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# FLOOD RISK REDUCTION STRATEGY IN ALGIERS A BRIEF MODERN HISTORY (XVI$^{th}$C -XIX$^{th}$C)

# STRATEGIE DE REDUCTION DU RISQUE INONDATION A ALGER APERCU HISTORIQUE (XVI$^{È}$ S- XIX$^{È}$ S)

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## ABSTRACT

This paper aim is to contribute better know the water related risks management heritage in Algeria while promoting in favor of contemporary cities resilience face to climate and environmental changes. Some relevant technical and organizational measures commonly used in Algiers until the beginning of the XIX$^{th}$ century may be consistent with the UN-disaster risk reduction strategies.

Thus specific objectives are to i) characterize the hydro meteorological context and identify the associated flood risk; ii) examine the urban growth and land use patterns consistency with the local water geography and dynamic; iii) assess the adequacy of past prevention and protection measures implemented against current recommending.

Results show i) the variability of flood effects over the city; ii) the integrated and pragmatic approach adopted to achieve prevention and protection goals; and iii) the significant role of urban planning in the flood risk reduction strategy.

**Keywords**: Algiers, flood risk, hydro meteorological hazards, urbanism, XVI$^{th}$c-XIX$^{th}$c.

## RESUME

Le principal objectif du présent article est de contribuer à la connaissance du patrimoine historique de gestion des risques liés à l'eau à Alger et promouvoir sa valorisation en faveur de la résilience des villes contemporaines face aux changements climatiques et environnementaux. Les prémisses de la stratégie des Nations Unies pour la réduction des risques de catastrophes naturelles apparaissent en effet dans certaines mesures techniques et organisationnelles en usage à Alger jusqu'au début du XIX$^{è}$s.

Les objectifs spécifiques consistent à: i) caractériser le contexte hydro météorologique en termes d'aléas et risques d'inondation associés; ii) apprécier la pertinence du schéma de développement urbain en termes d'occupation et d'usage du sol par rapport à la géographie et dynamique locale de l'eau; iii) apprécier l'adéquation des mesures de prévention et protection mises en œuvre par le passé avec les principales dispositions recommandées aujourd'hui.

Les résultats montrent i) une distribution spatiale différenciée des effets des inondations ; ii) l'adoption d'une approche intégrée visant la prévention et protection contre plusieurs risques liés à l'eau ; iii) le rôle notable de l'urbanisme dans la stratégie de réduction du risque inondation.

**Mots clés** : aléas hydro météorologiques, Alger, risque d'inondation, urbanisme, XVI$^{è}$ s-XIX$^{è}$ s

## INTRODUCTION

Human societies used to set next to water bodies for the benefit of military defense, water and food easy supply, transport amenities, leisure, and even religious ritual as it is along the Ganges in India. Many ancient cities around the world have invested coastal and river plains. Some have flourished such as *Fez*, founded in 789 AD in the *Wad Faz* valley, Roma founded in 735 BC in the Tiber valley, Buenos Aires, founded in 1536 along Rio de la Plata coastal estuary. Some others have been abandoned over time such as Ur, the ancient *Ibrahim* (pbuh) town, that was once an island city on the Euphrates River northern the Persian Gulf, being nowadays an inland archeological site in the Iraq desert. In Algeria, the famous *Qalat Bani Hammad*, founded by *Hammad Ibn Bulughin* in 1007-1008 on the *Maadid* mountainside overhanging Chott Hodna, is now a world heritage city, registered on the UNESCO World Heritage List since 1980.

In the collective imagination, water sounds like the Eden as much as the deluge as one day the river may naturally overflow just as the swell may naturally break on the continent. Resulting floods, submersion, erosion and marine intrusion phenomena pose a threat to surrounding landscapes, biodiversity, ecosystems and therefore populations whose livelihood depends on. According to future climate scenario, such hydro-meteorological hazards are even becoming more frequent and intense in the Mediterranean region causing disasters and perils when severely affecting human life and natural environment integrity (IPCC, 2019; Cramer et al, 2018). Thus the exposure level is expected to be higher in the near future.

At the same time, the rapid urban sprawl is creating a critical issue challenging cities being at the origin of an increasing vulnerability and thus an amplified disaster risk

(IPCC, 2018-d; UN-Habitat, 2018-b; UN-Habitat, 2011). Thus hydro-meteorological events become more risky when crossing or embracing fragile human settlement areas. The danger is of critical level when water geography and dynamic are notably disturbed due *inter alia* to the inappropriate (qualitative criterion) and/or abusive land use pattern (quantitative criterion) either on surface or at depth. The more the watershed is artificialized, built and/or covered, the higher the effects are. For instance, flood effects are more significant when surface and subsurface runoff resulting from heavy rainfall cannot infiltrate or absorbed into the ground or conveyed over an appropriate sewerage. Then excess water collect locally (flat area) or flow downstream (sloping area) causing stagnant pool formation, contamination, pollution, erosion and finally flood. Technical solutions and legal texts alone may prove insufficient to improve the capacity of cities to protect against such an endless cycle of unpredictable and potentially irreversible consequences engaging human and natural environments into a non-linear change reality (UNDRR, 2015). For this purpose, urban planning/design is urged to involve in risk reduction strategy and contribute improving the city resilience by targeting causes factors prior to effects (Unesco-IHP, 2009; UNDRR, 2015).

For the purpose, the United Nations strategy for disaster risk reduction and more specifically integrated flood management strategy recommends some pragmatic provisions here synthesized by Oosterberg et al (2005):

- keep floods away from urban areas in order to minimize the exposure level,
- keep urban areas away from floods in order to minimize the risk level,
- prepare urban areas for floods in order to minimize the fragility level,

Now some historical/ or vernacular cities do either conserve or sustain an advantageous water heritage combining technical with organizational measures dedicated to reduce risks associated with hydro-meteorological hazards and even to capitalize local environmental variables (ICOMOS, 2015). In this respect, the Unesco project for the reduction of hydro-meteorological risks in Asia-Pacific underlined the need to promote water local knowledge which well proved to be effective and sustainable (Hiwasaki et al., 2014). This paper is in line with that perspective arguing that technical and organizational measures used in Algiers until the beginning of the 19th century are quite in line with the United Nations strategy for disaster risk reduction and more particularly with the integrated flood management strategy (UNDRR, 2017; UNDRR, 2015; Oosterberg et al., 2005).

In Algeria, some historical cities do still display a set of water works relics, some of which are still operating locally as like the *foggara* southern Algeria (Remini, 2008). That water heritage should be systematically identified, classified and possibly capitalized in favor of contemporary cities resilience in face of climate and environmental changes. Many primary related source documents are just waiting to be investigated. In addition to the irreplaceable archives and original manuscripts, number of printed materials is available in Algeria. As example, Devoulx, who was the Conservateur des Archives arabes du Service de l'Enregistrement et des Domaines in Algiers, has collected some valuable documents clarifying the role of local religious corporations in water management (Devoulx, 1912). Pasquali's thesis dedicated to the *Casbah of Algiers* (Pasquali, 1951) and his paper examining Algiers' water supply issue (Pasquali, 1953) described in detail the water system implemented during the Ottoman (XVI$^{th}$-XIX$^{th}$ c.) and colonial periods (1830-1962). More recently, Professor Belhamissi has dedicated a book to the original Algiers water heritage between the 16$^{th}$ century and the XIX$^{th}$ century (Belhamissi, 2004). Additionally, water supply and sanitation systems in Algiers during the same time interval have been previously addressed by the author (Aroua, 1998; Aroua, 2005). Algiers is formulated as a relevant case study due to that heritage and present nagging water issue.

However, the consulted bibliography shows that water has been generally addressed as a resource rather than a risk and even less as a landscape asset (including wetlands) while all are at work and interact systematically within the global water cycle. Flood risk in particular has been deeply reinvested only since the 2001Bab al-wad tragedy (Cheikh lounis et al, 2015; Behlouli, 2003; Djelouli and Saci, 2003; Behlouli, 2001). Otherwise, past shortage and contamination events have been analyzed by the author in previous works as cited above. Similarly, past health risks such as public health and water-borne diseases have been examined by Chibane and Aroua (Chibane and Aroua, 2005). However, the topic is far from being exhausted.

## METHOD AND TOOLS

Regarding the popular knowledge relevance, effectiveness and sustainability, number of civil associations and international organizations are rightly calling to capitalize in restoring the deliquescent relationship between nature and man beings (Setten et al, 2019; Wisner, 2009). This paper aim is just to contribute better know the water heritage dedicated to flood risk reduction in Algiers before the French colonization as it has been developed during the Ottoman period (XVI$^{th}$-XIX$^{th}$ c.). It is to question the city strategy to get adapted to the hydro-meteorological context and measures implemented in order to cope with flood events. Ultimately it is to promote that heritage in favor of contemporary cities resilience in face to climate change associated extremes.

Algiers and the modern time interval are considered for this study in view of the potential contribution of the past water heritage to addressing present critical water issues associated with anthropogenic, environmental and climate changes. The ottoman period is considered *first*, as regards the huge quantity of water works built starting from the XVI$^{th}$ century and *second*, the continuing improvement of the urban water system including technical inputs from al-Andalus.

As used in this paper, Algiers designates the historic city as it was on the eve of the French colonization. The city map shows the original urban layout after Morin while architect Guion drawings document number of streets and buildings just before the massive demolitions of downstream districts few years later. As shown in Fig. 3, the proper perimeter of that world heritage city is roughly equal to the *Casbah* municipality boundaries within the Wilaya of Algiers (maybe the smallest municipality 1.09 km$^2$ out of 808.89 km$^2$ after the Wilaya of Algiers website (http://www.wilaya-alger.dz).

The flood risk strategy implemented during the study time interval is examined as per:

- the target objective, whether it comes to prevention scope (dealing with causes) or to the protection scope (dealing with effects),
- the privileged urban planning pattern (zoning, specific servitudes and governance provisions) .

The method consists of a qualitative analysis aiming to:

i) profile the hydro-meteorological context and delineate associated urban flood risk,

ii) compare the urban growth pattern against the local water geography and flood risk perimeter.

iii) compare implemented flood risk reduction measures against current recommended strategy principles.

Besides, the analysis refers to the following terminology:

i) the hydro-meteorological hazards classified as natural events closely depending on the rainfall regime,

ii) the flood event classified as derived phenomena involving the natural hazard and human issues simultaneously, including material issues.

iii) the risk system incorporating source and target subsystems as modeled by Aroua. (Aroua, 2012). As shown in Fig. 1, this system dynamic is powered by some interacting events:

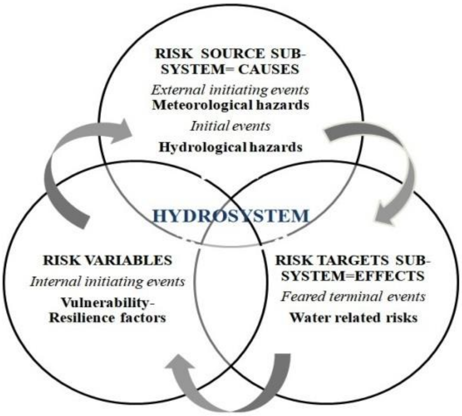


**Figure 1: Risk system associated with hydro-meteorological hazards (Aroua, 2012)**

- *External initiating events* (meteorological hazard = heavy or low rainfall) and *initial events* (hydrological hazard = drought, flood, erosion, landslide, etc.) whose conjunction generates hydro-meteorological hazards. Although being recurrent, the latter remain unpredictable and uncontainable depending on the irregular rainfall regime characteristic of the Mediterranean region (Burak and Margat, 2016). As per the study time interval, initial events mainly consist in drought affecting the surface and underground water components, storm water, floods, erosion and landslides. As long as they occur during the continental phase of the global water cycle they may present a risk for the populations living within their occurring area.

- *Internal initiating events* that designate the urban vulnerability-resilience factors as resulting from the hazard interacting with human issues being at the origin of the risk system. Vulnerability depends on environmental factors designating the exposure level from one hand and anthropogenic factors designating the fragility level from another hand. Resilience depends on structural factors designating the adaptation capacity from one hand and functional factors designating the transformability or flexibility from another hand.

- *Terminal events* associated with hydro-meteorological hazards designate the potential risk such as scarcity, contamination, insalubrities and flooding, infectious and water-borne diseases.

**Hydro-meteorological context, natural hazards and associated risks**

Algiers is located along the interface between four morphological entities within the Algiers coastal watershed as shown in Fig. 2:

-The Algiers mountain (also named *Bouzareah* Mountain) 407 m altitude, facing the Mediterranean Sea northern and eastern, and the *Mitidja* plain western. The ruins of the Phoenician post named *Ikosim* (~ 2$^{nd}$ century BC) and the Roman city named *Icosium* (from the 1$^{st}$ century BC) are at downstream (Le Glay, 1968; Pasquali, 1951). In the 10$^{th}$ century, the medieval city, *Djazair Beni Mezghenna*, is built on the ruins of the Roman city, around the small harbor. Then it continues to grow gradually investing the mountain eastern side well beyond the twenty meters coastline. During the study time interval, Algiers grows up and densifies within a constant perimeter delineated by two deep thalwegs northwestern and southwestern. The site is crossed by several temporary watercourses such as *Maghasal Wad*, *Kniss Wad* and *Beni Messous Wad* originating in the *Bouzaréah* Mountain and running over the *Fahs* hills area. That sloping topography (greater than 35%) do naturally expose upstream districts to erosion and landslides. Downstream districts are rather exposed to flash flood events as shown in Fig. 2 (GGA, 1998).

-The hilly area named *Sahel* (50 to 250 m altitude), with limestone-sandstone, blue marls and sedimentary deposits substrate, profiling the *Fahs* region. It is the fertile and green countryside where Algiers dignitaries' used to set their secondary residences. It is crossed by several small rivers and emerging sources.

-The *Mitidja* coastal plain is 130,000 hectares with almost 100 km long and about 15 to 20 km wide. It is the farming area par excellence, drained by several rivers, the longers are *Mazafran River* (98 km), *Harrach River* (59 km), *Hamiz River* (35 km) and *Reghaia River* (13 km). The clay soil, naturally impermeable, associated with a very slight slope (0 to 3%) and a weak drainage network are at the origin of a large wetland area. It registers recurrent slow plain floods (Aroua, 2012; Khodja, 1985).

- The Blida Mountain or Blida Atlas Tell, 1000 to 1600m altitude, bordering the *Mitidja* plain southern.

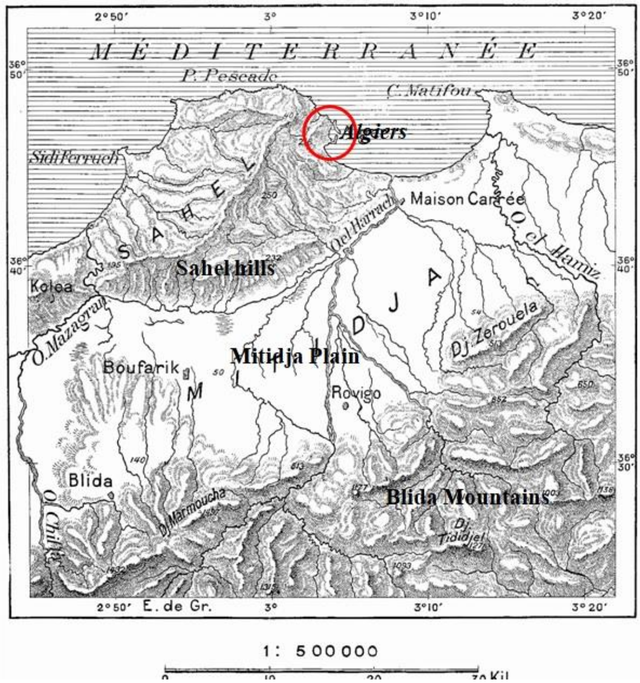


**Figure 2: Physical geography of Algiers coastal watershed as shown (Reclus E., 1905)**

The Algiers coastal hydrographic basin which incorporates Algiers is located in the sub humid bioclimatic domain with high agricultural value (ABH-AHS, 2002). The minimum (16-18° C) and maximum (33-35° C) average temperatures distinguish two main seasons, cold and humid from September to May, hot and dry from June to August. The site is sometimes crossed by warm south winds (the sirocco) resulting in an increase temperature exceeding 40° C. Between June and September humidity level is maximum (88 to 90%) and water evaporation more rapid. The low water period generally begins in May. Average rainfall varies from 600 to 800 mm / year. The first rains generally fall between September and November while the finals fall in April-May. In December-January, they are intense possibly exceeding 100 mm. In July-

August, they are almost null. The rainfall irregularity from year to year naturally exposes the whole region to drought and floods.

Episodes of heavy precipitation are reported by some authors who stayed in Algiers during the study time interval such as Haedo in the 16th century (Captive in Algiers from 1578 to 1581), Shaw in the 18th century (English chaplain attached to Algiers from 1720 to 1732), Venture de Paradis in the 18th century (on reconnaissance mission in Algiers from 1788 to 1790), Shaler in the 19th century (United States Consul in Algiers from 1815 to 1828). Considering the length of their stay, their statement is of great interest as regards the study of Algiers past climate and weather conditions. For example, in the 1579 winter time, Haedo noticed heavy storm water invading ravines and downstream streets with mud (Haedo, 1870). In 1732, Shaw reported a singular two or three-day stormy rains (Shaw, 1830). Regular extreme events cumulating 600 to 700 mm, or even more than 1000 mm are generally observed between November and December (Shaler, 1830; Shaw, 1830). In 1788, Venture de Paradis recorded an unusual two-day snowy episode (Paradis (de), 1983).

## Urban growth pattern *vs* the local water geography and dynamic

Starting from the beginning of the 16th century, Algiers is the capital of an almost independent State

The proper city perimeter includes two morphological units:

- downstream, *al-w'ta* (ie the lower zone) is the main social-economic, religious and political activities zone, accommodating number of public facilities, some of which are of strategic importance such as the Government House named *al-Djanina*, military barracks and above all the port which the country's economy strongly depends on. The major commercial street connects two main gates named *Bab-al-wad* and *Bab-Azoun* from north to south (in red on the map / Fig. 3).
- upstream, *al-djabal* (i.e. the mountain) is the quasi strict residential zone where districts get organized around a semi-private square and houses around a central courtyard. Some houses are interconnected by wooden corbellings forming covered passageways which may occasionally provide sun/rain protection (De Paradis, 1983). From the very beginning of the XVIth century up the XIXth c, each house generally has its own well and many have also an underground cistern (Balhamissi, 2004; Haedo, 1988; Raymond, 1985).

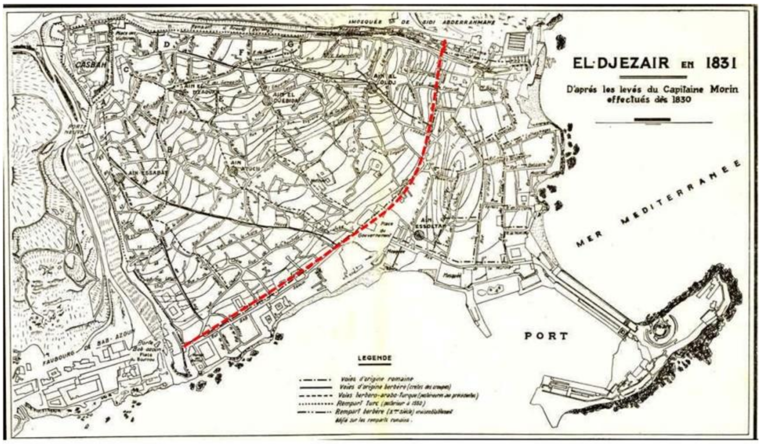


**Figure 3: Algiers en 1831 after Morin.**

The city map shows an original street network differentiated into wide streets named *zanqa* and squares named *rahba* in the downtown and alleys named *zniqa* and dead ends named *driba* upstream. Street ramifications delineate the urban layout. In the lower part of the city, they are sometimes parallel (*Bab al-Wad - Bab Azzoun* north-south axis, designating the Roman *cardo*) and sometimes perpendicular to the coast line (Rue de la Marine, designating the Roman *decumanus*) (Pasquali, 1951). As shown in Fig. 3, streets layout, including dead ends, do precisely follow the natural land gradient in order to facilitate runoff drainage (Boyer, 1963). Some ravines are covered and serve as a sewage network leading to the main city public square named *al-badistan* and from there to the sea (Pasquali, 1951).

The city districts are variably impacted by flash flood events depending on their location. Lower zone, *al-w'ta*, do more suffer water congestion in addition to sludge. People mobility, transport and consequently urban activities may then record material damages. Whatever streets are paved and well-maintained, but they can be significant as it was in winter 1536 when heavy rains partially damaged the city walls (Belhamissi, 2004, Shaler, 1830). Besides, when floods are concomitant with storm at sea, damages may be even more important. The 1541 violent storm and strong northwest winds remained famous as for breaking the fleet of Charles V when trying to assault Algiers (Rozetet Carette, 1980).

## RESULTS AND DISCUSSION

After the risk system model (Fig. 1), the flood event (i.e. initial event) may result from an unusual heavy rainfall episode (i.e. external initiating event). They both represent natural causes behind the flood risk within the risk source sub-system. As such, they are obviously out of any human control. By contrast, the flood risk variables are clearly of human responsibility. Reducing the vulnerability level comes to reduce the exposure and the fragility levels and improve the resilience capacity. As per the flood risk, it is simply to adapt to the hydro-meteorological context by keeping urban areas far from any known flood perimeter and vice versa when planning for suitable urban water works. First are to mitigate the risk causes and thus set prevention measures, second are to mitigate the effects and thus set protection measures. As demonstrated here below, Algiers water heritage dedicated to flood risk reduction did well invest that time water knowledge by combining pragmatic solutions resulting from centuries of experience with water specific science theory and jurisprudence.

**Keep floods away from urban areas (minimize the exposure level)**

Algiers location is a natural defensive place in addition to being well provided with surface and ground water. It is a very suitable safety sedentary human settlement as stated by many authors (Le Glay, 1968; Bonnafont, 1839). While human societies generally prefer to settle over the plain, neither the Phoenician post *Ikosim*, nor the Roman city *Icosium*, or even *Djazair Beni Mezghenna* founded by *Bologhine* in the 10$^{th}$ century, did move away from the Bouzarea Mountain. Likewise in the beginning of the 16$^{th}$ century when Algiers becomes the Capital city, basing a large part of its economy on maritime trade and intense port activity. As shown in Fig. 4, at that time, residential areas rather are upstream while social-economic facilities are roughly concentrated in the lower area where main amenities can be found. That zoning process efficacy is widely recognized and recommended nowadays (Jha et al, 2012).

**Figure 4: Commercial area downstream (left) and residential districts upstream (right), (Guion, 1938-1940)**

Referring to the collected literature, the city used to record flash floods due to heavy rainfall episodes. Regarding the local topography, effects must have been more significant downstream. Flood events are naturally more devastating *extra muros* over the *Fahs* surrounding hills and the *Mitidja* plain either due to river flooding or water level rises. Fortunately, rivers originating in Bouzarea Mountain do not cross the city. The *Mitidja* plain records regular floods being crossed by many rivers from west to east including Wad Harrach and tributaries (Aroua, 2012). For a long time, it has been the supplier hinterland providing the city with abundant food and water. No permanent urban settlement has been built there until the beginning of the 19$^{th}$ century and the first French colonial villages (Aroua, 2011).

Keeping the primitive urban site on the mountainside far from devastating flood perimeter contributes minimizing the exposure level. It comes to land use and town planning.

**Keep urban areas away from floods (minimize the risk level)**

In wet weather, high speed runoff crashes towards lower districts along thalweg lines transformed into streets and alleys. Although streets are daily cleaned, water flows may carry waste material, contaminants and polluting substances engendering ponds and mud collection downstream. That may result in urban insalubrities, traffic interruption, material loss, and subsequently social-economic damages. Although generated damages are reversible, minor to significant, they can be of critical to major level if human life is threatened (Aroua, 2012).

The strategy implemented based on two measures. *First*, was to reduce the high runoff volume upstream by systematically collecting and storing rainfall water in private cistern which each house had to set under a government decree dating from the 17$^{th}$ century (Belhamissi, 2004, Laugier de Tassy cited by Lespès, 1930). *Second*, was to facilitate runoff precipitation by draining over the sewage network in order to reduce the storm water runoff volume and flow downstream. For instance, the sewer network has been generalized in the early 17$^{th}$ century (Aroua, 2005; Belhamissi, 2004). Those measures also contribute anticipating water scarcity and urban insalubrities.

Keeping urban areas away from flooding water path by systemizing private harvesting and public draining practices contributes minimizing the risk level. It comes to domestic architecture, land use and urban street amenities.

**Prepare urban areas for floods (minimize the fragility level)**

The strategy implemented was *first*, to prevent obstruction or diversion of runoff water path, and *second*, to prevent infiltration and percolation into underground. As shown in Fig. 5, while the city gradually expanded and densified over the mountain slope, thalwegs have been conserved and the general profile of the site remained little changed (Pasquali, 1951). Although built surfaces increased, but the land storage capacity and time runoff would have been little modified due to the streets limestone pavers that contribute compensating waterproofed infiltration areas. Besides, as long as urban wastes were daily removed, transport of debris and polluting products is minimized (Paradis (de), 1983; Pasquali, 1953; Klein, 1910).

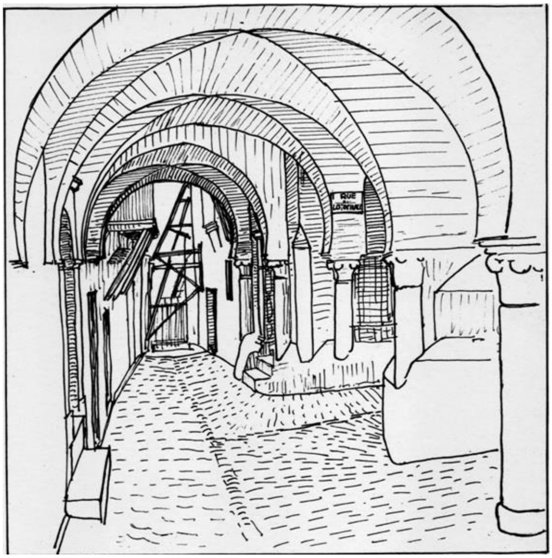

**Figure 5: Paved street with small central drainage channel (Guion, 1938-1940)**

Furthermore, from the beginning of the Ottoman period, the population increase and urban growth called for many urban services including water supply as well as the adoption of some public health and sanitation measures such as streets maintenance and cleaning, solid waste collection, removal and recycling in addition to wastewater drainage (Aroua, 2005). These functions were performed by professional corporations each administered by a chief named *amin* or *khodja* who used to ensure compliance and effective execution in due time using local usage rules (Devoulx, 1912). Inhabitants were asked to bring domestic waste into an appropriate cavity in the outside wall in order to facilitate and systematize their removal in the morning (Rozet cited by Lespès, 1930). Any dirt unclean doorstep or voluntary contamination of public fountains water was liable to fines and severely punished (Paradis (de), 1983).

Preparing urban areas for floods come to urban planning and urban governance. They contribute to the protection strategy since avoiding the aggravation of storm water effects from up to downstream. They subsequently contribute minimizing the urban vulnerability and improving resilience face to both flood and contamination risks.

## CONCLUSIONS

This paper objective is to contribute better know while promoting the water heritage dedicated to flood risk reduction in favor of the resilience of contemporary cities in face of current climate and environmental changes. The paper refers to some relevant documents related to water issues in Algiers during the ottoman period. However, for an exhaustive and more detailed state of art, it is worth examining number of additional archives and stay reports dating from the pre-colonial era. Exceptional weather conditions and flood events may have been noticed over three centuries while the city should have systematically widened and/or improved its coping strategy in flood risk reduction. A valuable research perspective could be opened on the topic. Past lessons learnt are of great interest with regard to present challenges.

For instance, results show that the flood risk reduction strategy implemented in Algiers during the study time interval has well combined structural with non-structural measures in shaping a management system in line with key principles of the current integrated water cycle management strategy along with the United Nations strategy for disaster risk reduction and integrated flood management strategy (UNDRR, 2015; UNESCO-IHE, 2014; UNESCO-IHP, 2009). In that sense that strategy did simultaneously address other water related risks such as contamination and scarcity. This so-called multi-risk approach is highly recommended nowadays (UNDRR, 2015)

Flood risks associated with hydro-meteorological hazards, result in fact from the combined action of environmental factors with anthropogenic factors. Indeed some urban growth/design patterns that seem to be profitable *a priori* (economically in particular) can interfere negatively in the water cycle being disastrous in the long run (Aroua, 2020). Effects may be unpredictable, possibly irreversible and difficult to control *a posteriori* as cascading effects can diffuse beyond the event proper perimeter and duration (UNDRR, 2015). For instance, experience demonstrated more than once the validity of coping with hydro-meteorological hazards and associated risks at the watershed scale over the long run by combining structural with non-structural measures (Albuquerque et al, 2019; Shih et al, 2019; Petri, 2002). Results show that those principles have been partly incorporated into the flood risk reduction strategy implemented in Algiers during the study time interval as demonstrated above.

Moreover, that management system has just based on the commitment of inhabitants and the State government as well, in addition to a specific legislation and a set of effective techniques alongside a judicious land use pattern *intra* and *extra muros*. Urban planning and architecture played a key role in preventing risk causes and protecting against its cascading effects by adapting to the hydro-meteorological context and local physiography. While addressing systemic interactions between the natural environment and human societies, urban planning is able to effectively contribute conserving and/or restoring the water natural geography and dynamics by facilitating surface and ground water courses over the city proper perimeter and beyond as it used to be dine in Algiers in that time.

History and experience show that whenever natural phenomena interfere with highly anthropogenic environments, they may generate critical risks threatening public health and safety. It is a major challenge to invest in urban water sensitive planning far from universal norms and theoretical concepts. While hydro meteorological science has considerably progressed since the beginning of the 20th century (Desmons, 2015), now the question is how and when should be integrated into land and urban planning in order to contribute preserving human right to water and social cohesion for present and future generations.

## REFERENCES

Agence des Nations Unies pour les réfugiés /UNHCR. (2017). Le changement climatique, les catastrophes et les déplacements humains, 38p.

Agence du Bassin Hydrographique Algérois-Hodna-Soummam. (2002). Carnet de l'Agence du Bassin Hydrographique Algérois-Hodna-Soummam, n°1, Mai 2002.

ALBUQUERQUE M.B., ARDENGUE de ARAÚJ A., MARTINEZ C.E.N.M., MAUAD F.F. OKAWA C.M.P. (2019). Sustainable Urban Drainage: a brief review of the compensatory techniques of structural and non-structural measures, REVISTA ELETRÔNICA EM GESTÃO, EDUCAÇÃO E TECNOLOGIA AMBIENTAL, Santa Maria Vol.23, pp 1-9.

AROUA N. (2020). Géohistoire des effets de l'urbanisation sur les hydrosystèmes côtiers algérois, Proceeding de Acqua e terra neipaesaggimonastici:gestione, cura e costruzionedelsuolo, Abbazia di Praglia16-18 maggio 2019.

AROUA N. (2012). Facteurs de vulnérabilité et capacité de résilience du milieu urbain face aux risques hydro climatiques dans la commune algéroise d'el Harrach. Thèse Es Doctorat soutenue à l'Ecole polytechnique d'architecture et d'urbanisme d'Alger, 294 p+ Annexes.

AROUA N. (2011). Peuplement de la plaine orientale d'alger, urbanisation ou vulnérabilisation ?, Revue du Nord - N° 26 Hors série Collection Histoire, pp 307-317

AROUA N. (2005). Approvisionnement en eau et assainissement à Alger à l'époque othomane, 38th International Congress of the History of Medicine, Ed. Sari N., Bayat A.H., Ulman Y. et Isin M., Ankara, pp 963-975.

AROUA N. (1998). Hygiène et santé publique en milieu urbain algérois à l'époque othomane, 36è Congrès Mondial d'Histoire de la Médecine. Tunis. 6-11 Septembre 1998.

BEHLOULI L. (2003). Evènement Bab el-Oued du 09/10/2001, Séminaire « Architecture, risques naturels et environnement, Alger.

BEHLOULI L. (2001). Crues et inondations en Algérie, ANRH, 43 p.

BELHAMISSI M. (2004), Alger par ses eaux XVIè-XIXè siècles, Ministère de la communication et de la culture, 156p.

BONNAFONT J-P. (1839). Géographie médicale d’Alger et de ses environs, Alger,177 pages.

BOYER P. (1963). La vie quotidienne à Alger à la veille de l’intervention française, Ed Hachette, 268p.

BURAK S., MARGAT J. (2016). Water Management in the Mediterranean Region: Concepts and Policies, Water Resour Manage DOI 10.1007/s11269-016-1389-4, 19p.

CHEIKH LOUNIS G., CHATELAIN J-L. , MIMOUNI O., MACHANE D. (2015). Assessment of Flood Risk in Kniss Wadi Catchment in Urbain Area Algiers—Algeria, G. Lollino et al. (eds.), Engineering Geology for Society and Territory – Vol. 3, pp 459-462.

CHIBANE S., AROUA M. (2005). Médecine et santé en Algérie pendant la période ottomane, 38th International Congress of the History of Medicine, Ed. Sari N., Bayat A.H., Ulman Y. et Isin M., Ankara, pp 947-962.

CRAMER W., GUIOT J., FADER M., GARRABOU J., GATTUSO J-P., IGLESIAS A., LANGE MA., LIONELLO P., LLA-SAT MC., PAZ S., PEÑUELAS J., SNOUSSI M., TORETI A., TSIMPLIS MN., XOPLAKI E. (2018). Climate change and interconnected risks to sustainable development in the Mediterranean. Nature Climate Change Vol.8, pp 972-980.

DESMONS J. (2015). Génie climatique, Dunod, 4è édition, 541p.

DEVOULX A. (1912). Notice sur les corporations religieuses d’Alger, Alger, Ed Jourdan, 79p.

DJELLOULI Y., SACI A. (2003). Catastrophe « naturelle » : les inondations dévastatrices du 9 et 10 novembre 2001 à Bâb el Oued (Alger, Algérie), Publication de l'Association Internationale de Climatologie, Vol. 15, pp 236-242.

Gouvernorat du Grand Alger (1998). Alger, Capitale du 21è siècle, Vol. 1, 319p.

GUION P. (1938-1940). Images du Vieil Alger, SEPIA.

HAEDO D. (1870). Topographie et histoire générale d’Alger, Traduit de l’espagnol par Monnereau et Berbrugger A., 224p.

HIWASAKI L., EMMANUEL L., SYAMSIDIK, RAJIB S. (2014). Local and indigenous knowledge for community resilience, UNESCO, 60 p.

ICOMOS (2015). Cultural heritages of water in the Middle East and Maghreb, First edition, International Council on Monuments and Sites, 300p.

IPCC, (2019). Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, Summary for Policymakers, 80p.

JHA A.K., BLOCH R., LAMOND J. (2012). Cities and Flooding A Guide to Integrated Urban Flood Risk Management for the 21st Century, The World Bank, 631p.

KHODJA H. (1985). Le Miroir, Ed Sindbad, 319p.

KLEIN H. (2003). Feuillets d'El-Djezaïr, Editions du Tell, Tome 2, 190p.

LE GLAY M. (1968). A la recherché d'Icosium, Antiquités africaines, Tome 2, pp 7-54.

LESPES R. (1930). Alger. Esquisse de géographie urbaine, Paris, 860 p.

OOSTERBERG W., VAN DRIMMELEN C., VAN DER VLIST M. (2005). Strategies to harmonize urbanization and flood risk management in delta's, Study commissioned by the Directorate General of Water Affairs (DCWA of the Dutch Ministry of Transport, Public Works and Water Management (V & W), in New Economics Papers, August 2005, 31 p.

PASQUALI E. (1953). L'alimentation en eau potable d'Alger de l'époque romaine à nos jours, 20 p.

PASQUALI E. (1951). La Casbah d'Alger, 215 p

PARADIS (de) V. (1983). Tunis et Alger au XVIIIè siècle, Ed Sindbad, 290p.

PETRI B. (2002). Keynote lecture: Coping with floods: complementarity of structural and non-structural measures, Flood defense, pp 60-70.

RECLUS E. (1905). L'Homme et la terre, Tome 5, Livre 13, Chapitre 17

REMINI B. (2008). La Foggara, Editions OPU, 132p.

ROZET C.A., CARETTE M.E., (1980). Algérie. Etats tripolitains, 2è Ed, Edition Bouslama, Tunis, 490 p,

SETTEN G., LEIN H. (2019). "We draw on what we know anyway": The meaning and role of local knowledge in natural hazard management, International Journal of Disaster Risk Reduction Vol. 38, pp 1-8.

SHALER W. (1830). Tr Blanchi M.X. Esquisse de l'Etat d'Alger, Imprimerie de Gaultier Languioni, 408p.

SHAW T. (1830).Voyage dans la régence d'Alger, Ed. CHEZ MARLLN, 406p.

SHIH S., KUO P-H., LAI J-S. (2019). A non structural flood prevention measure for mitigating urban inundation impacts along with river flooding effects, Journal of Environmental Management, 11p.

UNESCO-IHE. (2014). Towards Integrated Water Resources Management, 31p.

UNESCO- IHP, (2009). IWRM at River Basin Level, P, art 1. Principles, 24p.

UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION (UNDRR). (2015). Flood hazard and risk assessment, UNISDR Edition, 16p.

UNITED NATIONS OFFICE FOR DISASTER RISK REDUCTION (UNDRR). (2015). Sendai Framework for Disaster Risk Reduction 2015-2030, UNISDR Edition 32p.

WISNER B. (2009). Local Knowledge and Disaster Risk Reduction, Keynote, Side Meeting on Indigenous Knowledge, Global Platform for Disaster Reduction, 7p.