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Urban Growth, Sewerage Network and Flooding Risk: Flooding of November 10, 2001 in Algiers

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***Abstract*—**The objective of this work is to present a expertise on flooding hazard analysis and how to reduce the risk. The analysis concerns the disaster induced by the flood on November 10/11, 2001 in the Bab El Oued district of the city of Algiers.The study begins by an expertise of damages in related with the urban environment and the history of the urban growth of the site. After this phase, the work is focalized on the identification of the existing correlations between the development of the town and its vulnerability. The final step consists to elaborate the interpretations on the interactions between the urban growth, the sewerage network and the vulnerability of the urban system.In conclusion, several recommendations are formulated permitting the mitigation of the risk in the future. The principal recommendations concern the new urban operations and the existing urbanized sites.

***Keywords*—**urban growth, sewerage network, vulnerability of town, flooding risk, mitigation

I. Introduction

THE question of risks in urban environment is associated to hazard and the fragility of spaces and the component elements of these spaces. In the same way as to the evolution of the responsibility concept, the notion of sanitary, social, natural, technological risk imposes itself more and more in the world. The risk is very often linked to the evolution of the social, cultural, political or environmental conditions. In its common formulation, the environmental question is expressed generally in term of "problem" of pollution, of deterioration...; concretely, the analysis of the problem often leads to the notion of risk [1]. For example, the urban growth is considered as an environmental problem when it takes little place on sites auspicious to the construction (on the ill-adjusted slopes or on flooded lands for example) and that it generate some threats.

The developmental works involving physical, topographical changes alter the natural processes in the area. It is necessary to evaluate the effects of such changes on the natural drainage patterns of the urban area. Infrastructural planning of urban area should require careful attention to urban drainage characteristics. But large volume of physical data is required to be collected for this purpose. When this is not done, the extreme rainfall event as was witnessed by Bab El Oued in November 2001 takes the city by shock and surprise.It is necessary to study how the precipitated water travels in the catchment to understand the process of inundation and flooding. The soil type, the vegetative cover, topographical features of the land surface and the physical structure in the catchment play a key role in influencing the runoff process. Urban areas tend to reduce the natural vegetative cover as they develop. The impact which a hazard has had on a society must be considered as risk [2].

Population growth calls for more land development, redevelopment and densification of structures. The developmental structures in urban areas such as roads, pavements, buildings (residential and non-residential), paved parking lots and sidewalks, driveways increase the impervious surfaces in the catchments. The drainage systems must be designed to cater to the runoff of the area which must be calculated only then can city function properly in case of heavy rains [3].

A. Description of the flood and its estimated damages

In the flooding event of November the 10th, 2001, the studied area was highly damaged because the main collector of the sewage system, which is located downstream the pouring basin and upstream of the district of Bab El Oued, did not get its diameter enlarged nor doubling the system. The two subcatchments, in the district of Triolet, were full of sand, while the sewage systems, all categories, have not known any maintenance operation since a decade ago. The continuous rainfall that lasted 14 hours (all night and in the morning) was followed by the disaster. The recorded precipitations in the city of Algiers were evaluated by the weather services [4] to be about 210 mm during 24 hours. The rise of the water level was progressive and regular in a first time which was estimated at two hours, then suddenly a large wave evaluated to two or three meters of height surged in streets near of the Triolet place and the Maillot hospital at 9 a.m (local time) in the morning of October 10, 2001. The water tracing converged toward Maillot hospital from the west and the south and throw out at the sea front boulevard. The water speed has been estimated between 20 to 30 km/h. The water wave strength was such that reversed the persons and vehicles and carried away vehicles as corks. After the passage of the wave, the progression of mudflow with the solid blocs affected first floors of buildings on a height sometimes reaching two meters. The road traffic has not been stopped neither upstream nor downstream the damaged zone. The waters have carried away a large number of citizens, mainly those trying to help the drowned people in streets.

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The first estimation of the flood was given by the government as following:

• 712 human lives lost, 350 injured persons and 116 missing persons,
• 1800 housing units suffered damage,
• 56 schools suffered considerable from damage,
• Many bridges, roads and public works were damaged,
• 1,000,000 M3 of mud in the streets,
• More than 350 vehicles (cars, trucks and buses with passengers) were buried under mud or
throw out at the sea,
• Estimation cost of the damages: U.S. 250 millions.

By comparison, the costs of damages in the world are estimated to more of 80 billions US Dollard during 2002 year **[5].** Te figure 1 illustrates the cost estimation of the loss engendered by the natural disasters.

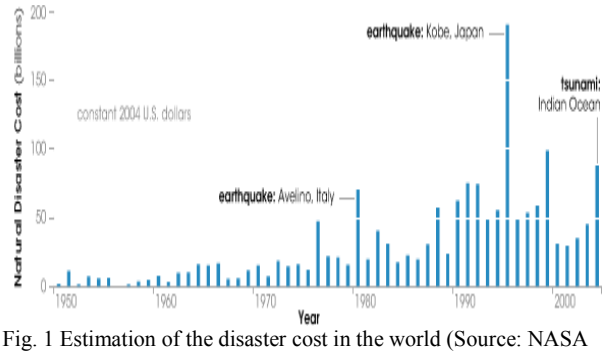

Fig. 1 Estimation of the disaster cost in the world (Source: NASA Observatory)

B. Presentation of the bab El Oued zone

The inventory of flooding events, in Algeria and in Algiers particularly, confirms that the rainfall season concerns the period October to December. All rivers are susceptible to be the source of violent flow and dramatic accident but don't constitute necessarily a "major risk of flooding", except in the case of obstruction. The history of flooding and landslides in Algiers shows events occurred in 1955, 1962 and 2001 [4]. The figure 2 shows the map of zone of Bab El Oued district in the city of Algiers and the figure 3 shows the old urban zone in the zone of Bab El Oued district.The figure 4 and the the figure 5 show respectively the new urban zone in upstream of Bab El Oued district and Zone of the dramatic flood in the distict of Bab El Oued.The figure 6 schematises the morphology of the Bab El Oued zone (basin area with significant slope).

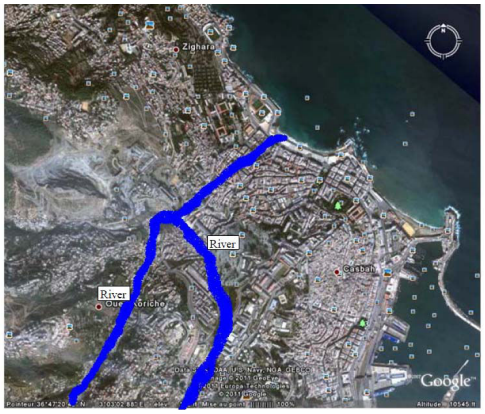

Fig. 2 Map of the zone of Bab El Oued district in the city of Algiers

Fig. 3 Map of the old urban zone in the zone of Bab El Oued district

Fig. 4 Map of the new urban zone in upstream of Bab El Oued

Fig. 5 Zone of the dramatic flood in the distict of Bab El Oued

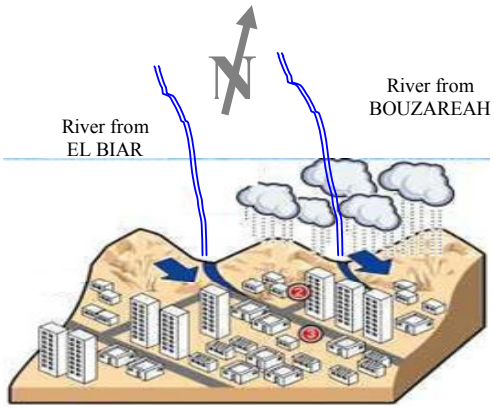

Fig. 6 Schema of the morphology of the Bab El Oued zone

II. View on the Risk Analysis Method

The vulnerability notion is linked with the hazard and vulnerability.

A. Hazard and Risk

This notion of risk is permanently in the centre of the analysis of amplification process of the site and deterioration of the environment [**6** IPCC,]. It gets logically the idea to use the notion of risk to define consequences of the deterioration of the environment [**7**]. On another side, taking into account the notion of risk in the analysis of the urban environment allows to approach the way whose social and political questioning come together around the environmental question, in terms of collective security [8]. In this way, one can consider the collective security like common goods, and the risk like a reach carried to this common good. The definition of this notion of risk and its derivatives combined with notions of common good and urban environment form another conceptual research way that appears to contribute to the understanding of question environment in urban site. The concept of risk leads directly to the two notions: the risk and the vulnerability. The question of the vulnerability, itself, sensitive in its largest acceptance, can be useful to the definition of the development, insofar as if the vulnerability is considered like an indicator of underdevelopment. One can consider that what characterizes a developed society is its low vulnerability to natural, technological, social or economic hazards [9]. These questions appear crucial in the historic context of apparition of the prevention principle, in the same way as to the evolution of the responsibility notion. Questions of environment and notions of sustainable city, common good and risks cannot be avoided and lead to a progressive transformation. This is the reason one can develop the idea of security through the notion of common good; the risk being the reach carried to this good, which one can identify the causes of its production and that of its damage. Associated to the problematic of the environment and the relationship between science and politics, the problematic of risks is a gigantic research field that mobilizes researchers and experts more and more from all over the world.

B. Natural risks in urban environment

In urban environment, the problematic of risks imposes itself first in priorities at the same time in a specific way by the exposure of concentrated population sites to the multiple risks in a limited space. The complexity and the multiplicity of the technical network (lifelines systems) increase the vulnerability of the city. The thematic axis on risks developed within universities and laboratories for urban environment and urban engineering limits itself, currently, to the problematic of natural risks. More and more decision-makers and scientists are getting convinced of the necessity to widen the risk analysis to other types of risks (social, technological, policies).

A more and more strong attention is given to natural a risk that means that the threat and the potential consequences of a disaster triggered by a natural phenomenon or in which the nature is an important component. This attention is the reflection of a new look of the society to its environment, notably natural. From that point of view, the survey of the risk says natural origin is indivisible from the political and scientific context of the environmental question [10].

One could think that in the case of natural risks, no responsibility is identifiable and put it on the account of the fatality. The recent evolution of the notion of risk associated to the notion of responsibility to protect the population and its property from natural risks [4**]**. The legal and institutional structures set up as agencies and policies of prevention (seismic resistant design and construction code for example) assign persons responsible on the other hand in power and designate often in technocratic way, in the absence of all democratic debate, the limit of the " acceptable " risk. This question of the acceptable risk is a strong stake of urban management policies.

Risks of natural origin threaten numerous cities, particularly in developing countries, that experience high growth of their population. This, very often, causes a disorganized urban growth and an irrational urban form. Administrators of these cities, mainly the megacities, often show the need to implement preventive measures of risk reduction.

However, these measures are often difficult and costly to

implement in using, either by the lack of previous studies on factors of physical and social risk, because the research works conceived in a long term, do not provide immediately any applicable results, or because that their content is inadequate to the site, in the sense where it doesn't give elements of knowledge usable to formulate a policy of risk prevention at short-term. This vision is a response to the social demand [**11**].

In this context, two big axes of research can be distinguished: identification and the analysis of risk factors on the one hand, and the analysis of reduction of factors risk on the other hand. Damage caused by movements of land and flood sometimes reaches some relatively important costs [12].

III. Post Investigations and Observations on the Site

After five days, the first observations and investigations have begun into the site and its surroundings and they lasted five months. The figures 7 to 13 show some many observations on the urban hydraulic network.

A. Investigations

- According to our estimates, the urban area of Greater Algiers has doubled while the area of Bab El Oued neighborhood and West has tripled.
- The new urban areas were made on the slopes of the basin that supplies during floods, the river bearing the name of Bab El Oued.
- This site has been cleared in large part, has a slate floor and original clay relatively rugged topography and very rough in places.
- The urban aspect of the product is characterized by either an urban or a rational spatial axis.
- Some are downright building backed by cliff-like slope, suggesting they wanted to enlarge the surface grip of houses.
- The location of buildings and roads following a path almost perpendicular to the contour lines and does not comply with a regulatory alignment. Gutters for collecting rain water along the streets are far apart from each other and their gates are battered in their great majority.
- The mains water sanitation located downstream of the watershed upstream of the town, has not been enlarged in diameter or doubling of Conduct [4].
- The spillway basin located in the area of the district Triolet was partly silted up, while the network of sewers, any category, had no known maintenance operation for a decade.
- The disaster was preceded by a constant rain that lasted 14 hours (all night plus most of the morning).
- Rainfall in the capital was estimated at 210 mm / 24 hours
- The rise in water level has been gradual and steady at first estimated at two hours, then suddenly a huge wave estimated at two to three meters high swept through the streets of areas near the district hospital and Triolet place (around 9:00 in the morning of October 11, 2001).
- The route of water flow converged on the hospital jersey from the west and south, to go and throw a can down the boulevard to the waterfront.
- The speed of the water was estimated to be that of a runner that is 20 to 30 km / h.
- The strength of the wave of water was such that the trucks were overturned and light vehicles carried like corks.
- After crossing the surf, it was the turn of the increase of sludge and solid objects that have resulted in siltation of the cellars and ground floor of buildings to a height up to two meters.
- The mechanical movement was not stopped, either upstream or downstream from the disaster area.
- A large number of citizens, who stepped to the rescue of drowning in the streets, were taken in turn by the power of water.
- The scale of the disaster was not known until several hours later.

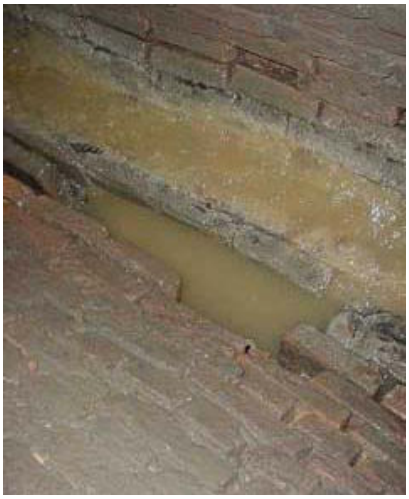

Fig. 7a Deterioration of the bottom of the sewerage canalisation by the velocity of water.

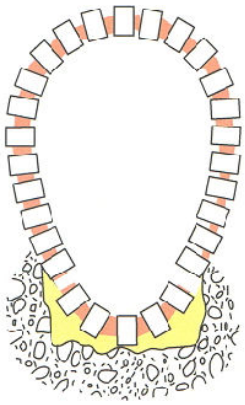

Fig. 7b Explanation of the figure 6a: deterioration by collapse of joint mortar and water infiltration (weak maintenance)

Fig. 8 Obstruction and reduction of the diametere of canalisation. (weak maintenance)

Fig. 9 Obstruction and reduction of the diametere of canalisation of the drainage by sedimentation (weak maintenance)

Fig. 10 Delamination of the canalisation by the flood.

Fig. 11 Obstruction of the canalisation connection by old mud deposits (weak maintenance).

Fig. 12 Obstruction and fissuration of the canalisation by vegetation (weak maintenance).

Fig. 13 Destroy of the wall of culvert by the water pressure (Absence of pore drainage in the wall: weak maintenance).

B. Deductions

The following deductions were established:

- The site is downstream a large pouring catchments, controlled by the massif of Bouzareha (in the west) and the El Biar zone (in the east), do not possess any hydraulic infrastructure facilities for protection against flooding,
- The high urbanisation of these catchments increase the impermeability of the soil,
- The site presents a hilly topography, which encourages the erosion of soil and the surface waters flow,
- The absence of an urban shape proves that the urban design is not sufficiently rational and is not adapted, considering the characteristics of the site,
- Banks of the oued are not being protected. This fact encourages the overflow and the change of tracing flow,
- The deterioration of the site morphology can provoke eventual landslides,
- The most damaged zone (Triolet - Maillot hospital) situated in the entry of the funnel of the catchments should be reserved to green spaces, not to dwellings and commerce,
- The sewage system (that is unit type) being close to the seafront is certainly overloaded because historically the urban extension started from the seafront,
- The power of the water wave resides not in its height but in its kinetic strength. The water's mass came from a long distance,
- The water wave speed presents an enormous mass of water which has been blocked somewhere and then suddenly set free,
- The enormous quantity of water that surged on places of the disaster zone, proves that the hydraulic evacuation network was not functional because of an inadequate maintenance,
- There is a large network of road side open drains in suburbs. These roadside drains require attention throughout the year as many of these roadside drains carry sullage; it is an eyesore and a health hazard,
- The soil type, the vegetative cover, topographical features of the land surface and the physical structure in the catchment play a key role in influencing the runoff process. Urban areas tend to reduce the natural vegetative cover as they develop.

The major deficiencies in the storm water system which causes flooding are elaborated below:

- Many gradients are flat and the drains are affected by tides,
- A large number of drains were found to be of inadequate capacity,
- Many obstructions were there in the larger drains,
- Poor workmanship and lack of attention to proper repairs when the drains have been punctured to construct utility services has left many of these locations in a poor state of structural repair,
- Access for maintenance to some drains is restricted by development over the manholes,
- Interconnections of storm water and sewerage networks are collapse,
- Encroachment on the pavement and the street drainage reducing access for maintenance,
- Some storm water network in city and most of the storm water networks in suburbs are open system.

The figures 7 to 13 show the damages sustained by the drainage and sewerage network and give explanations about these destructions. The hydraulic network shows many signs that attest the absence of maintenance and the under-dimensioning of canalisations.

IV. Discussion and Recommendations for the Risk Mitigation

Damages caused by the 2001 Algiers's flooding have given the opportunity to launch a large discussion on the safety in the megacities.

The narrowness of the space, the insufficiency of the infrastructure inherited in terms of road network, drinking water system, housing, have pushed since 1974 to the decentralization on several "wilaya" (administrative regions) that are Tipasa, Blida and Boumerdes. In spite of the realization of several new urban zones and the multiplication of new urban districts since the 1980's, the increased requirements of the high and middle social layers aggravated the housing deficit. The need of the habitat has already consumed well more agricultural space than didn't make the previous implantations
of industrial activities.

The reduction of the risk is linked to the efficiency of policies (management) adopted in risk prevention. It is about determining what can be acceptable for the concerned community, not only on the economic and financial plan, but also, and maybe especially, on the social, political and cultural level. Any proposition concerning risk mitigation aims in facto to modify behaviours, sometimes deeply anchored in the culture, the tradition, the social practices (those, notably, which assure a minimum capacity of subsistence to the poorest). The problem is to know how to modify these behaviours for risk reduction, while using to best the tradition and the existing social practices. Only the narrow association between the different disciplines can go in this direction and can clear on the efficient propositions leading to what is acceptable, adapted and lasting.

The consensus that it is accepted of the disaster management process, in the United Nations system, is to take simultaneously into consideration risk factors and vulnerability with the one of the risk management according to the relation (1) [13]:

$$Risk = Hazard. \text{ Vulnerability} \quad (1)$$

$$Risk = Hazard. (Vul\text{nerability} / Policy) \quad (2)$$

By comparison, to the old definition (1) that neglected the notion of the preventive management, the new approach (2) defined the fragility like a science being a matter for the domain of the appraisal and the domain of sciences of the politics of the urban management prevention. A great effort remains to achieve in the definition of the fragility. Indeed, the reference in terms of fragility leads directly to the today's standards.

For the "possibilist" method, three scales are globally to be considered for the identification of conditions to reduce the factors of risk that will be able to realise concrete actions of prevention:

- The macro-scale (regional and national scales): structural factors and processes that contribute to generate risks may be apprehended, while increasing the vulnerability of populations and of the city as a whole, as poverty, phenomena of rural exodus, unemployment, the economic and political instability, etc. Researchers may very well propose solutions. However these factors or processes are not easily mastered and do not permit to propose sufficiently targeted solutions, efficient and aiming in the short term.
- The middle-scale (intermediate scale of the city) where general solutions to middle or long terms are foreseeable. It is notably about measures of urban preventive scheduling and to establish urban disaster management.
- The micro-scale where we find amplified risk, the very local forms of vulnerability and the common survey subjects between disciplines. According to the analysis of the risk and the weakness of technical design (technical approach of the vulnerability), earth sciences and the civil engineering may elaborate solutions, or even estimate the cost of it. The role of human sciences is to orient and to propose solutions by the identification of conditions of risk reduction.

These elements constitute the urban system (populations, proprieties, functions, activities, modes of management and decision-making...) cannot be studied in an exhaustive and deepened manner in terms of risks and vulnerability. To be efficient the research must focalise on certain spaces and certain elements taking in account that the risk would constitute a major handicap for the community concerned, the urban functions and the development of the city (or even of the country). The problematic supposes to privilege the last two levels of geographical analysis; therefore, the first one at the level of the city, the second concerning the local scale and more precisely of spaces and elements (challenges) important within the city. The first level of analysis doesn't constitute an end in itself but stands to the service of the second level whose findings should be operational. The multidisciplinary studies should be therefore adapted to the needs of these two levels of analysis, so much in their nature that in their precision.

The "phenomenological" approach permits, once the challenges are identified, to reconstitute the causes of the damage. For this, the historical development of the urban system could be coupled with the physical process evolution in order to understand multi factorial interactions to the causes of the damage. Reactions of populations as the political decision of the public power facing the damage must be recovered and analysed, in order to value its induced effects. For example, structures built in preventing risks linked to water and earthquakes do not reduce the vulnerability systematically. The behaviour of the urban populations may have a significant impact on the perception of the risk. Only detailed case studies of some urban sites allow establish a diagnosis in order to propose measures that justify the recent evolution of the territorial organization under damage. There are now opportunities to bring together earth scientists, engineers and social scientists from Algeria to propose a methodology for reduction risk using semi-empirical data and field surveys. As a result, various kinds of mitigation measures are being applied. These recommendations concern the urban policy of the city of Algiers after the flooding of November, 10, 2001.

To avoid a sectorial and segmented vision, the risk disaster must be considered in a global and integrated approach. Indeed taking into account simultaneously all factors of the risks goes in a rational and voluntary approach permitting to reduce the disasters impact on the city and on the territory. A methodology that permits to take the risk disaster in charge in the urban politics is necessary. Our study permits to underline the following propositions and recommendations:

- The creation of urbanism service to the intercommunity links for small cities having as mission to contribute to the technical plan of soil occupation and the director plan of urban planning, and carry technical free help to citizens. This service may collaborate with services of the land registering and services of the regional development in the scale of intercommunity.
- The unification of the technical services of the cities with the different ministerial departments for more coordination in action.
- The obligation to do impact studies for projects of important size in the cities.
- The creation of an institution charged for the prevention and the management of disasters. Its action must rest on the creation of database oriented toward knowledge of reasons, consequences and relative circumstances (conjunctions) to phenomena of disasters in a general manner. This approach permits to model disasters and to simulate scenarios. It may do comparisons between the local cases and the cases of disaster in others countries and establish rules for the urban risk reduction and create specific risk databases. These databases consist of the geological, geotechnical and structural engineering data provided by geographic information systems [14]. These databases are important in characterising the urban risk: earthquake source database, geotechnical hazard database, and vulnerability database.
- Adoption of a rational urban insurance policy [15] and urban planning.

The urban design in the district is one component of the urban composition in the town. For the national policy, the town is one part of the region planning. The vision of the urban disaster must be taken in account during the urban process of the town planning, before and after the realization of the town. This approach associates the action of the technician actor with the action of the policy actor [16] and [17].

V. Conclusion

Storm Water Drains, Sewerage System and Solid Waste handling are the vital components of urban civic management. Given its geographical shape, topography, coastal nature,

population density including floating population and rate of precipitation, proper performance of Algiers's systems of Storm Water Drains, Sewerage and Solid Waste Handling is always very important.

The city area has no natural drainage outlet. The central area forming a depression, flanked by hills, and being on reclaimed grounds barely two to three meters above sea level is liable to flooding during the autumn season. *The main factors contributing to the disaster are identified as follows:*

- Heavy rain;
- Obstruction of the main collectors of rainwater;
- Termination of green space (impermeable);
- Obstruction of streets by parked vehicles (formation of dams that have failed suddenly);
- Malfunction in the system of early warning: the weather has sent an alarming report to the authorities 18 hours prior to the disaster (Figure 6);
- failure in the management of road traffic (most of the victims were students and workers stranded in buses and cars),
- Lack of rigor in the technical management of the city.

The approach based on the expertise has permit to set the links between urban planning, urban development and disasters like flooding. Management of the urban can not to be divided into isolated segments because the city is a system composed of a space, considered as a social, economic and political support.

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