horizontally cross the city before arriving at the Atlantic coast knowas :Wadi El-Maleh and WadiN'fifikh.

1. **WadiN'fifikh:** The watershed is an area of 830 km<sup>2</sup>, formed for the essential by the Land shaly waterproof.
2. **WadiMellah:** It is the most important of the coastal wadis. It startsin the north of the city of Khouribga on the northern edge of the plateau of phosphates and drains the northwest part of this plateau. The surface of its watershed is around 2800 km<sup>2</sup>. This basin is equipped with three adjustments to know:
  - The El Mellah DAM, put in water in 1932, for the development of the irrigation;
  - The medium-sized Zamrine dam, built in 1951, which is currently completely silted up;
  - The Boukerkour dam recently built to protect the city of Mohammedia against the floods.



**Fig.1:** Digital Terrain Model of Mohammedia City

### III. SPATIAL ANALYSIS OF THE CITY

#### 3.1 Urban frame of the city of Mohammedia:

The city of Mohammedia occupies a very important place in the region of the Great Casablanca. Its urban frame is composed schematically of three major categories :

- A very large industrial area to the west of the city comprised mainly by factories and companies of reference as well as warehouses ;
- An area of habitat in the heart of the city characterized by the joint Habitat (social economic +) to the west of the city, residential and the means standing in the center and finally the very high standing in the northeast part ;
- A tourist area The long coastline of the city.

#### 3.2 The road and rail network:

The city is served by the motorway "A3" linking Rabat and Casablanca. As well, it has by the National Road "RN9" which connects to Mhamid-el-Ghizlane. As well, Mohammedia is served by two regional routes, the first is the "RR3113" in the form of an expressway, while the second is "RR322" which connects it to Casablanca. In the matter of railway track, Mohammedia is a main station where several trains make a stop under an average frequency of 30min.

#### 3.3 The economic fabric:

The city of flowers is characterized by a strong industrial concentration, and particularly by the presence of complex units (*petroleum district, Society of supply of gas,...*), the largest thermal plant of the country as well as the unique oil pole - until today - and which provides more than 95% of the needs in petroleum products with an annual traffic exceeding the ten million tonnes.

**The economic fabric of the city of Mohammedia has two main vocations: Industrial and tourist activities.**

- The first activity is located, on the one hand, in the district of oil, with a surface area of 500ha which houses of societies to international reference, and on the other hand, in the northwestern part, there are many production units who have elected domicile in the industrial zone of an area surrounding the 60 ha
- The second activity relating to tourism: the city of flowers has very considerable tourist assets. On the whole of the littoral, the study area has a lithological diversity morphological and with the presence of a biogenic sand and dunes fabulous. Also, a place very exceptional called "the cliff of Fédala", which is the place of privileged promenade of all Fédaliens.

### IV. URBAN PLANNING

In Morocco, the urban planning is based on several documents of urbanism opposable to the administrations and other to third parties to know the pattern of development and urban design "SDAU," the plan development "PA", the rural development plan of agglomeration "PDAR" and the zoning plan "PZ".

The SDAU has for vocation the determination of the great forward-looking, orientations and strategies of urban development on a territory well determined. Of course, in view of several strategic reasons including the integration of the risk dimension in its planning, **the SDAU of the Great Casablanca has been reviewed** and has taken into consideration the study on the protection of the prefecture of Mohammedia against floods established by the Agency for Hydraulic Basin of bouregreg and Chaouia. Of this fact, the SDAU has been newly approved in 2010. Also, we note the presence of a development plan of the city of Mohammedia approved in 2011. The latter has for main objective is to regulate the use of the soil.

### V. FLOODING RISK

A flood, is a natural phenomenon, characterized by a recovery of water that goes beyond the minor bed uncontrollably, flowing in the talwegs or depressions when the flow and volume of water of a flood are important. This phenomenon is beginning to be increasingly felt in different countries of the world because of the factors of the Fort demographic development, economic, urban, agricultural or industrial.

In Morocco, several actions have been undertaken by the Department in charge of the water and the environment, or by the actors and local managers. A large scale, the said Department has put in place the National Plan for protection against floods (NBP) which is part of a policy of dams' protection. Therefore, the city of Mohammedia has been classified between other, according to the NBP, **among the 390 priority areas for intervention of emergency which the treatment will be carried out before the deadline 2020.**

Furthermore, we note that the Kingdom has decided through its high government body, to put in place a national strategy for the integrated management of natural risks (SNGIRN) and whose major objective is to have a global vision, concerted and integrated. This last is headed by the Ministry of the Interior.

### 5.1 Flood and urban planning in Morocco:

In terms of urban planning and up to today, there is no regulation that requires the actors in charge of the planning to take into account the risk of flooding in the implementation process of the documents of town planning. Given the different phases of coordination, the local actors get along with the bodies responsible for the management of the water in particular the Agency of Hydraulic Basin. This last, and depending on the availability of the information and data, communicates to the contracting authority the exact delimitation of flood areas, sites historically likely to receive floods, or in the best of cases, detailed studies of protection against floods. In addition, a number of maps urbanization capacity are being developed according to a strategic vision of the government department in charge of urban planning.

### 5.2 GIS between flood and urban development:

Of our days, the geo-spatial technologies in general and the Geographic Information Systems (GIS) in particular have become tools of analysis unavoidable and of the instruments of aid to decision-making by excellence. The city of Mohammedia, by its strategic positioning and its history with the floods, justifies the implementation of a GIS for the management and prevention of the risk of flooding. In this regard, and to achieve the desired objectives, a geographic database has been put in place containing a mass of information and economic data and important statistics.

## VI. HISTORY OF FLOODING IN MOHAMMEDIA CITY

During the last two decades, the study area was hit by heavy flooding and by consequence, the generation of unexpected floods. These latest dates from 1996, 2002 and 2010 have exceeded the 135mm in only 4 days. Although the floods of 1996 and 2010 were dramatic, the November **2002** remains the most striking on the historic plan since it has been qualified as a flood of reference with a flow rate which has reached 168,9mm, (from 14 to 25 November). Otherwise, and following these harsh weather, the city of Mohammedia has suffered a theater of catastrophic floods representative to roughly 45% of the rain that falls in a normal year (**169/383**) in mm.

Therefore, this unfortunate event has created a psychosis of the population and the balance sheet may be summarized as follows:

- **On the hydrological plan:** registration of a flow of 460 m<sup>3</sup>/s, flooding of 500 hectares of the lower part of the city as well as the degradation of sanitation networks;
- **On the infrastructure plan:** 04 damaged bridges (two on the part "West" and two on the part "East" of the City), the closure of several public and private institutions as well as the degradation of road networks;
- **On the economic plan:** the industrial zone has been severely affected and therefore the supply disruption of the Kingdom in hydrocarbons and in gas;
- **On the human plan:** two dead, wounded and hundreds of affected households. A serious accident has been registered at the entrance of Beni Yakhlef (*transport of personal*).

## VII. HYDROLOGIC ANALYSIS

### 7.1 Climatology of the study area:

The climate data processed are derived from the meteorological station in Mohammedia. They range from the year 1991 to the year 2009. The diagram ombrothermique, which represents the monthly variations on a year of temperatures and precipitation according to standardized gradations (P=2T) reveals:

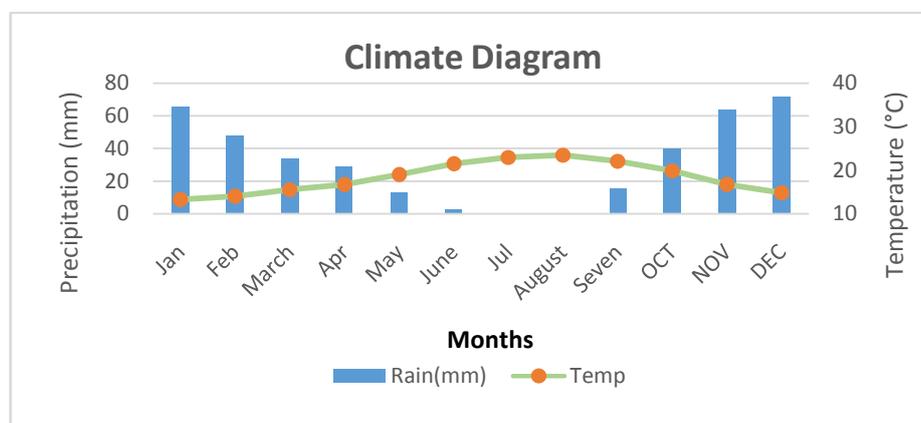


Fig. 2: Ombrothermic Diagram - Post of Mohammedia

We note, a dry periodicity of spreading on average over six months (April to September), It is noticed a periodic dry season spread out in average over six months. The climate of the Mohammedia region is therefore of Mediterranean type. According to the mathematical formula for Emberger (1931), the quotient of rainfall is 128,79, calculated as follows :  $Q = 3.43 * P / (M - m)$

With: **P**: Annual Average Precipitation (mm)

**M** :Maximal Average temperatures of the warmest month in (°K)

**m**:Mean minimum temperature of the coldest month in (°K).

According to the classification of Köppen,(1918), the area enjoys a Mediterranean climate. According to the Emberger quotient calculated above, the climate characterising the area of study is wet type to **warm winter**.

## 7.2 Aridity of the studied area:

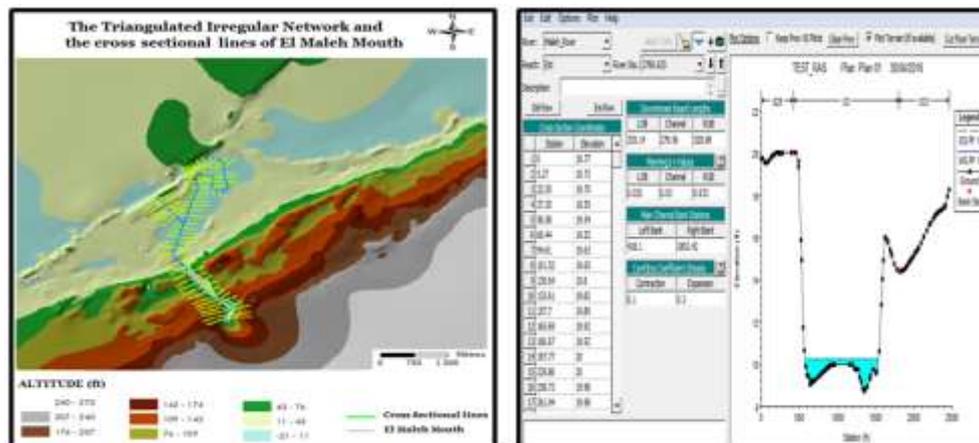
The "De Martonne" index of aridity developed in 1923 is a quantitative indicator of the degree of the lack of water present in a given location (John E. Oliver. 2006). It is defined as the ratio between the average annual precipitation and the average annual temperatures. Explicitly, it is formulated as follows:  $A = P / T + 10$

The index of the aridity increases (between 20 and 30) when the value of precipitation is very considerable (Table above). On the opposite, a zone is called hyper-arid (between 5 and 10) when there is a shortage in the precipitation. Given that the index of aridity is between 10 and 20, it is deduced that the Mohammedia city enjoys a **semi-arid climate**.

## VIII. MODELING AND HYDRAULIC ANALYSIS

The city of Mohammedia encloses two mouths, East and West. The main objective of this part is based on the hydraulic modeling of the Oued El Maleh through the simulation software " Hec-Ras" in its version 5.1 . The latter is able to assess the flow rates in heights of water on the entire section of the mouth and therefore determining flood zones.

The hydraulic simulation requires several operations in order to enclose flood zones (extraction of the data of the elevation of the terrain, creation of a soil profile through the flow of channel (Channel Flow) as well as the establishment of the cross-sectional lines (Cross-Section)). These lines have been drawn using the ArcGIS software 10.2 and subsequently, they have been superimposed on a surface of triangular irregular network (TIN) of the city. The latter was generated by a digital terrain model (mnt) specific, based on the topography of the region (topographic map of Mohammedia in 1/5000).



**Fig. 3:** The triangular irregular network (TIN) and the transverse lines of the mouth of Oued El Maleh  
**Fig. 4:** The stations and associated elevations of the mouth of Oued El Maleh under HecRAS

These lines of cross-sectional cut are used to extract the ground elevation data to create a soil profile through the stream channel. The station of the river gives the distance in feet of the higher end downstream of the river. In our case, 3790.625 feet is the distance from this section on the Oued El Maleh at the point the most downstream on the Creek shown above.

### 8.1 Mapping of flood risk areas:

The delimitation of the flood prone areas is defined after the creation of a polygon that connects the ends of the transverse lines determined previously. This is done after a post processing of data under HecRAS by the generation of profiles and the constant flow (Steady Flow).First of all, there is the creation of a surface of

elevation of water for the generated profile under HecRas and as such a new "TIN" is created, which is going to define a zone linking the outside points of the polygon limits (*polygon boundary*). Consequently, the TIN will include a potential surface out of the effective flood zone.

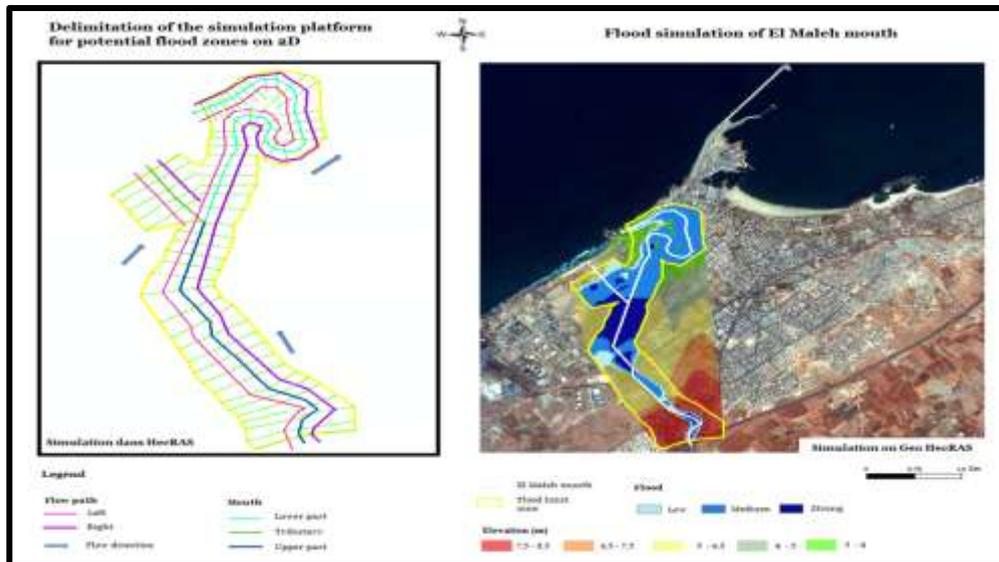


Fig.5: Simulation of the floods at the entrance of Oued El Maleh - city of Mohammedia

### 8.2 Impact of flood risk areas on the development of the plan:

This step aims to conduct a geo-spatial analysis of a potential flood impact on the development plan of the city of Mohammedia. In other words, it is to determine on the one hand the level of flooding, and on the other hand, the percentage of the surface area affected by the floods in terms of zoning, equipment, road infrastructure and thus their relationship with the sectors.

**In terms of zoning:** This simulation reveals that **3%** of the total area of the study area of the study would be the object of floods as well as **7%** of the potential area of flooding corresponds to the industrial zone Low (I2) which contains the thermal plant and the refinery of the Kingdom. The industrial area (I5) located to the west of the city would be impacted by heavy floods and who will be able to occupy **4%** of its territory. The most sensitive part would be at the level of the port of the city precisely the area (I5S6) with a submergence that will reach **3%** of its total area.

In addition, what is reassuring is that more populated and urbanized part of the city would be in perfect security (which is confirmed in the Fig. n°1 : by an altitude between 15 m and 45m).

A great deal of work has been done by the developers under the supervision and control of the Urban Agency in Casablanca which has defined in the PA of Mohammedia city, an area called “not aedificandi”, which is a wet zone, considered as the area most threatened in this simulation. A gulf is already built in this area and which could reach a level of flooding of **77%** of its area with a maximum elevation of the order of **2.88m**.



Fig. 6: Impact of the floods on the urban planning in Mohammedia city

**In terms of equipment :** In the northwest part of the city, the area I5 which currently contains public and private facilities (*NBSC, Hotel of the cliff, Strogaz, phone group, fish market,...*) and the zone has6s1 which houses the primary school JaquesHerssent. The impacted area is of the order of **4%** of the zone I5 and **2%** of the area has with a level of rise which reaches 1m.

**In terms of infrastructure and road networks :** the west of the city would be amply affected by floods including the railway track linking Casa-Mohammedia-Rabat, and this, on a distance of 25m. Well also the two main receipts will be totally submerged as well the bridge of the Oued El Maleh in the direction of the Boulevard Hassan II and the second (*near the Samir*) in the direction of the Boulevard Mohamed Ben Abdellah bringing to the different neighborhoods of the city and the city center, and this, respectively on distances of flood (*boundary flood polygon*) of 140m and 350m. A little more distant to the northwest of the city, the national roadRN (9), Boulevard de Zenata, Boulevard of FarhatHachad as well as the streets of Ibn Sina, Ibn Toumart, street of the Mauritania, OquadZam will be moderately flooded with a Height between 1,2m and 2.8m.

## **IX. CONCLUSION AND PROSPECTS**

Different sets of recommendations have been taken by the local authorities in order to prevent a possible surprise in the future. So, as an example, the establishment of a dam in Oued El Maleh, whose aim is to mitigate the effect of the torrential flood that may arise as a result of a heavy and sudden precipitation.

The use of geo-spatial tools in the field of the planning and development of the territory has become a vital necessity. Through this study, these tools (ArcGIS and GeoHecRas) have played a crucial role for the determination of areas likely to receive floods and estimate by elsewhere the socio-economic impacts in a quasi-precise way.

After an inventory on hazards and issues present in the studied territory as well as the knowledge of the processes leading to the emergence of the risk flood, a set of provisions, which aim to reduce the impacts of the phenomenon flood, are recommended. We quote in this regard:

- 1. Forecasting, monitoring and alerting :** In order to strengthen the territorial standby, the warning system already put in place, will communicate with the GIS system developed in order to supply the database with precise information and simulate in 3D the susceptibility of a flood. This trigger of alert should be shared with the different local actors in order to strengthen the vigilance and also be informed in real time.
- 2. Regulation on soil occupation:** A description of a plan for the prevention of risks in order to put an end to a spontaneous urbanisation and unconscious in flood risk areas. In addition, the IRPP remains as a servitude of public utility and exhibit existing mistress before the launch of a document of urban planning. On the one hand, it must be taken into consideration during the development of the plans, and on the other hand, after the approval of PA, issued by the Urban Agency to the various petitioners At the request of the note of intelligence.
- 3. Disaster recovery plan and management of crises :** the development of IRPP allows local actors in consultation with the officers of the Authority and the civil protection to have a general cartography on the territory, to put in place a contingency plan in order to shelter the population and therefore be updated to manage the different degrees of crises.

To guarantee the success of this prevention process, this approach must be accompanied by a set of legislative and regulatory provisions (*laws, decrees, circulars,...*). In other words, the establishment of a legal arsenal is becoming an indisputable priority because it:

- Regulate the land use ;
- Lean the different resources in charge of urban planning by reliable and high value-added territorial documents, delineating accurately the different areas exposed to flood risk.

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