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Thesis

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By:

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Flood risk management in Annaba, issues and policy instruments

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" تسيير خطر الفيضانات في مدينة عنابة، الرهانات و أدوات التدخل "

الملخص:

تعتبر الفيضانات من أكثر الاخطار الطبيعية التي تهدد الانسان، لذا فإن بناء أي استراتيجية لإدارة هذا النوع من القضايا يتطلب تقييما شاملا لجميع عناصر الخطر عن طريق جمع أكبر قدر من البيانات الخاصة بالمنطقة، من أجل القيام بالتحليل الأولي الذي من شأنه ان يعطي نتائج قابلة للنقاش على نطاق واسع، تقوم هذه الدراسة بتقييم سياسات إدارة الفيضانات في مدينة عنابة، ودراسة كيفية مواجهة صناع القرار لهذه التحديات حيث تهدف إلى التقليل من التعرض للخطر. ومن ثم اقتراح خطة شاملة لإدارة الاخطار المتعلقة بالفيضانات قائمة على تحليل مكونات مخاطر الفيضانات .باستخدام منهجية قائمة على تحليل صنع القرار متعدد المعايير مثل عملية التحليل الهرمي التسلسلي والتحقيق الميداني، حيث تقوم الدراسة بتقييم المخاطر المحتملة من خلال جمع البيانات وتحليلها. تشير النتائج إلى أن التعرض يتأثر بشكل كبير بحجم السكان وكثافتهم، مما يؤدي إلى احتمال كبير لوقوع خسائر بشرية ومادية في المنطقة. وعلى العكس من ذلك، يعمل الضعف على نطاق أصغر، مما يزيد من تأثير مخاطر الفيضانات على السكان والبيئة، تسلط هذه الدراسة الضوء على أن عدم اليقين في عملية التنبؤ بمخاطر الفيضانات يمكن أن يؤدي إلى نتائج وخيمة خلال الأحداث الاستثنائية. لذلك فاعتماد نظام شامل ومتخصص لإدارة المخاطر يعتبر حلا ملائما لبناء استراتيجية فعالة لهذا الغرض، علاوة على ذلك، يمكن للمواطن أن يلعب دورا حاسما في إدارة مخاطر الفيضانات . بالنظر الى تعقيدات السلوك الاجتماعي الذي يؤثر على نتائج وسيناريوهات الاحداث مما يجعل التنبؤ أكثر واقعية .تؤكد النتائج على أن المخاطر هي جانب متأصل في الطبيعة لذا فإن الإدارة الفعالة للمخاطر أمر ضروري للتخفيف من اثار الفيضانات، وتؤكد الدراسة على أهمية اقحام جميع الفاعلين في نهج تشاركي لتحقيق أفضل النتائج ودمجها في خطة شاملة لإدارة مخاطر الفيضانات .بهدف تقليل الخسائر الاقتصادية والبشرية المحتملة.

كلمات مفتاحية:مخاطر الفيضانات، تقييم الضعف، الهيدرولوجيا، التدابير الهيكلية، التنبؤ، الوقاية، الفاعلين.

« **La gestion de risque inondation à Annaba, enjeu et instruments d'action** »

Résumé :

Le risque d'inondation est l'une des menaces les plus courantes dans le monde, de sorte que l'élaboration de toute stratégie de gestion nécessite une évaluation complète de chaque facteur déterminant de risque, en collectant les données nécessaires pour la zone en question, afin d'effectuer une analyse préliminaire qui donnerait des résultats pouvant être largement discutés, qui permettre d'évaluer la place de la gestion de risque d'inondations à Annaba, examinant comment les acteurs locaux aborder cette problématique. Puis en proposant un plan intégré qui synthétise les éléments clés du risque d'inondation. En utilisant une méthode multicritère d'aide à la décision, telle que le processus d'analyse hiérarchique (AHP) et l'enquête sur le terrain. Les résultats indiquent que l'exposition est fortement influencée par la taille et la densité de la population, ce qui entraîne une forte probabilité de pertes matérielles et humaines dans la région. Par contre, la vulnérabilité opère à plus petite échelle, amplifiant l'impact des risques sur l'homme et l'environnement. L'étude souligne que la sous-estimation du risque due à l'incertitude dans la prévision des risques peut entraîner des conséquences dévastatrices lors d'événements exceptionnels. L'adoption d'un plan de gestion des risques complet et spécialisé est considérée comme l'une des solutions les plus efficace pour élaborer une stratégie globale sur la base des prévisions plus réalistes. Les résultats indiquent que le risque est un aspect inhérent à la nature, de sorte qu'une gestion rationnelle des risques est donc essentielle. L'étude révèle l'importance d'impliquer toutes les parties prenantes en partenariat dans une approche collaborative qui prendre en compte la complexité du comportement social pour améliorer la précision d'anticiper des scénarios.

Mots clés : Aléa inondation, Analyse de vulnérabilité, Hydrologie, Mesures structurelles, Prévision des crues, Prévention de risque, les acteurs de gestion.

« Flood Risk Management in Annaba, issues and policy instruments »

Abstract:

Considering that flooding is a major risk, the design of any measure should be centred on a comprehensive assessment of each determinant factors. This is achieved mainly by collecting the necessary inputs in aim to carry out preliminary analysis to give results that can be widely discussed. The present study evaluates flood management policies in Annaba, as a coastal city with increased susceptibility to these hazards, through examining measures taken by decision-makers and challenges associated with exposure mitigation. Using a Multi-Criteria Decision-Making support method, it refers to the Analytic Hierarchy Process (AHP) and field investigation. And then suggesting an integrated plan that synthesizes the core components of flood risk. Findings indicate that exposure is significantly correlated to the population size and density, leading to a high likelihood of human and material losses. Meanwhile, vulnerability operates on a more localized scale, exacerbating the impact of flood risks on both human populations and the environment. The uncertainty in hazard forecasting induces in a systematic underestimation of flood risk, this result in devastating outcomes, especially in exceptional events. By considering the complexity of social behaviour, the accuracy of scenario outcomes and consequently the efficiency of risk management plans are enhanced. The study emphasizes also the main role of involving all stakeholders in a partnership to achieve an integrated and a comprehensive flood risk management plan. The risk, as an inherent aspect of nature, in this regard, the collaborative approach has proven to be the most effective management strategy for fostering resilience and ensuring sustainable outcomes.

Key words: Flood hazard, Vulnerability assessment, Hydrology, Structural measures, Flood forecasting, Risk prevention, Stakeholders.

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This thesis represents not only my work completing this achievement, but also a milestone in years of collaborative and invaluable work. I would like to reflect on the people who have supported and helped me throughout this project.

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Thank you all for your unwavering support.

General introduction:

Floods represent one of the most devastating natural risks (Piao Shilong, 2010), resulting in a large human, economic and environmental damage around the world, especially in areas with high exposure. Annaba as a coastal city is deeply concerned by this issue. Encountered with this growing challenge, The need to address this issue has prompted a significant and widespread demand for viable solutions, and an effective management of flood risks becomes a priority. The plain objective is to protect inhabitants and their living environment against the devastating consequences of these disasters.

The mitigation of natural hazards in general and floods risk in particular due to its high frequency and consequent results in human lives around the world (SN Jonkman, 2024). This magnifies the challenge for all actors and decision-makers, especially in urbanized areas of high vulnerability such the case of Annaba city. Located in the North-East of the country, Annaba is facing recurring flooding episodes that threaten not only the safety of residents, but also the local economy and its national metropolis status. Understanding the related issues and identifying the appropriate policy instruments are crucial to develop an integrated management approach and effective mitigation strategies.

This thesis examines flood risk management in Annaba, a major issue facing the city, and analysing the action instruments available for risk mitigation. Through a multidisciplinary approach integrating geographical, environmental, political, and socio-economic aspects to assess this risk. This research highlights the particular challenges related to flood management in Annaba and to suggest an adequate strategy to strengthen the city resilience, by providing an analytical framework and operational recommendations. The resulted guidelines could be adopted as a toolkit to public authorities and local actors in mobilizing all the technical, organizational and normative levers available.

The adopted methodology consists in obtaining and discussing the socio-economic and environmental factors controlling the risk level in each area. In addition, the evaluation of current flood risk management practices and policies, analysing their effectiveness and potential shortcomings is a primary requirement for any study. Through a comparative analysis of different approaches and international successful practices, this research suggests practical and adaptive recommendations in stages of preparation, prevention and response to this type of disaster. These measures aim to reduce the likelihood and severity of flooding, along with improving the community resilience, and promote sustainable development in flood-prone areas.

This work aims to enriches the ongoing discourse on flood risk management highlighting the unique challenges and opportunities in Annaba. whereas, providing a meaningful insight for decision-makers, practitioners, and researchers engaged in natural disaster management, advocating for a holistic, systemic and participatory approach. Such a framework promotes coordinated, effective responses to extreme events and enhances the resilience and response capabilities of all involved stakeholders.

Research problem statement:

In urban environment, floods represent a growing public safety concern, it can cause significant damage to both public and private infrastructure, and in many cases human casualties. Located on the lower slopes of the Edough mountain massif, and due to its topography and climatic conditions, it is an established fact that Annaba city is particularly exposed to flood hazard.

Despite previous and recurrent experiences in the event log, the consequences on population and infrastructure still devastating, however, the attempts to minimise flood consequences did not live up to expectations reflecting an underestimation on the overall. More recent evidence on that is clear, such us the floods of January 24 and 25, 2019, according to the civil protection directorate, and resulted in the death of three and considerable damage to buildings, infrastructures, and a significant economic loss. From that the effectiveness of current policies is questionable in this regard, and the issue concerns not only officials, authorities and management actors, but also researchers.

A multidisciplinary approach is needed, covering all aspects: urban planning, economic development, hydrology and environment; for an effective assessment. To investigate the actual dynamics of flood risk management in Annaba, the research asks the following central question:

How well did decision makers succeed in efficient flood risk assessment? And how can local actors achieve an effective flood risk management in Annaba?

The sub-questions of this problem are:

Change in climate conditions: **Is there a remarkable change in flood dynamics complicating the assessment process and control? Does this affect the performance of the proposed solutions?**

Urban development and flood risk management tools: **Does the management system consider any planning tools for flood risk prevention? Does the problem reside in plans or in their implementation?**

Stakeholder dynamics: **What is the extent of interaction and coordination among management stakeholders? Is there a governance framework that integrates all actors including citizens, in decision-making processes at all levels?**

Citizen awareness: **How does the population react facing this threat? How effective are non-structural measures in mitigating flood risks impacts?**

Research hypotheses:

The following hypotheses are proposed as provisional implicit answers to the research questions:

H1: *Climate conditions and flood assessment:* Due to uncertainty in extreme weather events and the state of protectives measures, establishing a reliable hazard assessment is challenging. thus, it is hypothesized that this inadequacy significantly impairs the flood prediction.

H2: *The increased need for land:* It is hypothesized that the lack of an efficient risk prevention plan, combined with the increased demand for housing, contributes to the spread of construction in at-risk areas, resulting in insufficient protection against flood hazards.

H3: *Flood risk management system:* The effectiveness of flood risk management strategies is highly contingent upon the coordination and collaboration among local, regional, and national authorities across various levels of governance, as well as the active involvement of citizens in the decision-making process.

Research objectives, scope, and study significance:

The research topic was chosen based on objective and subjective implications.

Floods in Annaba: The wilaya of Annaba is regularly confronted with flood risks, which have been extensively examined in numerous studies and comprehensive reports. Annaba has been selected by the Ministry of Spatial Planning among 9 Wilayas exposed to natural risks. Frequent floods make it essential to carry out a thorough and up-to-date study to improve risk management.

Urbanization and urban management: This topic hold particular significance in the current context of urban management, highlighting the common problems of land use and anarchic urban sprawl. The rapid and often disorderly urbanisation of Annaba has modified the water flow conditions, thus increasing the vulnerability of certain areas to flooding.

Theoretical and applied enrichment: This subject makes it possible to enrich the theoretical framework with applied models. Flood risk management offers a platform that hosts a variety of applying several theories and methods of urban management, thus contributing to the scientific literature and providing practical solutions.

Research objectives: The main purpose of this study is to provide new scientific contributions by analysing the phenomenon of flood risk in Annaba, as well as, the way in which local authorities manage this risk. And to explore the phenomenon of natural risk, in particular floods. This research aims to study this risk through the different aggravating factors and to understand these different components. The emphasis will be placed on the environmental and managerial aspect, and uses an evaluation of the flood risk management policy and action tools in this process to achieve an integrated risk management that ensures the safety of residents within the framework of sustainable development.

Specific objectives:

Enrichment of Scientific Knowledge Bodies: Highlighting the importance of flood risk management in urban management. This study aims to add to existing knowledge by identifying the specific challenges posed by the floods in Annaba and the strategies employed to overcome these risks.

Impact on the population: To investigate the implications of flooding for the residents of Annaba. This includes the assessment of economic, social, and psychological consequences caused by the floods, as well as the search for effective solutions to mitigate these effects.

Coordination of stakeholders: Identify the management actors involved in flood risk management and suggest a methodology to improve coordination between all actors. This includes analysing the roles of local authorities, government agencies, non-governmental organizations (NGO) and the local community.

Methodological approach:

To answer these questions and testing these hypotheses relevance, the methodology adopted will be presented in this section, including details of methodological steps used to achieve the research objectives.

The regional approach is a study based on geography in a specific region, during a fixed or varying period of time. After using this approach, researchers learn about the variables that have occurred in a limited region such as natural risk studies, with knowledge of all the developments that have occurred since the increase in urbanisation (human activity) as a first generator element of natural hazards. However, followers of this approach may find themselves in a sea of geographical information, leaving the line between regional geography and historical geography unclear (Pavel, 2020).

For an effective flood risk management, a new regional approach is necessary to understand the recent theoretical developments have revealed that urban changes occurred in the city of Annaba, as well as the mechanisms that govern the risk process in the urban environment, because monitoring this phenomenon goes beyond the local scale, and requires taking into account an expanded spatial scale, the choice of this extent is the result of a scientific choice aimed at taking into account the integration of decision-making levels.

Multiscale and multidimensional analysis:

On the other hand, in order to evaluate the current policy in the field of risk management in general, a multi-scale approach was adopted, an approach that does not restrict itself to a single scale for understanding a geographical issue in management context, but takes into account a wide range of possible scales, from the international to the micro-local, based on an integrated approach to avoiding any imbalance in the decision-making process.

This approach is more widely used in population studies (Pafka, 2020), which is a key component of flood risk studies as a source of vulnerability assessment. This assessment does not necessarily have to cover all scales, but only involves considering the various phenomena at the appropriate and relevant geographical scope of the study and in line with the expected results.
Effective territorial management operates at three main levels: National, regional, and local. At the national level, it involves overall policies and frameworks that guide development across the state, including infrastructure programs. The regional level focuses on specific aspects within the country, addressing issues that affect a range of local areas, including risk management. Whereas, the local level is concerned with management of municipalities or communities, including local service zoning laws and community development initiatives. As for the international level, it is a formal cooperation that aims to obtain financing, training, and experiences exchange in the field of risk management.
Therefore, each level contributes significantly to ensuring balanced and sustainable development, with national policies setting the direction, regional plans adapting strategies to specific needs, and local actions implementing solutions on the ground. Since, the management evaluation process is based on this hierarchy for an effective risk assessment, which determines the relevance of the selected scope of analysis. These approaches have been influential in the field because it complies with risk analysis requirements, which is subject to a division based on natural boundaries rather than administrative divisions.

What tools, methods and data are needed for flood forecasting in Annaba?

In reference to the available research in this regard, we find that it is based on the classical approach based on return period, but in fact, recent practices have proved a change that following the results of research on climate change, that demonstrated the need for an integrative approach based on a multi-disciplinary approach of flood risk management is necessary for the aim to an efficient flood hazard forecasting.
This trend is based on a mixed approach combining risk analysis based on historical data, hydrological forecasting models, along with climate scenarios to assess current flood risk management. To study the existing reports, scientific studies and meteorological data concerning the floods in Annaba. This also includes the review of urban development plans and risk management policies, supported with conducting a survey within inhabitants of Annaba to collect data on the impact of the floods and their risks perception.
None of the existing methods can provide both a preventive and a precise quantitative assessment of flood risk (Yahiaoui, 2012), because of the uncertainty associated with risk behaviour, since we are dealing with nonstationary world, Therefore, this process requires flexibility in dealing with the environment components, and rationality in developing management plans after a comprehensive assessment of the risk factors

How can the flood risk be represented in form of spatial analysis and mapping?

In order to spatialize both empirical and theoretical data, with the aim of improving their accessibility and enhancing the explanation clarity, the Geographical Information Systems (GIS) tools is used to analyse flood zoning and mapping of areas with high vulnerability. This helps to visualize at risk areas and plan targeted interventions, therefore, the analysis of similar case studies of flood risk management in an effective way, and comparing these models to the situation in Annaba to identify best practices, this makes it possible to predict the effects of precipitation and identify the most effective prevention measures.

We collected secondary data from a number of different sources, including government reports, academic studies, and GIS databases. This data was used to establish a baseline of flood occurrence and institutional responses. This data is analysed using the AHP method, for aim to structure and analyse complex decisions. It is based on a hierarchical decomposition of the problem into criteria and sub-criteria, enabling a systematic evaluation of alternatives.

A questionnaire survey was carried out among residents and interview with local stakeholders in Annaba. The aim of the survey is to gather perceptions and experiences about flood risks and the current management measures efficiency. The questionnaire is structured around flood risk perception, prevention and response measures establishment, and suggestions for improving risk management, because following this methodology, this research aims to provide practical recommendations to improve the management of flood risk in Annaba and contribute to the safety and well-being of its inhabitants.

Determination of flood risk zoning and degree of risk for each zone using multicriteria analysis:

Synthesis of multicriteria risk analysis approach results that are used to draw up a flood risk prevention plan which suggests a specifics action, prioritized according to the weights assigned to the criteria by survey participants, the plan includes practical recommendations for improving the resilience to the city of Annaba against floodings, these recommendations cover guidelines to help decision-makers implement measures to mitigate the risk of flooding. Using environmental evaluation, and geomatic tools, we study the case of Annaba, this is not just to take stock of the situation, but to assess the territorial dynamics at work in order to make a forward-looking assessment of the risk. To this purpose, we are studying anthropogenic changes such as threats to the hydrodynamic functioning of watercourses, which are factors that increase social vulnerability to risk.

The plan was developed based on an analysis of the study area, taking into account its position in the regional context, for this aim, a new regional approach is necessary to understand the flood risk in the recent times that there has been a change in flood behaviour and return periods, as well as the mechanisms that control the risk generation process, because monitoring this phenomenon goes beyond the local scale, and requires taking into account the expanded spatial scale to maintain the logical sequence in addressing this issue.

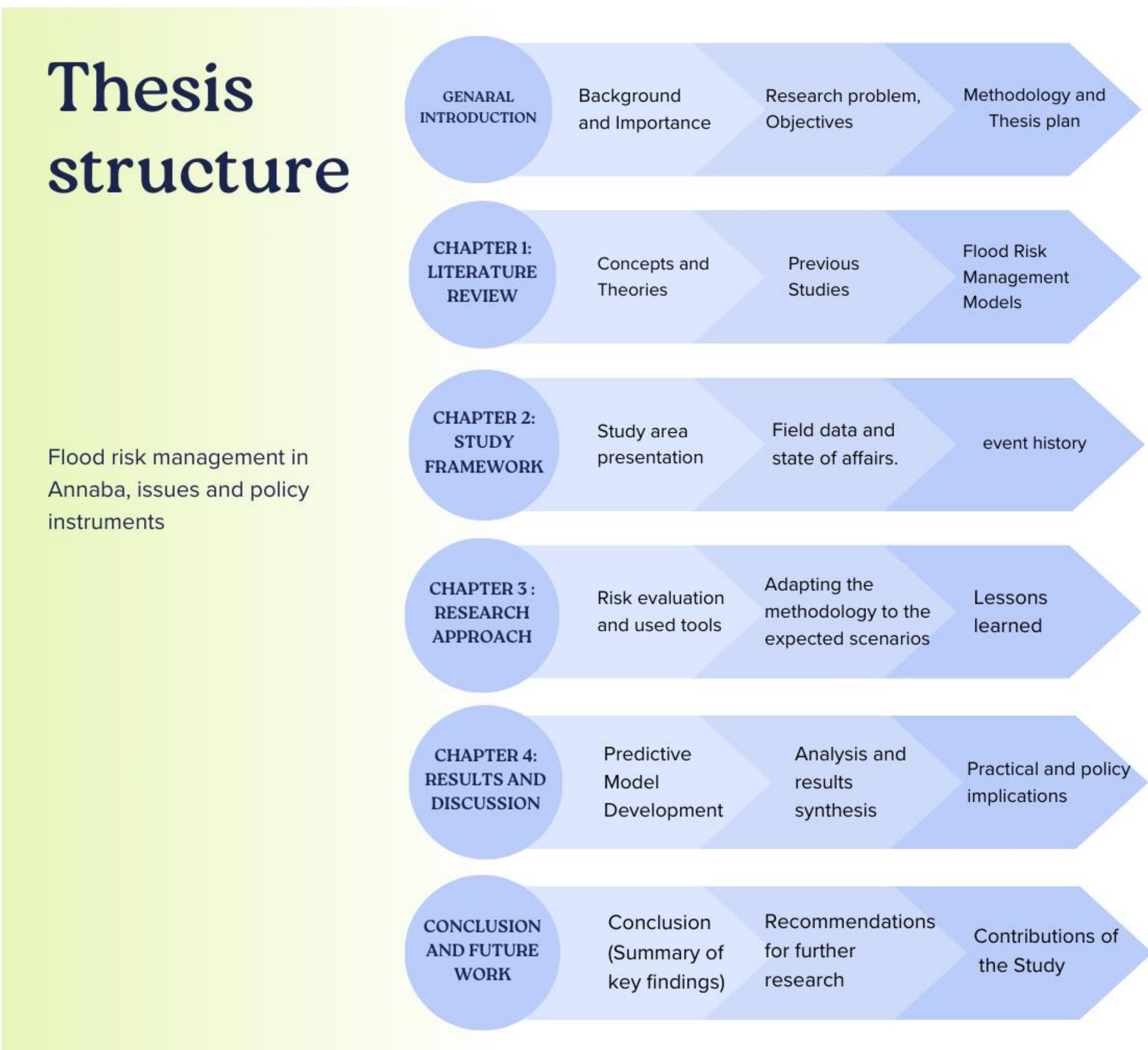
Current management policy evaluation using a field survey:

Monitoring the flood risk management policy by means of a survey is a common method of gathering qualitative and quantitative data on the perceptions. This approach makes it possible to measure the impact of current policies, identify shortcomings and gather suggestions for future improvements. By designing clear and relevant questions, in this case a wide range of participants can take part in the survey, including all categories of the community specifically employees, customers, and partners, allowing to take a comprehensive overview. The results can then be analysed statistically to identify significant trends and correlations. Overall, this approach is a powerful tool for risk management policy evaluation, facilitating informed decision-making and organisational practices improvement.

Thesis structure:

In order to achieve the aforementioned research objectives, the present manuscript is structured as follows according to the used methodology:

Figure 1: Thesis Organizational Chart



CHAPTER 1:
THEORETICAL, CONCEPTUAL FRAMEWORK, AND LITERATURE REVIEW

Introduction:

This thesis section aims to provide a theoretical and conceptual framework that underlies the study of flood risk management, with the aim of examining the basic concepts related to flood risks, Reviewing current practices in flood risk management. And on the other hand, by identifying the regulatory and flood risk management instruments used in different geographical and institutional contexts, and finally by evaluating the specific management issues in Algeria in general and in Annaba in particular.

In the course of this chapter, we will focus on discussing the risk related to urban environment in a general sense, and then the flood risk which is the subject of our research topic, this concept is defined in a general context and then access the explicit terminological framework. The aim of our work is to study the flood risk in terms of management through clarifying the role of key actors within the scope of disaster intervention, taking into account the history of previous events and the scenarios planned to respond to future ones, and on the other hand, the intervention instruments and the development policy adopted.

This part aims to establish a theoretical framework for our study and the state of the art concerning flood risk management. As an initial point, it is a question of defining the key concepts and presenting the different theoretical approaches on which risk management strategies are based on. Then, we will examine the tools, policies, and legislation in this regard, on the other hand, how to apply these policies to mitigate the flood consequences, relying on case studies and examples of notable studies regarding this issue to illustrate best practices. This theoretical framework will allow us to better situate the specific concerns, and the identification of priorities in the management process after having identified the main components of flood risk, and the significance of each in influencing the threat to urban environment in Annaba, and to suggests a concrete improvement solution for the management of flood risks in the region.

The general concepts of this topic provide an essential framework for understanding the challenges and opportunities related to flood risk reduction. By exploring the methodological approaches and management tools, this section prepares a framework for an in-depth analysis of flood risk management strategies adapted to the prevailing condition in Annaba, as long as, this research aspires to contribute to the improvement of flood risk management practices, by suggestion of applicable recommendations to strengthen the floods resilience.

1- Conceptualization and historical context of risk:

The historical approach of risk is a dynamic and evolving field, as a concept, it was first studied in context of gambling and finance during the Renaissance, with significant contributions from mathematicians such as Blaise Pascal and Pierre de Fermat (Binmore, 2021). In the 18th century, the development of probability theories led to a better understanding and quantification of risk, which extended to insurance and financial markets. In the 20th century, risk management encompassed a variety of fields, including industry, health and environment, with increasing attention paid to global risks and crises. Today, the concept of risk comprises multidisciplinary approaches, taking into account not only probabilities and impacts, but also social and cultural perceptions. This historical development shows how our understanding of risk has become more sophisticated, reflecting changes in our economic and societal environments.

1-1- Definition and concept of risk:

The concept of "risk" in modern contexts, is frequently associated with the implications of widespread urban development and the problems associated with it, this issue is a prominent topic of discussion as a part of society major element of daily life. A thorough understanding of this concept requires examining the origins of this term.

There are various references point to the etymological roots of the term "risk". The origin of the word "risk" is derived from Latin, it came from the word "Resecum". In the Middle Ages, this term was later associated with "Riscare" which translates in the Italian-French dictionary of "Véroni (1681)" by the word "Risque", from the XVII (17th) century, the notion of risk is used for economic activities in general (Nacol, 2016). There is another possible etymology, it's about the Romantic word "Rixicare","which means to argue or fighting, (Gaetano Liuzzo, 2014)

According to (Yvette Veyret, , 2004), this notion appearance is directly linked to the spread of insurance systems in the XIV (14th) century. By adopting a system based on paying a sum to the merchant-bankers to ensure the safety of goods against the risks that may affect them on their journey. According to (Mairal, 2020), This term can take a Mediterranean origin, this refers to the word "Risco" or "Rischio", in the thirteenth century by Italian merchants, which represents insurance for the transport of goods against the dangers to which could be exposed.

Theoretical perspectives on risk in geography:

Research on this topic is extensive, given the importance of this issue in geography, in light of the critical correlation between risk and geographical space, from a geographical point of view, risk refers to an event potentially harmful to humans, the environment, and infrastructure in a given area, of natural origin or due to anthropogenic action that aggravates the risk or generates other types of natural risks (Figure 2), such as climate change. This concept has always existed. In ancient civilizations, any event resulting in a catastrophe consider as a punishment of the gods according to their belief, considering the advancements in scientific knowledge, man is found that natural disasters are only natural phenomena.

An overview of the recent history of natural hazard:

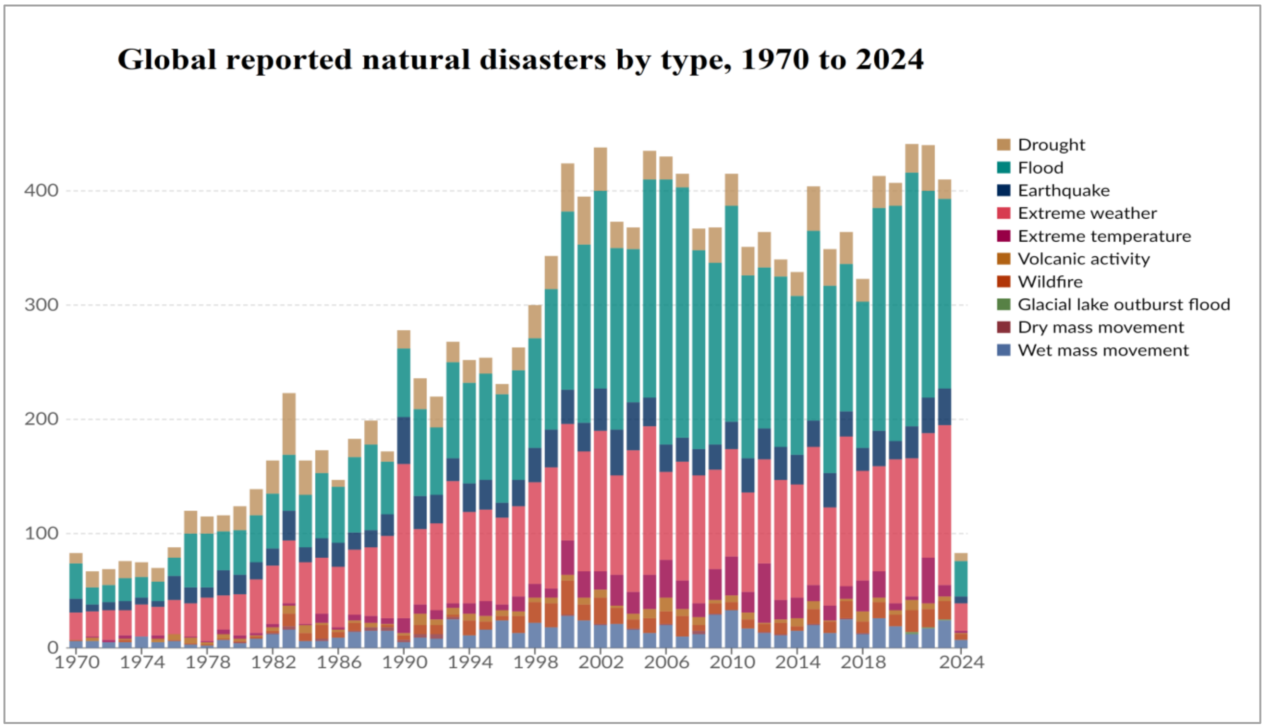
The risk is always characterized by constant transformation, depending on perimeters and intervention practices, on the other hand by tools and managing actors, recent history can be divided into three essential periods: During the period before the 20th century, research on natural hazards was characterized by a different perception of these events. From the Middle Ages, the need was more for new ways to manage the natural risks, due to the degradation caused by increasing exploitation of natural resources such as fauna and flora. This period is characterized by a limited understanding of natural phenomena and their associated risks due to the vulnerability of societies as a result of the limited level of technological progress and early warning systems during this period.

Another phase of the 20th century until the beginning of the 21st century, this period experienced substantial progress in the study of natural risk, which was necessary after the remarkable observed events during this period as shown in (Figure 2), to achieve the objective of increased risk management, which made it possible to highlight the past risks to better understand the risks in future.

Since the early 21st century up to the present, this period is characterized by an increasing need for a deeper understanding of climate change impacts, which has aggravated the intensity and frequency of major events, where the need to develop in-depth cooperation in order to minimize the damage resulting from natural hazards has become necessary.

The natural risk is an integral part of society; however, it remains different because vulnerability and hazard present the core elements of risk are not the same in all cases, it is rather linked to the aggravating risk factors, and the available means, and it differs from one case to another. The classic concept of risk can be defined as the possible hazard consequences on the stakes (Aven, 2011). With regard to our case, we are interested in natural risk in its managerial context, and the consequences of human activities in risk increasing.

Figure 2: Statistics of natural disasters in the world.



Source: EM-DAT: *(International Disaster Database - Catholic University of Louvain - Brussels – Belgium)*

In light of the substantial progress made in the field of risk management, whether physical or human, the need is more than ever increased to seek effective solutions to protect residents and their property. Arriving at the 1980s and in response to the increasing focus on environmental protection, this era marked the initial introduction of the term "Cindynique", invented by the

Sorbonne University in 1987 to avoid confusion between "danger" and "risk" this concept indicates much more to the major risks.

1-2- Anthropogenic components of risk: Hazard and Vulnerability:

Within the general perspective on natural risks, the stakes represent any object that can be damageable by a disastrous event, which have the potential to cause both human and material losses. The study of the stakes is complicated because their evaluation requires a thorough analysis, social, economic and spatial, this is likely to evaluate the risk management policy. The stakes can be used to define the vulnerability based on the assumption that it is considered as the degree of damage on the stakes affected by a disaster, and this degree measured by the number of affected populations relative to the total number of populations.

There are several basic concepts that vary according to the risk degree, these components which are: hazard, and vulnerability degree which is varied according to the degree of interaction between hazard and stakes. Therefore, the risk management from a strategic point of view is based on hazard control for vulnerability reduction.

The social dimension of risk is defined by the issues that are represented by the inhabitants, public and private infrastructures, economic activities, and environment exposed to hazard (Yvette Veyret, , 2004). Therefore, the issues can be classified into different types: "heritage, human, economic, functional, identity or territorial, and political issues", while the degree of risk impact is varied according to the vulnerability which represents the likely extent of destructibility related to these issues in face of hazard, it varies according to the spatial-temporal conditions associated with the risk. The vulnerability studies revolve around the approach which indicates that vulnerability is the susceptibility to damage of people and property exposed to the risk like shown in (Figure 2), this can change depending on society's response, and the intrinsic factor of the individual himself, such as health, status, and age. Some American geographers have linked vulnerability to poverty, because the infrastructure fragility is more present in poor urban areas (Kenneth, 1983). Vulnerability has an inverse relationship with resilience which is defined as the ability of a society to return to the initial state after a disaster, and as inevitable, based on the social component to reduce vulnerability repercussions.

1-3- Theoretical approaches to risk classification:

According to (Barroca, 2006) who introduces a risk classification through:

The type of risk according to the nature of hazard: for example, (flood, ground movement, earthquakes, volcano, forest fire), or technological risk like (nuclear accidents), and pollution such as (environmental waste).

Type of risk according to frequency (return period).

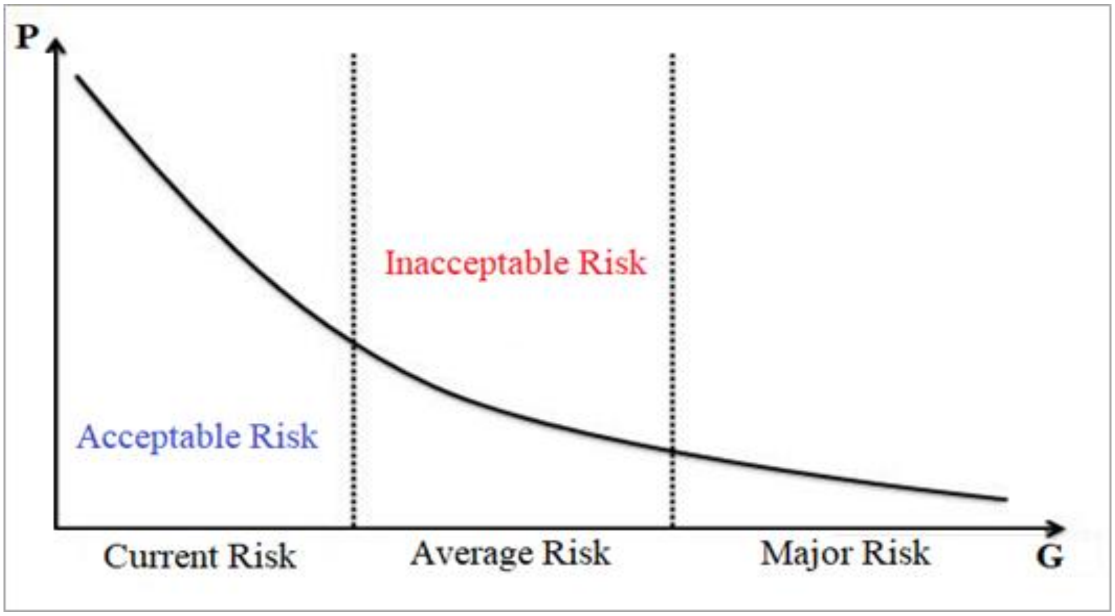
Type of risk according to the level of damage, presented by the affected population, and the economic cost.

Type of risk according to the scale or spatial extent of hazard, it centres on (punctual, local, regional, and global scale).

Type of risk according to the primitive spatial origin.

Most of the classifications that have been made are similar to being involved in the basis of nature of risk on one hand, and on the other hand the source of risk: in our case study, the flood risk falls into the category of natural risk, according to the forms of hazard.
Frank Reginald FARMER demonstrated a link between risk and its acceptable frequency with the event probability. Farmer's curves (Figure 03) are a cumulative risk profiles that complement accident results, comparing the probability with risk severity.

Figure 3: Curve of Farmer (Risk probability).



Source: (Ben , Boutheina, Christophe , & Narjes, 2011)

1-4- Concepts and implications of risk of flooding:

Flood risk is a multidimensional concept, as it varies across different contexts, the main factor triggering the phenomenon is precipitation, in interaction with the other risk components which are varied according to space and time and manifests differently depending on the characteristics of each case. As previously referenced, the risk is defined as the result of two factors considered independent that are hazard and vulnerability to measure and compare the independent factors of flood risk to arrive at an objective risk quantification (Gilard. O, 1998)The inundation and flood risk are known as a natural phenomenon that can have serious consequences on human health and life, the economy, and the environment, driven by a hydrometeorological hazard and the vulnerability of the affected area.
If we consider the historical context of antiquity, it can be observed that the human settlement of ancient civilizations is associated with waterways, like the Pharaonic civilization and that of Mesopotamian. This hydrographic network provides drinking water supply, irrigation, and wastewater disposal, and also as a transport means. And to adapt with the specificities of these delta areas, the need was to build drainage networks, to absorb the amount of rainwater or the possibility of triggering a hydro-climatic hazard.

Based on the fact that the flood risk is results from the convergence of two essential components: the hazard (hydraulic, hydrographic, hydrological, hydro-climatic) and the vulnerability of the exposed space, so a good diagnosis of these two components ensures to take the appropriate course of action.

1-4-1- Surface runoff: Represents a seasonal natural phenomenon, that causes the increase in level and flow of a watercourse, characterized by three parameters: flow rate, water height, and flow velocity, the water can occupy the Streambed or overflow on the Floodway and Floodplain of a river, with a higher flow rate. The geographers affirm that a flood is occurred if the water level shows 3 to 5 times greater than the average level, which causes the submergence of a large surface that outcrops on the talweg, or by the runoff of heavy rains from thunderstorms on the watersheds, and this could also by a break in the structure, (in the case of dykes, for example.), because the surface runoff is in response to the nature of the soil and these characteristics, permeability, infiltration, and the vegetation cover, which can play an important role in the absorption of a large portion of rainwater (Kate A. Brauman, 2007), and also the urbanization that demines the infiltration rate of spatial area limiting its permeability, and as a final point the essential element of flood genesis is the rainfall intensity.
Runoff can be classified into three types:
Simple Runoff: as a result of heavy rainfall occurring over a brief duration, these events occur when there is a high concentration of precipitation (rain or snow) over a relatively short period that bring a large amount of water.
Multiple runoffs: due to long-term rainfall, these occur after a prolonged accumulation of rainfall, which can be moderate but persistent for several days or weeks.
A complex runoff: this combines the two previous types.

1-4-2- Flood dynamics:
The risk can be outlined according to the damage caused by hazard on a vulnerable space, so flooding is the submersion of a land with a specific topography, in a relatively short period of time, due to heavy precipitation in an urbanized area. Influenced by other determining factors such as precipitation as a key element determinant of flooding, by the interaction with the morphological and pedological factor that would lead to the hazard occurrence as a main component with other components such as exposure and consequently vulnerability, the flood risk emerges to exist (Figure 4).
In addition to these factors, floods can vary depending on the processes leading to the factors of the increase in the flow of a watercourse such as: The melting of snows. Repeated rains. Short showers with a great intensity.

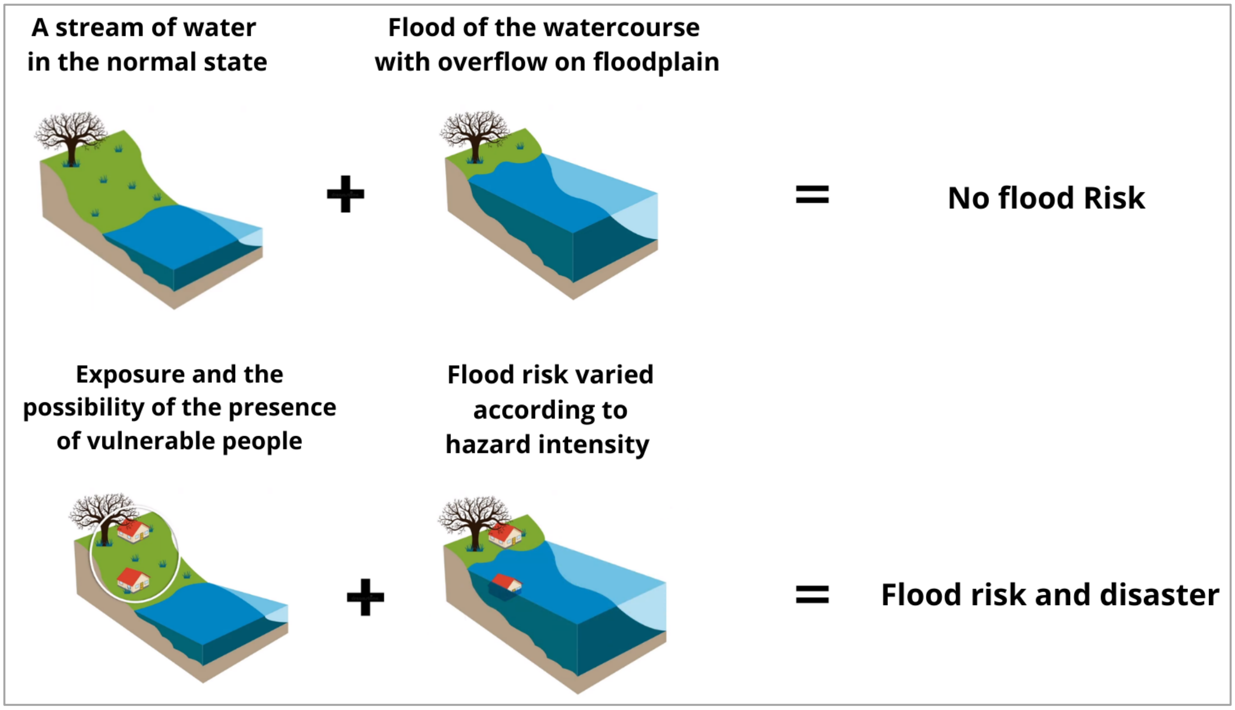
a) The concentration time:
Is the time elapsed for a drop of rain to make its way to the outlet, so it responds to the characteristics of the watershed, land use, and other circumstances that hinder or facilitate the process.
b) The flood spreading:

In the case of a flood, the water takes its way in its downstream course, the point flow is demined when the flow field is wide, and also in the case of a low slope, here the water submerges a relatively large surface.

c) The overflow:

Overflow is the amount of water that exceeds the maximum capacity of the Channel and overflows to the Floodway, among the characteristics of overflow is that it has no return period, its prevalence and frequency varies from one area to another.

Figure 4: Flood hazard and flood risk.



Source: (The researcher 2024)

1-4-3- Impact of flood-forming elements:

Precipitation and land use patterns, particularly urbanization, are key natural factors that decrease the water concentration time, or by the vegetation cover that does the opposite, and also the topography which control the spread of floods as mentioned above, in addition to another important element it is the material jams, and also among the factors that influence the flood genesis, in the case of dams, the power of water to create a large wave downstream, and thus leads to terrible consequences.

Watershed characteristics: "A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel. The word watershed is sometimes used interchangeably with drainage basin or catchment." (Maidment, 1993). Each watershed has its own specific parameters such as:

Geology: It's about the geological perspectives of the land, in particular the geological layers and its characteristics such as permeability.

Pedology: Type of soil, by infiltration and other characteristics.
Topography and geometry: It pertain to the topographical features of the earth and the drainage surface.
Biology: The vegetation cover and its role in the water flow control.
Anthropogenic: The alterations to the spatial configuration by human intervention through urbanization (Stéphane & Emmanuèle, 2012).
Mastering all these parameters is necessary, because a good knowledge of the territory makes it possible to facilitate the management of flood risks.

Mechanisms of risk triggering and aggravation factors:

The primary factor that triggers and aggravating the flooding phenomenon is the anthropogenic factor, the modifications due to the watershed urbanization, and the flow conditions modification of the hydrographic network are the main causes of hazard amplification.
The artificialization of hydrographic network is clearly apparent in the sewerage system and also the canals (underground or open-air) this operation can cause a double risk: the lines of the pipes are not exactly consistent with the flow and the position of natural waterways, on the other hand, the sewerage network can have a very harmful effect, so that it causes the increase in peak flow, because of reduced infiltration, the other factor is the urbanization of the areas of natural expansion of floods, which causes a shift in the sharing of watershed beds.

Other natural factors conditioning floods:

Climate change is one of the aggravating elements of the hydrological hazard (Maarten & Ian, 2002), based on this, the heavy precipitation is able to causes the increase in sea level in areas that know floodings by rising sea level, so future events will be more catastrophic. According to a study published in 2007 by the Intergovernmental Panel on Climate Change (IPCC), the world temperature over the past 50 years has increased by 0.5° and the sea level rises to 20cm.
This increase in temperatures and precipitation, and to address this problem, a program has been adopted to identify climate change scenarios. The Algerian State and with cooperation with the United Nations, setting up a program called United Nations Development Program (UNDP) it has for the purpose of strengthening national capacities for the analysis of vulnerability factors related to natural risks and disasters in Algeria, a section has been designated for flood risk management, and another for forest fires, in addition, among the axes studied, climate change and its consequences, despite the fact that studies on climate change in Algeria remain limited, in reviewing the literature, no clear evidence was found on the association between climate change and change in flood behaviour in Algeria, climatic factors represent a topic of conversation on their roles aggravating flood risk, on the other hand, it is obvious that anthropogenic factors are often aggravating elements of flood risk (deforestation of slopes, urbanization in at risk areas flooding…etc).

The impact of urbanization on rainfall patterns, contexts and consequences:

The protection of human life from potential risks has remained a constant and pressing need, simultaneously with the evolution over time and what followed by successive urbanization growth, the need for protection has intensified with the growth of urban agglomerations, making the challenge even more significant.

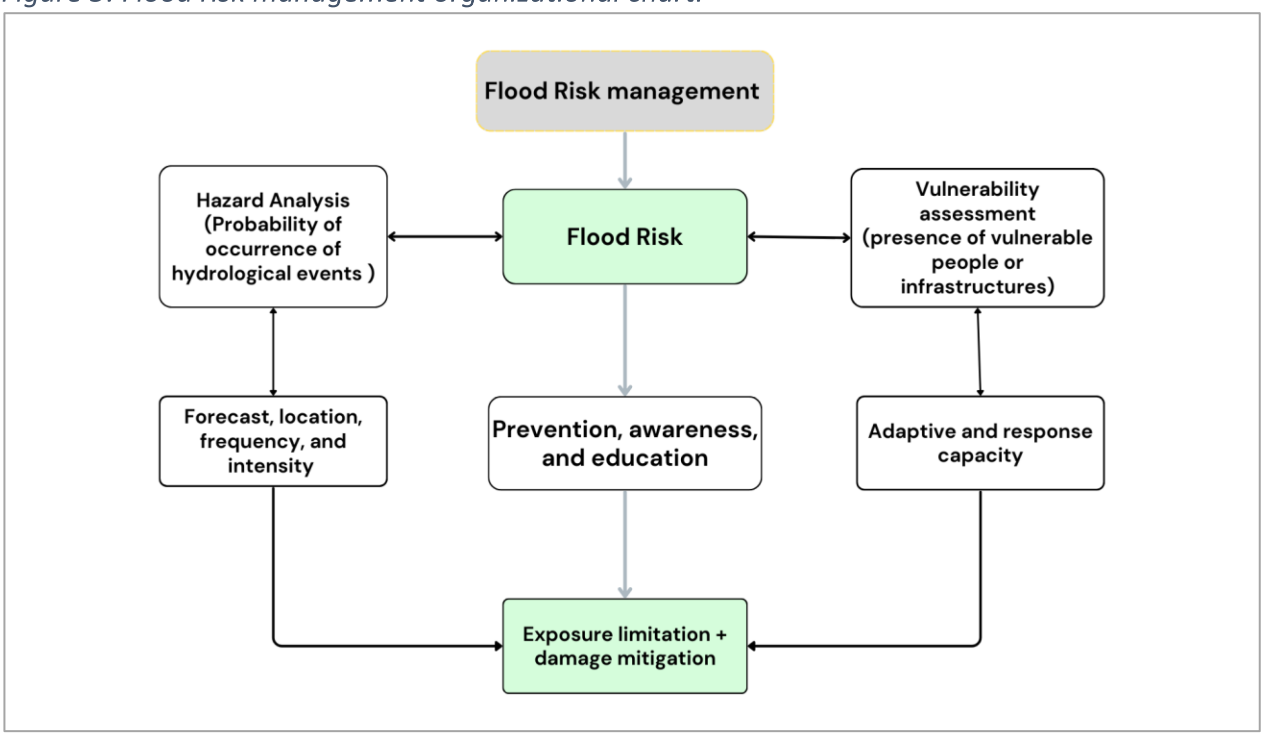
With the increased consumption and demand for land, urbanization is spreading to occupy a large area, sometimes does not take into account the land constructability, and thus, from a hydrological viewpoint, urbanization has made a drastic change on the territory, due to human activity which causes consequences on water flow conditions and the permeability of space.

The influence of urbanization due to human activity appeared especially in the distribution of roughness, which causes turbulence of mechanical origin. According to (BESSEMOULIN, 1980) in a preliminary meteorological study on 8 cities between 1971 and 1975, the results were as follows: a thunderstorm increase in 6 cities out of 8, known an increase in thunderstorm activity depending on the size of the city, for example cities with a population of more than 3 million know an increase of more than 30%, its results can be varied from an area to another, because of specificities of the space concerned, It is however indisputable that urbanization has a relationship with the climate, whatever its effect.

The heavy impact of urbanization on surface runoff also appeared in increasing the speed and flow magnitude (Ashim Ratna , Ritu , & Shreema , 2015), which in most cases causes floods in the urban environment. Rapid growth necessitates a shift toward construction in the natural places of water storage, such as Floodplain, which lead to a high rate of accumulation of rainwater due to the impermeable roads, and roofs that increases the runoff speed, in addition to the modification of flow conditions which reduces the flow capacity. All these factors, which manifest themselves in uncontrolled urbanization, eventually lead to violent floods.

1-5- Flooding types and mechanisms:

Figure 5: Flood risk management organizational chart.



1-5-1- Flood variants based on key characteristics:

The hazard is classified according to several criteria, in particular the origin of the hazard, such as precipitation type and intensity, or morphology of the geographical area in which the hazard is concentrated (the site), as well as the intensity and frequency of hazard, giving a classification of the most common flood risks as follow:

a)-Pluvial Floods: It is a sudden character, generated by stormy rains, in the form of intense local downpours, usually affects small watersheds for few kilometres, it can generate sudden floods in a relatively short time and a strong rise in water levels, in the space of a few hours, it falls into the type of rapid floods, like the floods of Oued R'hiou October 20, 1993, where the rains take only 20 minutes it was enough to cause 23 deaths, and 20 injured (MERABET, 2006)

b)-Large watersheds floodings: This type concerns a larger surface, and generalized episodes of rainfall with a less intense character, and a long duration of precipitation lead to saturation of the soil with water, thus floods occur, this type falling into the category of slow floods or lowland, depending on its duration which can exceed 15 days.

Floods vary according to the physical specificities of concerned area and the hazard intensity, it can consequently take several forms and types, including:

c)-Slow floods (lowland floods): This type is typically found in plains characterized by a low to zero slope, and in some cases, areas that are even below sea level, and impermeable or water-saturated terrains, it also forms on the uplands and downstream, it can occupy vast areas. The rapid rise of water in this type of flooding in addition to the low slope, it is also attributed to the wide valley which reduce the flow of flood point. This type of flood has a short time interval that can cause a certain number of victims, which is mainly due to lack of awareness of the risk, and the duration of flooding can take a long time, which can extend up to several days, which has consequences on the activities and mental state of the inhabitants.

d)-Flash floods: This type of flooding concerns the case in which the flood has a relatively short concentration time, the main causes of this type are torrential thunderstorms and heavy showers, in addition to the topography of the site which is characterized by a steep slope. In the case of this type, the time between the generating rains and the floods overflow is very difficult to determine, not to say impossible for the alert of the population.

e)- Floods by urban runoff: This type concerns urban areas built on the floodplain, the water takes its way into the road and overflows towards the buildings, in the event that the sewerage network is saturated, obstructed, or non-existent. The intense urbanization of the small catchment areas is the direct cause of floods, because it increases the soil permeability in the waterway, because of sludge and floating objects, causes an obstruction in the sanitation network.

1-5-2- Specific types of floods:

There are various specific types of floods with particular characteristics and causes. Each type of flood presents a challenge in terms of forecasting, management and mitigation. Understanding these patterns helps to better prepare for and respond to flood events. Here are the main types:

a)-Torrential floods: Torrents are streams that have a steep slope (more than 6%), with a large flow rate, in the case of prolonged rains, the flood causes erosion and carries objects and detrital materials of variable size to the downstream, so over time the slope becomes lower, and this through the process of transport and sedimentation.

b)-Coastal Floods: Are temporary floods, affect the coastal areas, caused by storm surges, it affects much more the areas located at the height below sea level, due to the lack of protective structures or a break in the dikes, the submersion can take a few hours, the marine water can carry a large amount of sediment.

c)-Riverine Floods: In this case, a combination of the two phenomena which are the river flooding, and the rising sea level which blocks the flood runoff; thus, a blockage occurs and therefore the water overflows, and a reverse return process occurs.

d)- Backflow-induced flooding in storm sewer systems: In the case of intense thunderstorms in an urbanized area, the entire amount of water can be absorbed by the rainwater drainage network, and if the amount of water exceeds its capacity the network discharges to the surface, this is the case where the network is prevented by a rising water level, this discharge represents a danger for both the population and the environment.

e)-Groundwater floods: The underground water table can reach the Earth's surface, and it can represent a risk for humans and natural ecosystem, in can distinguish two types of water table rise:

The floods by natural phenomenon of water table rise: The prolonged rainfall, which attains an exceptional rate, causes the saturation of the groundwater, then it rises on the surface and submerges a large surface which can be damaging also for buildings and infrastructures.

Flooding by artificial rising of groundwater: This pertains to the cessation of pumping or exploitation of groundwater, in other words, it causes the accumulation of a quantity of water from an underground source.

2- Theoretical foundations of hazard:

We can understand the concept of Hazard according to its context, which indicates that it is a phenomenon that has a duration and a probability over a given space, (The United Nations Office for Disaster Risk Reduction). According to (Gilard. O, 1998), the hazard is defined as "a measure of the uncertainty surrounding future events, and which can be expressed in terms of probability or danger". In other words, Hazard is a potential event that can lead to negative consequences for companies and society as a whole. (Dauphiné & Damienne, 2001), proposes to link it with a spatiotemporal dimension. According to (Pauline, 2008), The flood resulted from the reaction between the metrological hazard and the hydrological, hydraulic, and hydrographic hazard.

2-1- The historical hazard concentration:

The study of natural disasters in its abstract sense is quite recent, in Western societies, this is known as CALAMITY or PLAGUE, which can be used figuratively to describe any major calamity or disaster according to the French Wiktionary. On the other hand, natural risk management in the form of prevention is old in principle, but the forms of management are not the same according to the change in the nature of the issues.

The Anglo-Saxons followed management methods adapted with the nature of society, and field data to control the floods of Mississippi (USA), in the early 19th century, this policy confronted some barriers relating to aid for reconstruction.

The controversy and the debate focused on the role of the federal state, until the beginning of the 20th century and especially before the second world war, in 1913 a catastrophic flood caused 415 deaths and more than 200 million dollars in material losses, after this catastrophic event the state revisited its management policy by the bill of 1917, the flood control act of 1917, which relies on the strengthening of the role of engineers, and the financing of reconstruction projects. After 1927, research began on the possibility of developing the watersheds of the rivers, where the valley are favourable lands either for agriculture or urbanization.

The new methodologies of natural risk management in general appeared and developed for the first time in USA, and then disseminated to Europe, after the second World war, what are called Risk assessment techniques**.**

2-2- Technocentric perspectives on hazard:

This paradigm has been in place and widespread until the end of the 20th century, emphasizes the understanding of natural disasters as physical phenomena (hazards) that can be better known by using scientific expertise to propose control techniques at an economically justified cost (Greg , 2003). In other words: Risk management must adopt a rational strategy based on scientific techniques.

The risk is the result of a natural fact, and to control this question, it is necessary to master its physical processes by taking into consideration the economic means of the provided solutions.

After 1945 the use of investigative means in the forecasting phase for risk analysis, then the taking of the necessary planning measures, and finally crisis management, and this by the establishment of emergency plans. The risk based on a quantitative approach based on statistics while chance adopts a qualitative approach based on the calculation of return periods, and estimated damages, and then the adoption of a management policy based on the cost-benefit principle. According to (Kunreuther, 2017) the recommendations of the technocentric approach are positive because its method is based on a good knowledge of risk, and make alert and monitoring systems more effective.

2-3- The weather-related hazard:

This concept is the most used argument by local actors in case of a disaster related to hurricanes or floods, to justify or explain the damage and the consequences of an event, because it represents the apparent factor causing the flood hazard, with the interaction of the physical environment and precisely the watershed. The meteorological hazard is determined by the intensity, duration and frequency of rains (IDF curves) through these elements we can estimate the potential damage, which depends on the speed, flow rate, and the height of water in each return period, (SOLTANI & Antoine , 2019)

Among the most important floods characteristics, the return period, it varies from one region to another depending on the prevailing climate and other factors related to anthropogenic

modifications on space, (Bruno, 2006) suggests a distribution and classification of precipitation according to the return period of 10-100 years and more than 100 years.
To understand the flood hazard, research should be focused on the functioning of this phenomenon, and the interaction of its various components, be it the physical environment or precipitation, and the feedback to anticipate future scenarios, from this point, decision-makers take the appropriate decision in terms of risk prevention. On a managerial level, the flooding phenomenon is always linked to the ability of stakeholders to offer security to the citizen and keep them safe from natural risks in general, and the attempt to find the best way to take into consideration the available means.

2-4- Hazard assessment by urban runoff:

In order to identify the hydrological hazard, and like other disciplines, it must be based on a real and reliable source of data and real statistics (Figure 6), with a certain margin of error because it is subject to uncertainty (nature data are not exact sciences) according to (Gérard , 2006), On this basis, the return period method is one of the most common methods, and often used for the characterization of the hydrological hazard, with spatiotemporal limits, and even for the establishment of risk maps, where the value of return period is strongly influenced by the modifications on space by the urbanization of minor watershed bed.

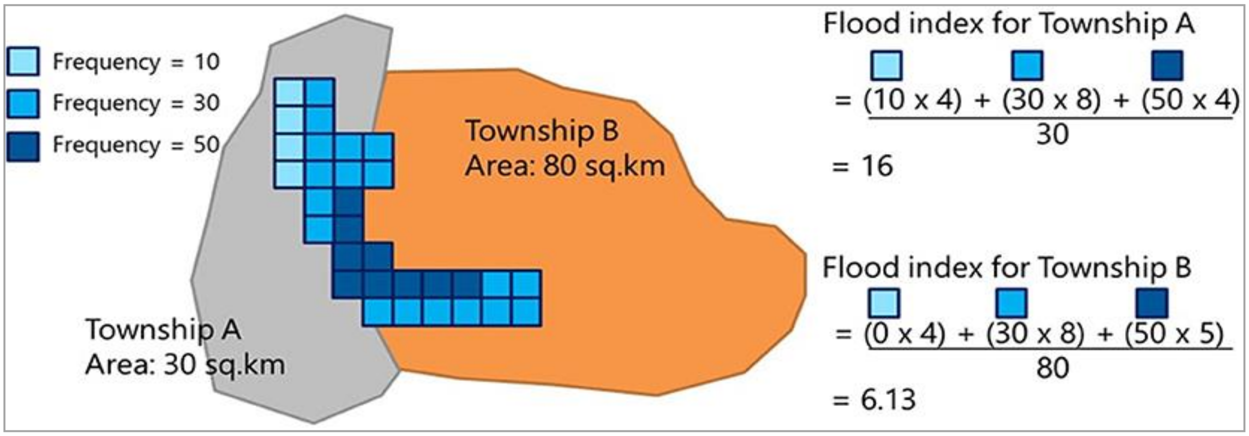
The return period of a meteorological event is different from that of a hydrological event. Because the conditions for triggering a hydrological event are not always the same, and the hydrological event is not the sole determinant of flood risk. According to (Bruno, 2006), the identification of the return period is made from observation series, for example a period of 50 years can know it from a series of 150 years, in the case of period 100 it remains probable, there is no precise method for this purpose. On the other hand, in the case of a short return period, the method of gauging the height and flow of the rivers make it possible to give sufficient time for the managers to intervene.
In this case, the technical solutions are based on the characteristics of flood reference, such as the submersion height.

Flood hazard Index calculation:

$$FHI = \sum_{i=1}^{n} \frac{FiNi}{A} \tag{1.1}$$

This is one of the most common methods of Hazard calculation as an essential element, based on return period as a classic approach adopted to determine the flood risk zoning without taking into account other variables to determine the flood risk, such as vulnerability and exposure

Figure 6: Example of flood hazard index calculation for individual Townships.



Source: (Phongsapan, 2019).

The water rise is depending to the reaction time of the watershed, the decaying operation can take a long time to evacuate the stagnant water, it can damage certain components such as roads and buildings because each material possesses a specific threshold of resistance. The hazard timing is the guide of the managers to determine the alert thresholds, for inhabitants, and for the movement of the goods affected by the flood, generally this time is too short.

And this will help to give the evacuation order in real time to ensure the right conditions.

2-5- The hazard as a risk-producing factor:

The risk studies generally include the temporal dimension, in addition to the spatial dimension. According to (Dauphiné & Damienne, 2001) the risk can be defined as: the hazard that affects an area, for an undetermined period. Because the spatial dimension refers to the geographical affected area, while the temporal dimension refers to the time and occurrence duration. "The black swan theory" of (Taleb, 2007) which refers to the uncertainty of the probable hazard, so the risk management actors will take up a great challenge to determine the spatiotemporal framework of the hazard to properly prepare and prevent the risk. The hazard is closely linked to the physical aspect of the phenomenon, since it is closely related to the site of the watershed, this requires an efficient flood risk management strategy to address this problem, in this case the return period is used to define it.

3-Vulnerability:

The term vulnerability is often linked to catastrophic events and risk in general, whether, natural, or human-related, it shows the fragility of a society, it is a scientific concept for sensitivity analysis, that it takes into account the social and economic aspect. There are several definitions of vulnerability, and to determine the definition that accurately reflects the reality of natural risks, it is necessary to return to its genesis and based on the scientific treatment of risk.

3-1- Concept of vulnerability:

In our case study, we pay more attention to the terminological aspect and more precisely from a territorial point of view. The appearance of vulnerability notion was originally linked to the damage cost, in other words it took an economic turn, and later the notion had transformed to the social aspect.

According to (Dauphiné & Damienne, 2001) : vulnerability can be estimated before the risk occurs, not in the post-disaster phase, moreover, we can go through crisis management to risk prevention (Jean-Claude & Robert , 1996).

3-1-1-Source of the concept: The risk is mainly influenced by physical factors in the first instance, thereby making the managers continuously seek to control them through technical solutions, and also put into practice the concepts of population safety, because citizens are a part of the exposed issues to risk, and how society responds in a disaster event, "there is no natural disaster, it is the hazards that are natural, but for a hazard to become a disaster it must affect a vulnerable population (Cannon, 2008), In another way, we can say that the change in the context of vulnerability modify the concept of natural risk and its management and make it relative.

A)- The Chicago School contribution:

According to the Anglo-Saxons, the risk study revolves around two main axes: the concept of disaster from the sociological point of view, and geography as a discipline that analyses the relationship between nature and society. The exploration of the social concept of risk occurred during the period from 1950 to 1970, following the adoption of the classical approach in the 1940s, and according to (Gilbert F. W., 1973) this approach was ineffective because it does not address the requirements of the social dimension of risk. The physical risk factors alone are insufficient to result in a disaster, as they are contingent upon society's response to the risk. Thus, a hazard is not necessarily the sole cause of a disaster. Societies vary in their capacity to cope with risk, responding according to its fragility and its ability to adapt, these factors are varied according to the conditions (places and times).

B)-Natural hazard research school:

The geographers of Chicago: G. F. White, I. Burton and R. W. Kates. Publish a book entitled: *The environment as a hazard*. They criticize the previous planning policy and these hard technical solutions, which cannot reduce the number of disasters in the northern countries, while in the southern countries the number of victims remains stagnant, and this shows that technical solutions cannot be effective if it does not integrate society. Collaboration, as a result the so-called concept of vulnerability appeared in 1975, which relies on the ability of a society to cope, and this paves the way for the appearance of this concept as a risk component. After that, it was adopted as a central concept, among the first who use this term are (Wisner, Davis, Cannon , & Blaikie, 1994).

3-1-2- The development of vulnerability concept:

The structuralist paradigm, based on experiences from the developing world, posits that within the framework of the structuralist school, a hazard remains merely a hazard unless it intersects with a vulnerable population, at which point it transforms into a disaster (David , 2002), The structuralist school and the behaviourist school agree that disasters can be summarized in the conjunction of two objects, hazard and exposed population, However, they disagree when it comes to the volume of hazard and vulnerability. Most of the time the inhabitants of the areas exposed to the hazard are the poor, and it comes down to several factors: such as the cost of land, and the materials for building houses, we can say that there is a correlation relationship between vulnerability and poverty.

3-1-3- Frequent definitions of vulnerability:

The word Vulnerability comes from the word 'Vulnus' in Latin which means the wound, which applies to the soldier that causes death. We can group the definitions into two main trends:

The first: is from a physical and engineering point of view, they define vulnerability as the degree of damage in the face of a hazard, and the second: is from the point of view of social sciences which define it as the ability of individuals to cope.

3-1-4- Vulnerability elements in urban areas:

The classical approach to vulnerability is based on the degree of damage, and population response to the risk. The vulnerability concept became more popular especially after the dissemination of the notion of sustainable development, which appeared as a bet for managers to find solutions within the limits of what guarantees the right of future generations to a decent living environment, and the environment preservation on the other hand.

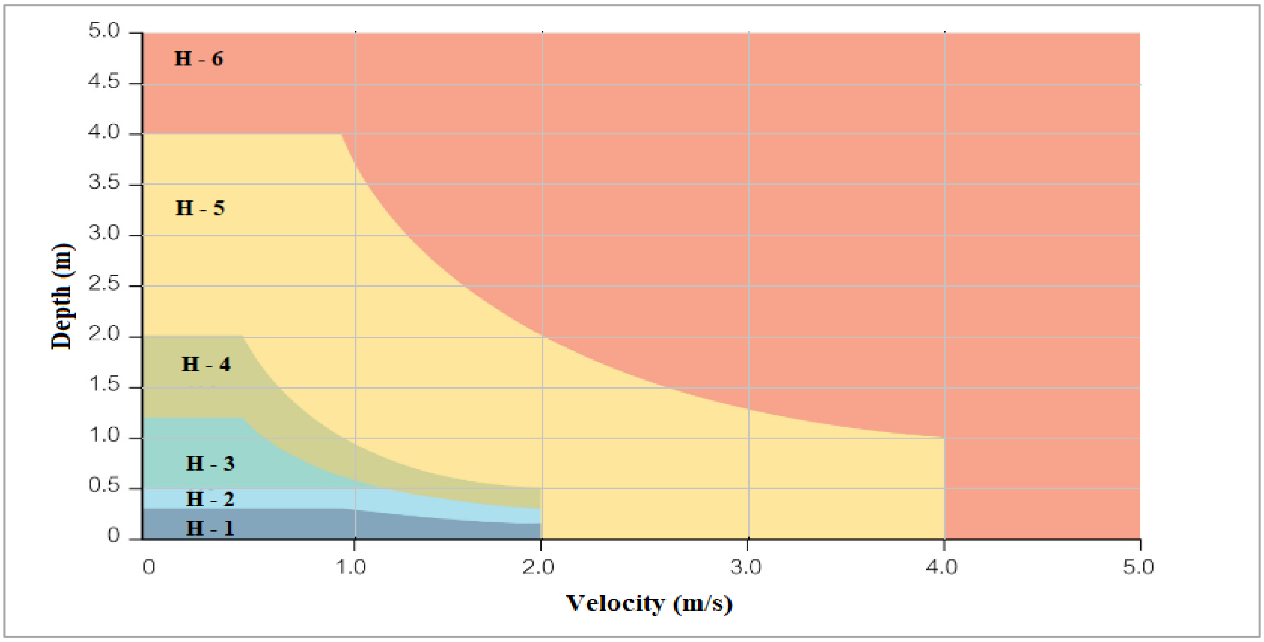
Core elements of vulnerability: The vulnerability of a society and goods exposed to the risk can be defined by multidisciplinary studies, based on sociological, economic, technical, political factors, and also on the history of past events.

Sociological elements: Concerning the population occupying the space and all its characteristics (standard of living, function, displacements.), and the possibility to presence of people with special needs, the elderly, and children who represent the most vulnerable classes.

Physical and technical elements: concerning the type of building, the materials and techniques used in the constructions to be utilized to determine the structural vulnerability, Including the network and the quality of intervention services following the disaster, such as evacuation and rescue operations (civil protection, health services ...)

Political elements: These are the management actors who possess the authority to influence and direct interventions in the spatial context, as well as to implement applicable legislation and state regulations. They are required to develop solutions for risk prevention, and crisis management in the post-disaster phase, considering that legislation can be evaluated by its effectiveness in reducing vulnerability to risk through the application of the regulatory tool.

Figure 7: General combined hazard and vulnerability curve.



Source: (Smith, 2014)

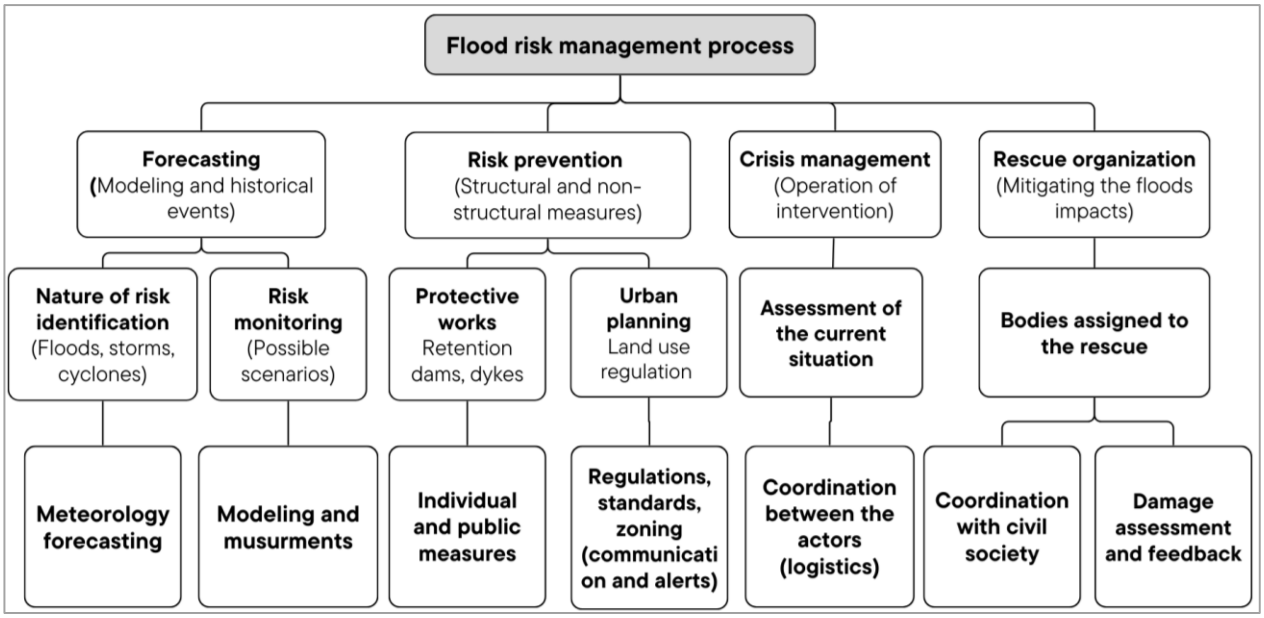
(Smith et al 2014) developed thresholds that enable classifying the flood risk through floodplains and flood scenarios of different levels, based on flood depth and velocity, using information obtained from hydraulic models into 6 categories in approach combines the hazard and vulnerability showed in (Figure 7), this approach combined structural and social vulnerability and the degree of stability of vehicles, people, and building against the hazard.

H6. Unsafe for vehicles and people. All building types considered vulnerable to failure.
H5. Unsafe for vehicles and people. All buildings vulnerable to structural damage.
H4. Unsafe for vehicles and people.
H3. Unsafe for vehicles, children and elderly.
H2: Unsafe for small vehicles.
H1. Generally safe for vehicles, people, and buildings.

4- Flood Risk Management frameworks:

While flooding is a predictable phenomenon, accurately pinpointing its timing and location presents significant challenges, the protection of populations, more precisely the risks prevention is the priority of actors and city managers to protect them, seeing that flood risk management is for the purpose of reducing human losses in the first place, and then material damage in flood prone areas, which gives the highest priority to vulnerability, without ignoring the hazard effect, to achieve effective flood risk management. As stated previously, the main objective of the local actors in the management process is to ensure a sense of security among residents, and provide a more better living environment and protect their property (Figure 8). With the urban expansion of cities, these circumstances have made it necessary to develop new urban management techniques, so there is a direct correlation between the size and complexity of city management. For this purpose, urban management must belong not only to politicians, but to several parties (political power, technical power, professional know-how, and civil society).

Figure 8: Flood risk management process phases.



In this regard we find:

4-1- Flood forecasting approaches:

This stage comes before all the measures adopted by local actors such as technical solutions, since flooding is a predictable phenomenon, the problem remains in the time of warning and rescue organization. It represents the preliminary phase, where it relies on the meteorological aspect and when the amount of precipitation plays an essential role, take into account the hydrological aspect. Precipitation is one of the essential elements of risk forecasting, because it serves as the principal floods risk factor, the meteorological services should set up networks of rainfall measurements in flood-prone areas, because it represents an essential information source that can be used to citizen alert in case of heavy precipitation. The forecasting serves as a critical tool in flood management by assessing the hydrographic network to quantify both liquid and solid flows within the hydrological system. This process facilitates the collection of data, which is essential for determining flood intensity and ultimately aids in informing citizens.

The accurate risk prediction depends on:

Forecasting in a crisis context: The risk prevention is usually linked with feedback, because through previous experiences the prevention process was carried out simultaneously with it, on the other hand, forecasting is linked with crisis management, through which future scenarios are predicted on the basis of previous ones.

The forecast is based on meteorological and hydrological data, with the probability of occurrence, which determines the time and place framework (return period), in which the correct forecast depends on the alert of citizens in real time, in order to facilitate the approach of the rescue plan and emergency plans (Plan d’Organisation et de Secours [ORSEC]) This approach must be based on a true vulnerability determination of each sector, Considering these physical characteristics (topography, soil type) and hazard characteristics (intensity, duration, frequency) is essential to ensure the relevance of the intervention. To achieve this objective, providing a flood warning service is crucial for informing the population. This can be achieved through consultation among local stakeholders that facilitate risk prediction through the coordination of various services, ultimately leading to a more accurate diagnosis of potential flooding events.

4-2- Risk prevention strategies:

This management stage is frequently relying on the data collected in the feedback phase, and then the extraction of recommendations to help create risk management plans. The principle of prevention is to reduce the consequences of natural phenomena on the stakes, and so that it is impossible to prevent the phenomenon from occurring, as well as the protective measures cannot guarantee absolute protection against flooding, therefore, more emphasis must be placed on rationing the establishment in risk areas, this aspect is based on the physical aspect of the floods. Going back to previous events, we can see that society's response to risk plays a decisive role in recognizing the risk, in order to find technical solutions to reduce the hazard effect, through protective measures, and crisis management through emergency rescue procedures.

4-2-1- Vulnerability diminution: from a managerial point of view, reducing vulnerability is the most reliable risk management tool by reducing potential damage, on the other hand, the mitigation is applies to economic assets, livelihoods, sensitive equipment and necessary for crisis management such as (electricity, drinking water supply, communications network... etc), nevertheless, local actors should be well aware of the risk, the stakeholders and also the citizen can contribute to reducing their own vulnerability by being aware of the risk.

4-2-2- Reducing the torrential floods severity: It is essential to intervene in the watercourse by installing corrective measures aimed at reducing the transportation of debris in the low-flow channel of the watershed. Additionally, cleaning and restoring watercourses are necessary to facilitate the passage of floodwaters into the dammed flow, thereby decreasing the water height.

a)-Protection works: including structural measures with the aim of reducing the hazard effect, and this by the protection works.

b)-Mastering urbanization to reduce vulnerability: urban planning and environmental law requires taking into account natural risks in the development of all planning documents, before the implementation of any construction project, through these plans, the red zones in which construction is prohibited "non-developable lands or developable with conditions" are identified, also taking into account the observation of natural and artificial easements.

4-2-3- Flood risk consideration in planning: The means that demonstrate its global relevance is the establishment of laws regulating the management of natural risks, particularly within the frameworks of planning and urban development tools, with the help of other plans such as the exposure and risk prevention plan, they made it possible to prevent settlements in at risk areas, by refusing to give permission to build in these areas, with the objective of controlling development in flood-prone areas and preventing the expansion of flood-affected zones.

a)-The distribution of responsibilities: The role of each of the main actors in the management process lies in fully playing its role in a chain that does not accept the loss of any of its links, the population by giving their opinions and their awareness of how to act in the face of risk, and the State by the management measures and the alert summarized in the development and urban planning plans, and the Flood Risk Prevention Plan (Plan de Prévention du Risque Inondation [PPRI]) risk prevention plans.

b)-Preventive information: It pertains to informing citizens in case of risk is one of the essential elements in risk prevention, to facilitate crisis management, and to make the citizen feel responsible in the management of natural risks.

c)-The alert process: First by an audible signal, and then by the diffusion of a message transmitted on available means such as radio and television, by which the population is directed on how to act according to the developments that occur, moment by moment.

d)-Anticipating the crisis: The effective risks anticipation that represents the way of treating the flood at the individual level before the arrival of the rescuers, it is necessary to put in place plans for the population information in this direction, to promote the protection of oneself to the citizen. In this phase, the actors are required to go on standby using all means available to intervene according to the type and degree of probable danger.

4-3- Crisis management and response:

This stage is more extensively happens in the case of a major disaster, the intervention in this case is made by state authorities for crisis management, and exploiting all possibilities for this purpose, and the intervention even of the National Army if it is necessary. Unlike prevention, which revolved around the technical measures to be taken before the risk occurrence, crisis management comes just after the outbreak of a flood event, which requires direct intervention on the field to reduce disaster consequences by mitigation where managers are tasked with minimizing damage, conducting recovery efforts, cleaning up, and repairing disaster-related impacts. And then the feedback in the purpose to learn from the disaster, and this by sharing direct experience with citizens to reduce social vulnerability, and also by assessing disasters consequences to properly manage the risk, because each stakeholder in risk management must evaluate their experience and the lessons learned from the experience, to improve the effectiveness of future interventions.

Operational strategies of relief organizations: This is the last phase of crisis management, it is for the purpose of saving the inhabitants affected by hazard, by employing interventions that are both effective and well-qualified, such as civil protection, and also the services of sanitary facilities, which go in accordance with the organization and rescue plan. And then the population compensation, it should be noted that natural disaster insurance is often mandatory but there are no mechanisms for applying this in Algerian law according to statistics related to the insurance coverage for natural disasters.

4-4- Global stages of disaster management (Disaster management cycle):

The management of catastrophic events requires the mastery of several fields, such as hydrology, hydraulics and urban planning, followed by a thorough evaluation of the specific details of the phenomenon being addressed. To this end, this process divided into certain stages depending on the spatial and temporal position as shown in (Figure 9), and each phase, along with its specific characteristics and involved stakeholders:

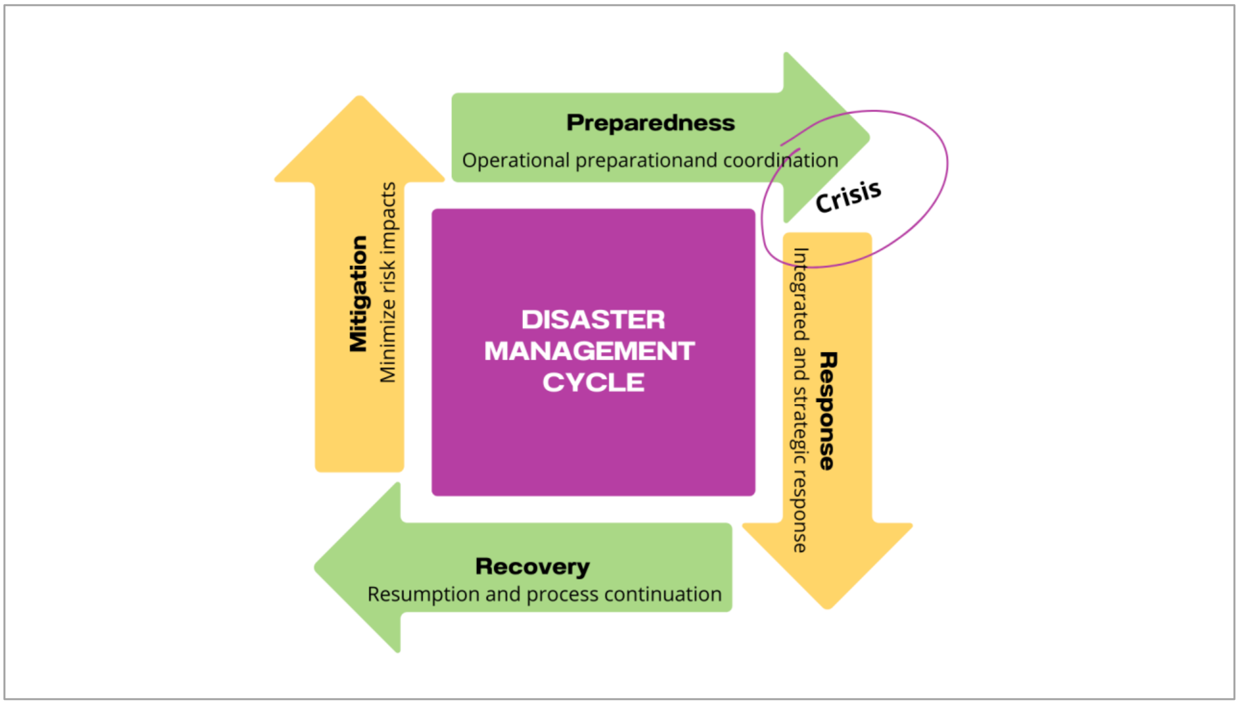
Preparedness: This phase includes the prediction and risk prevention, through risk assessment and programming and the implementation of structural measures, and the determination of the appropriate course of action according to the prevailing circumstances, to make the risk acceptable, the next step comes before the event is the risk information stage or alert.

Response: This stage comes immediately after the event occurrence, as in the (Figure 9), this is the stage of limiting probable damage and controlling the risk, this stage also represents the intervention phase as part of the emergency plans, and damage mitigation. And then the restoration phase by taking provisional measures to rely on the means of communications and transport for the alert and evacuation of the stricken population.

Recovery: This point in the process is aimed at the implementation of mitigation measures, and then the evaluation of the management system performance, and feedback to strengthen the risk memory to the citizen, which would be valuable for managing future events and establishing benchmarks, such as water height; subsequently, the financing phase for reconstruction follows.

Mitigation: As a last phase in disaster management cycle focuses on minimizing the long-term impact of floods, this involves protective measures, Key actions include: Infrastructure Improvements by building levees, flood walls, drainage systems, and other protective structures. Another aspect is Land Use Planning by controlling development in flood-prone areas to reduce vulnerability, and increase the resilience. And with Natural Solutions by preserving wetlands and forests that can increases time concentration.

Figure 9: Disaster management cycle organigram.



Source: *(The researcher 2024)*

The approach built on hazard mitigation raises a question about the possibility of reducing the effect of a hydrological hazard in an urban area, the answer is through spatial planning which must take into account the development in vulnerable areas. Previous experiments have shown that some measures are compatible with multiple cases, it depends on the local specificity of the area and its measurements.

4-5- Foundational concepts in risk management:

Management measures are classified into two categories: structural and non-structural, relating to forecasting, prevention and protection, this classification was conducted by the Anglo-Saxon, in the 1940s by (WHITE, 1942) and 1970s by (Rowsell, Charles, & Chatterton, 1978) this terminology was used in 1960 in the USA and 1980 in France.

The evolution of risk management can be classified according to the management timing of measures: forecasting and warning, crisis management, and the post-disaster period and feedback, according to past experiences in the state policy on risk management, the bet was always to achieve a global risk management, which ensures the organization of actions according to the type of risk and the area characteristics.

Risk management measures are outlined as follows:

4-5-1- Structural solutions for risk reduction:

Technical solutions are fundamental in effectively managing water flow, as they provide essential strategies for addressing hazards and minimizing their impacts, particularly through civil engineering works. This type of measures is intended to reduce hazard consequences and effects, by controlling the surface runoff following a heavy precipitation, in this context, commonly employed solutions involve altering the conditions of water flow, in other words, the direct fight against the risk of flooding, by increasing the flow capacities, and this is done by the recalibration of the low flow of watercourse, and the construction of dykes to protect urban agglomerations, or by increasing water storage capacities in order to reduce the speed and flow of rivers, by the construction of natural dams, and retention basins.

The approach taken by public authorities typically emphasizes the establishment of necessary protective infrastructure. Executing these works does not require advanced and sophisticated technical capabilities, such as dykes, these are the old forms of flood risk management, among the disadvantages of this management policy is the ability to control exceptional floods in addition its feasibility is not always possible because of the issue of cost or ecological reasons, overall, even if the technical solutions are useful, but its performance in general is limited.

Flood control dams in hydraulic regulation:

This technique has historical significance, dating back to the 19th century and first employed in Paris, it is for the purpose of absorbing the amount of running water to limit the level rise of the water height. These dams are also useful for enriching water resources as a double utility. It has proven to be effective especially with the existence of dykes and low walls, because it ensures and fixes the flood level and prevents overflow, the only drawback is-it can be criticized as while being expensive.

In addition to dams, other solutions include: digging of flow channels and low and middle flow deepening.

In the field of dam construction, priority has always been given to irrigation dams, despite the fact that this type of installation favours the possibility of mitigating floods consequences, However, in light of the necessity and the anticipated benefits, it has become necessary to build retention dams in at risk areas for hazards prevention such as the Koudiat Aserdoune dam, and the project on the Bouhdid Wadi in Annaba, the mechanism of action of these dams is to reduce the flow of runoff and the height of flood water. The development of such projects should be based on an in-depth study, in accordance with the requirements and specificities of the watershed and the climate of the region.

Wetlands in environmental management:

Wetlands play a critical role in effective flood control due to their inherent characteristics and significant ecological functions; it reduces the volume and speed of surface runoff. In coastal areas, wetlands act as natural barriers against storm surges and high tides (Yanfeng Wu et al, 2023). The artificial storing runoff water technique is made in areas that are generally likely to accumulate and store a quantity of water by submersion, it can absorb the point flow and the flood wave, these areas are generally non-urbanized or less vulnerable, this practice has been the subject of numerous criticisms, such as questioning the purpose of the submersion of agricultural areas for urban purposes.
The wetland area in El-Rym neighbourhood (Figure 10) is redeveloped for aim to make it a park area as a leisure space for families, and to preserve the region's ecological diversity, and on the other hand, with another advantage is that it absorbs the quantity of peak flow water as a preventative measure against the risk of flooding, this Lake, has lost large surface areas over the past years due to construction on an already unbuildable area, this raises the question of the effectiveness of local policy in regulating construction in at-risk areas.

Figure 10: The wetland in EL-RYM district (Lac EL-RYM).

Source: (The researcher 2024)

Engineering of Dyke systems for flood control:

Dykes serve as one of the most effective means of defence for protecting flood-prone areas, the only drawback of this type of measures is the case of breaks in dykes, which requires regular maintenance, this does not exclude that the failure of this type of measures is frequently linked to the event intensity. These measures are often criticized because of its negative effect on the environment and the natural ecosystem. Any modification on the scale of the water way in terms of the form or the recalibration of the flow and banks can lead to an increase in the surface runoff, except for a positive point of facilitating the transformation of water downstream and avoiding river obstruction.

In certain instances, structural measures may not fall under responsibility of the State, so the maintenance of its structures remains a dilemma in risk management process, where the structures can be located in privately owned land, the issue here is that this component can lead to ruptures or floods aggravation. Otherwise., feedback serves as an effective mechanism for evaluating the management process, enabling the functional verification of these measures and their adjustment as necessary.

4-5-2-Non-structural measures:

This type is evident in the discourse surrounding the work on issues exposed to risk and challenges at mitigating vulnerability through urban planning, information dissemination, and efficient crisis management, in other words the reduction of financial losses as a result of land use control. These measures do not require a large material resource like the previous one, because it being intangible, it adopt an approach of changing the stakes exposure in relation to the hazard, so, focusing on strengthening society in the face of risks. We can cite for example:

Modification of land use patterns: to prevent settlement in floodplains, or allowing with conditions (permission for some type of land use where exposure is low).

The modification of physical elements vulnerability: strengthening of the infrastructures of the urbanized sectors.

Commitment to management in order to deal with issues: An important part of the consequences of floods are due to the residents' behaviour, so information and awareness of citizens is one of the key elements of risk management in general. Through alert systems and awareness-raising of citizens through the media in case of risk, and the organization of flood awareness campaigns.

Insurance: this mode of intervention is done after the disaster in order to determine the cost of the damage, by compensation for the victims and reconstruction.

4-6- Water resource management in Algeria:

Relies on a common system affiliated to ministries of hydraulics, agriculture, and facilities, these ministries are responsible for water management structures, which in turn have representations at the province, and municipal level. The National Agency for Water Resources (Agence Nationale des Ressources Hydrauliques [ANRH]) an organization affiliated to the Ministry of facilities in charge of water resources management at regional and local level, and the preservation of water quality and address the risks arising from human activities, within the framework of sustainable development. The complexity of risk management consists of the multiplicity of actors involved: (State, experts, economists, financiers, elected officials, citizens) Thus, finding coordination mechanisms between the different actors is a more complex process. The methods adopted in flood risk management in the urban environment are multiple depending on many factors such as the social factor and the urban characteristics of the city. And depending on the compatibility of the proposed solutions, in some cases the effectiveness of non-structural measures may be more relevant than that of structural measures.

Types of management measures:

Consideration of anthropogenic action in water management:

In recent years, Algeria has experienced a significant increase in its urbanization rate, due to several factors, the strong demographic growth in addition to city attractiveness of rural population to improve their living conditions like proximity of facilities, this process has led to urban sprawl at an accelerated pace and therefore a high land consumption, this trend has inevitably resulted in the deterioration of ecosystems due to the silting effects of urbanization on natural environments, in addition to the decrease of forests in Algeria in general due to several factors, especially the drought and the high temperature that causes forest fires, which has recently caused a lot of confusion.

Urban and industrial projects in the alluvial plains: The principle of urban management is to place the population in areas or conditions of safety in the first place, and which preserves the integrity of their property., but the increased need for extension and the scarcity of land, and on the other hand a poor diagnosis for risk areas delimitation leads to the construction in flood prone areas.

The construction in flood zones inevitably leads to the modification of the flow conditions, in addition the inhabitants who occupy new urban areas build in the full flood zone, they have no experience of flood behaviour and flooding.

Exploitation of natural resources: Economic and industrial development requires the exploitation of natural resources to meet the needs of the population. For example, the exploitation of sand from river flows can cause serious imbalances in the hydrographic system, the exploitation of sand is regulated by Algerian law, but in the illegal situation always remains threatening the waterways, and leaves marks of serious erosion of the banks.

The failure of civil security: To ensure risk prevention, the main actor in the stage of crisis management and direct intervention in the event of a disaster is the civil protection and the other public forces as one of the most important actors, it constitutes a kind of link between the other management actors and the population., the latter must have sophisticated equipment, and well-qualified personnel to ensure that the intervention process takes place in appropriate conditions.

Algeria And by virtue of past experiences that it has taken as a result of previous events, it creates a *national prevention strategy* based on coordination at the central level and redouble efforts to achieve it at the local level.

4-7- The concept of major risk and disaster:

According to THE EUROPEAN AND MEDITERRANEAN AGREEMENT ON MAJOR RISKS (EUR-OPA), the word DISASTER dedicated to the risk that causes a significant number of deaths, and the cost of material damage. Therefore, the risk levels are classified as: (incident, accident, serious accident, very serious accidents, disaster, major disaster), according to the geographical extent and the consequences that result. In Algeria, the definition of this concept according to the Law n ° 04-20 of December 25, 2004: *"Is considered as a major risk, any probable threat to humans and their environment that may occur due to exceptional natural hazards, and/or due to human activity"* From this point on, local actors must establish a scale to assess the severity of risk, using the most serious event in history as a reference. The disaster is a materialization of the risk, the disaster is a phenomenon that causes significant material and human damage, on the other hand the risk may be less serious and more threatening to society. Since the spatial factor is closely linked to the disaster, if this is the case, it can be defined as the part of territory exposed to risk, affected by an incident, so the disaster is only the event that affects a part of territory at risk in a specific period of time.

5- The natural risk in urban planning documents:

Risk exposure plan, (Plan d'Exposition au Risque, [PER]): For a specific purpose, which is to identify the areas that are likely to be exposed to the risk, the risk exposure plan, PER, this plan shows the risk zoning, it is the only instrument that openly interests to the natural risk management in the Algerian regulation at the time. This plan uses risk areas mapping, it delimits areas with future urbanization, (developable, developable with conditions, non-developable), and as the procedures for developing this tool are strict, its acceptance and approval by the actors is limited, so it is supposed to put the flood risk protection plan as an effective method for this purpose.

The Master Plan of Urban Planning (Plan d'Urbanisme Directeur, [PUD]) was devoted to the organization of urbanization and urban extension of the cities, and the development of territories before the introduction of the Master Plan of Development and Urban Planning (Plan Directeur d'Aménagement et d'Urbanisme, [PDAU]), it does not take into account natural risks, and the evidence is the extensions that took place during this period that know deadly disasters.

In 1991 and with the law 29/90 the laws of urban planning and development PDAU and Land Use Plan (Plan d'Occupation du Sol, [POS]), it was the first time that Algeria adopted a specific law that explicitly defines the urban planning guidelines, which take into account the component of risks in the urban environment, in the form of natural easements, set up controls and rules that organize the implementation of urban planning projects.

The POS divides the territory into sectors: urbanized sector, developable sector, sector with future urbanization, and non-developable sector, the difference between the Land Use Plan POS and the Master Plan of Development and Urban Planning PDAU is the scale of intervention, so that the POS delimits all the details down to the level of buildings, and it delimits the type of intervention to each sector, showing the type of exploitation in at risk areas. The regulation of this tool also delimits the exceptions, in case of a (POS) located on a territory between two municipalities, it will place under the authority of the Wali, and in case of POS located between two municipalities of territory of two wilayas, it is done with the intervention of the Minister in charge of the development, this document also fixes the extension of the cities in case of insufficiency of land, by the law of expropriation and right of pre-emption for the public interest. The year 2004 marked the enactment of the law of environment. The Law n ° 04-09 of August 14, 2004 is a key legislation in terms of environmental protection in Algeria. It aims to encourage the implementation of clean energy techniques within the framework of sustainable development, and the fight against pollution on several aspects, including water management, Involve citizens and civil society in the development process.

The National Plan of Territorial Planning (Schéma National d'Aménagement du Territoire [SNAT]) 2025 and 2030, also know a part of major risks (technological and natural) and the (ORSEC) plans that limit and organize the intervention of the various actors in the event of a disaster, outlining the type of response required from each party.
The Law N ° 10-02 of July 5, 2010 relating to the management of natural disasters: Within the framework of the National Spatial Planning Scheme, this law which defines the general framework for the management of natural risks, including floods, and determines the distribution of tasks between the actors in the prevention and management of disasters.
The need for a Risk Prevention Plan (Plan de Prévention des Risques [PPR]): In Algeria, the development policy needs such a plan, centred on risk prevention, this document must go through the stages and the classic procedures for developing such plans, (a public inquiry, prescription, and approval). It fits into the territorial planning policy for the objective of the representation of power of the state, protection and prevention of risk and safeguard, and reduction of vulnerability, and reduce the consequences and the probable damages in case of disaster by mastering the stakes.
The PPR: This was part of the framework of the law 04-20 of December 25, 2004 relating to the prevention of major risks and disaster management within the framework of sustainable development, Contains a graphic document that uses cadastral cartographic funds, it is: hazard map, and stakes map, with the superposition of the two maps provides with a risk zoning, that it takes into consideration the magnitude of probable risk by colour, red, or blue, and the nature of the issues exposed vulnerability. The intended objective of this plan is to regulate land use and reduce exposed issues to the risk, The challenges to the smooth operation of this tool primarily involve its practical implementation, by local actors, due to the indeterminacy of the interests of this plan in the long term.
This plan is based on historical flood studies and the issues in its risk zoning distribution, and not on hydrological studies, and vulnerability. This is done at the local scale to promote the aim of decentralized management, and encouraging consultation with citizens through associations, to help them accept some decision and recommendation of this plan such as the relocation of residents.
In order to improve living conditions and foster positive social and environmental interaction, as well as the population, there is also urban heritage which poses a major challenge in risk management, as a preserved sites, and economic facilities, with the evolution in urban management, there should therefore be an increasing need for consistency at the level of development and urban planning plans, and a certain severity in the application, and to find a cohesion between these tools in management., this process allows the differentiation between the various scales of development plans and those associated with risk management.

5-1-The need for surface water management plans:

Surface water management is done at the watershed level, involving collaboration among all stakeholders in the region and clearly defining the responsibilities of each participant, taking into account the physical specificities of the terrain, and rely on the history of floods in this area, to delimit the most damaging. As in England, which is considered one of the main countries in this field, surface water management plans are instruments to deal with water-related problems at the local level, such as heavy runoff, resulting from heavy rains. The development of risk management plans that it must have mainly a sustainability according to the hydrological, socio-cultural, and environmental specificity, before taking the measures for the risk management, and then the evaluation of each decision and its relevance. One of the shortcomings that should be highlighted is the absence of actors at the watershed level who would ensure removing obstacles in the process of sharing tasks between the different actors.

5-2- Emphasis the importance of prevention:

After the appearance of the PER law, for the purpose of delimiting the exposed areas to natural risk, in this case, the risk management is not limited to risk identification, but also to prevent it, The notion of risk prevention has been defined by the United Nations (UN) as *"The systematic application of directives, operational skills, capacities, and administrative organizations to implement appropriate policies, strategies, and response measures to mitigate the impact of natural hazards and the risks associated with environmental and technological disasters"* (UNITED NATIONS INTERNATIONAL STRATIGY FOR DISASTER REDUCTION). Therefore, the identification and reduction of the harmful effects of flood risk is an indispensable factor in the (UN) strategy, which should also be a priority for risk management plans such as the (PPR) and the (PER). These plans must be based on in-depth studies for prevention and flood risk anticipation.

In this case, the State is committed to include risk prevention as part of the spatial planning policy and take the place of flood control, this strategy will be more relevant with the partnership between the central State and local actors who must devote the principles of risk culture to the citizen.

5-3- The flood management mechanisms:

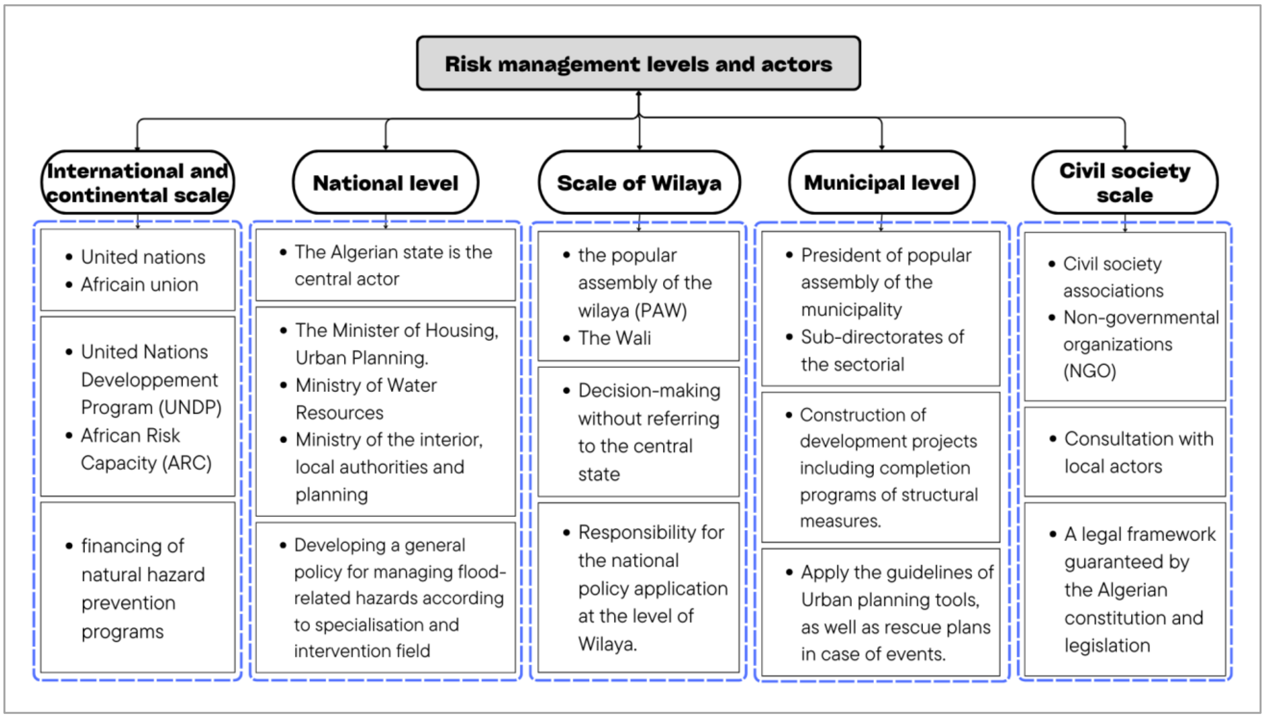
In a managerial context, the operational policy should encompass the various components of management, particularly forecasting and anticipation, extending to the provision of alerts and risk information, this last step requires vigilance both for local actors and the citizen. The need to prioritize non-structural measures for forecasting and prevention: Flood risk management before the 1980s was limited to the physical environment of risk, and after the failure recorded many times of this policy, the state was compelled to shift its focus towards addressing exposure by implementing non-structural measures, and the one who managed to reconcile the two types of measures was first implemented by the work of (Gilbert F. W., 1975). The structural measures are translated by the works of protection against the risk of flooding, (dams, dykes, expansion zones of floods). These management measures are more relevant at the watershed level than at the city level, Non-structural measures concerning more action on social vulnerability, through the development of a culture of risk and the prohibition of construction in flood-prone areas, and the organization and rescue plans. The management policy must integrate non-structural measures into its approach which adopts forecasting and prevention for an integrated risk management.

5-4- The territorial actors of risk management:

In the Algerian management system, risk management actors, much like those within the urban management system, are categorized into four distinct groups:

Decision-makers: Local actors, particularly the President of the Municipal People's Assembly (l'Assemblée Populaire Communale [APC]), play a pivotal role in this framework at the municipality level. At the provincial level, the president of the Provincial People's Assembly (L'assemblée Populaire de Wilaya [APW]), and the Wali in the Wilaya scale are the State representatives, their bet in risk management is linked to the extent of coordination between the other actors, including the ordinary citizen.
Experts: It constitutes the scientific basis of the management system, the political decision must take it as a reference in the decision, (the design offices, private or state).
The operators: It concerns the great collective actors, refers to the powerful entities or forces that shape and influence society, culture, and politics.
The population: It pertains to two distinct categories (citizens in the associative movement) and the public. The performance of management actors in a territory varies according to the material and financial available resources, and the specificity of the physical characteristics of each at risk area.

Figure 11: Level and actors of flood risk management:



The management actors:

Recently, several approaches have been widely adopted in the field of risk management, varied according to the scale and status. Currently, there is an evolution of management modes when it was based only on two actors Politicians and Experts. Then a period when there was the involvement of civil society as a management actor and part of the decision-making strategy. And at the end of the period, when the information accessibility has significantly improved due to the available resources, and the good distribution of tasks, to ensures good coordination between the different actors. The management actors are multiple according to the adopted management method in the area in question, they vary according to the type and risk scale, international as the

UNDP project, and at the national level is represented by the texts and the plans relating to risk management, and at the local level the APC and the directorates, however, the weight of the citizen in the management process remains limited. In a territory with decentralized management, the decision should find its way through the directorates that represent each ministry at the local level, it is enough to set up a mechanism to transform from one level to another in the scale of power. The decentralization of decision-making processes is often interfered with management tools, at national and local scale, which leads to the emergence of new management actors, if the prevention measure affects other disciplines such as the environment. Generally, state intervention is often in the form of financing prevention and protection projects, because decision-making is required to take into account the specificities of each area.

5-4-1- Key actors involved in flood risk management:

Flood risk management requires a sharing of tasks between several actors and at different levels, from international to national until local and civil society level, for an effective management strategy.

In international scale:

As the case of the notion of governance, it first appeared in the economic sector among the economists of the World Bank and the IMF, who implements a policy of governance dissemination, by financing development programs around the world, especially in developing countries, in line with the social and economic specificities of these countries. As an international tool for flood risk management, and to mitigate the overall impact of natural risks, some collaborations have been established concerning flood protection at the international level by United Nations programs, this is the United Nations Development Program UNDP is one of the examples of international management tools, developed by UN organization, and funded by WB, based on local data and reviewed according to the UN organization directories, the UNDP returns for the dissemination of the governance principles, throughout the world, and in multiple fields, among them the management of natural resources. The UNDP with the collaboration of National Economic and Social Council (NESC) established the National Report on Human Development (NRHD) report, which allows a social assessment of the Algerian population according to several criteria, such as the study on the life experience of citizens (76 years old) and the Human Poverty Index (HPI), these questionnaires are practical in defining social vulnerability in the risk area. And others at the continental level such as the flood directive, it should be noted the European experience, being leading countries in this field, this program contains a part of flood control, funded by the European fund for risk prevention, it resulted in the flood directive of 2007, adopted exclusively by the countries of the European Union (EU). And at the level of Africa, it should be noted that the African Risk Capacity (ARC) as an autonomous African financial entity aims to help the member countries of the African Union (AU) to improve their capacities to manage natural disasters related to drought and floods which ensures the facilitating financial flows.

National scale:
The Algerian State serves as the primary entity in flood risk management, collaborating with various ministries, including:
The Minister of Housing, Urban Planning and the City: Represented at the local level by the Directorate of Development and Urban Planning, (Direction de la Planification et de l'Aménagement du Territoire [DPAT]), and the Directorate of Housing and Urban Planning, for the realization of risk management plans.
Ministry of Water Resources: Represented by the directorates of hydraulics and the sub-directorates at the level of municipalities, for the realization of sanitation works and water evacuation works.
Ministry of the interior, local authorities and planning: Represented by the APC and the APW, for the establishment of planning and urban planning instruments and crisis management and relief. (Civil protection)
Ministry of Finance: Responsible for project financing and insurance mechanisms.
And other ministries such as agriculture, environment, higher education, and ministry of health with secondary roles in coordination with other ministries.

At Wilaya scale: At this level, the Wali embodies the authority of the State through decision-making and the organization of urban space, he is able to take decisions without referring to the central State, and at the same time the person responsible for the application of national policy at that local scale.

At the municipality level: The president of APC is the direct intervention manager at the level of the municipality, is coordinating with the various actors through the municipality means, according to the regulatory tools (local authorities code or Municipal Code), and these different tools, the actions of president of APC go through preventive information, and the application of organization and rescue ORSEC plans.

Civil society scale: The role of civil society is manifested through both associations and individual citizens, who are directly concerned with and impacted by the risks, and therefore, the flood risk management is based on a hierarchy with sequences of different scales, and according to several actors, and the lack of coordination between the actors can lead to a failure of flood management processes.

5-5- Measures to mitigate social vulnerability:

The vulnerability mitigation refers to the reduction of damage resulting from a disaster, by non-structural measures before the crisis, and actions in the post-disaster period for reconstruction, these measures are framed and regulated by planning and urban planning tools and risk management plans. Mitigation includes protection by simple solutions such as sandbags, and prevention by adapting land use. This approach is carried out by a process that must integrate the consultation among actors, it requires an identification of issues that brings together all the actors, and the population, that constitutes the most significant actor, because of the unconsciousness of risk and the inaccuracy of the information, Therefore, the citizen must promote his responsibility for risk, with the help of associations, these associations may, at times, contest the implementation of protective measures such as that of the environment defence associations. It is therefore a real desire to achieve a good diagnosis of vulnerability and then the mitigation.

Preventive information and awareness:

This process constitutes an important element of risk management, is the enhancement of the organization's resilience to various risks, and this by making related documents available for preventive information in the form of files. These tools must be complementary, for example the Communal Safeguarding Plans (Plan Communal de Sauvegarde [PCS]), and the ORSEC plans, both instruments are mandatory in the municipalities that have a PPR. The process of informing citizens is carried out on the basis of forecast information, so this operation involves flood forecasting, then hazard determination, and this through meteorological vigilance, to this end, the weather services must provide metrological data both for local actors and citizens, through advanced communication means, in order to deliver information in real time, and thus prepare the citizen to face the event. During the crisis the main management tool is the ORSEC emergency plans, the triggering of its plans is according to the severity of the crisis. The post-disaster period consists the phase of resilience, through reconstruction and the elimination of flood residues, at this stage that the severity of the event is known, as soon as we address the role of the State in the Natural Hazards insurance (Catastrophes Naturelles [CatNat]) framework, particularly concerning the financing of reconstruction projects.

5-6- Risk mapping analysis and applications:

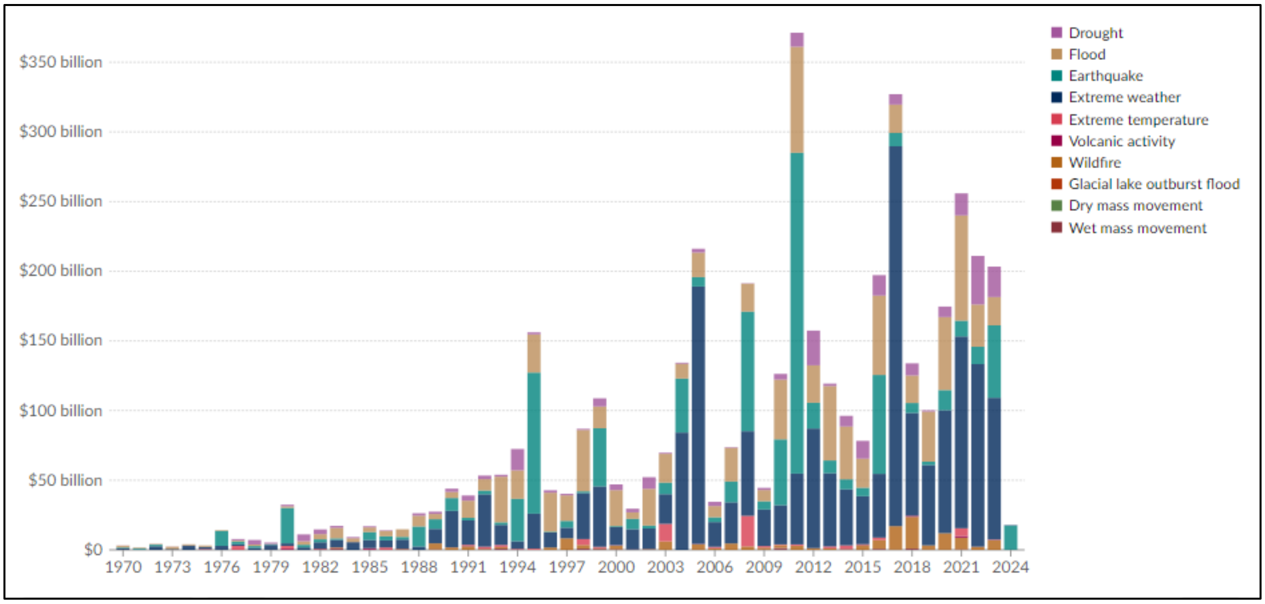
According to (Molin Valdes, 1994) and (OJ, 2009) the risk is consisting of 2 essential components: hazard and vulnerability. Modelling serves as a method to quantify risk effectively, and this is done by analysing these two components, it enables the conduct of a quantitative risk analysis for a specific territory, to enhance decision-making efficiency between different management actors. This approach is based on the implementation of vulnerability map resulting from land use and demographic factor, on the other hand, the hazard map which is the result of the interaction of the hydraulic phenomenon with the topography of the area.

Comprehensive risk assessment:

The risk management needs to begin with a forecast that assesses whether hazards are attributable to land use practices, and this applies to the level of different risk components (Hazard, Exposure, Vulnerability). The forecasting is required to indicate the possibility of hazard occurrence, it is essential to rely on hydrometeorological quantification with hydraulic simulation, and the scenarios should take into account all future changes (climate change, and land use change) the result of the analysis of its factors can give the flood frequency, also flood zones.
Hazard map: Flood simulation, by superimposing rainfall data with field data.
Vulnerability map: Concerning the spatial distribution of issues and vulnerable socio-economic and environmental objects, according to the characteristics of each issue.
Risk map: The intersection of the two aspects produces the risk map, a tool through which the degree of risk in hazard-affected areas can be estimated. Runoff floods are easy to determine

compared to lowland floods. Flooding resulting from urban runoff is frequently more severe and destructive due to land anthropization, that increases the capacity of surface runoff, furthermore, waste accumulation impedes water drainage within the sewerage network. From a geographical point of view, throughout the areas exposed to risk, we can calculate the potential damage by the economic damage assessment compared to the return period, we derive the damage in cubic meters per year ($ /m^2/ year) The economic assessment of the issues is effective in assessing vulnerability, without losing sight of non-economic objects, because working-class neighbourhoods usually have a high vulnerability without significant economic value.

Figure 12: Economic damage by natural disaster type, 1970 to 2024.



Source: EM-DAT: *International Disaster Database - Catholic University of Louvain - Brussels - Belgium)*

Black spots:

Depending on the previous operation, the risk analysis is essential to facilitate the allocation of points that represent at risk areas, this approach will help in tasks distribution between different sectors (Givone, 1995). This risk study methodology is based on the analysis of hydrological and hydraulic data and the projection of these data on space according to (land use) and finally we arrive at the risk mapping. It is worth noting that it aims much more to study of hazard more than the vulnerability because it is based on a hydraulic and hydrological model and a cartographic model. The examination of hazards constitutes a critical component of risk analysis due to the fact that floods are the result of an overflowing.

The study of vulnerability can be measured by the economic cost shown in (Figure 12) and also by sociological values that can change across social classes. (The QdF "flow-duration-frequency" this method makes it possible to define a statistical model to give the details of the floods observed on a given area, and the TOP (T: return period and, and OP: Protection Objective) these parameters must be exposed on each plot within the study area to obtain the vulnerability map.

5-7-The feedback as a vulnerability assessment tool:

Starting from the concept of vulnerability, which can be analysed on the basis of two main concepts represented by: the set of human and material stakes exposed to risk, which can be damaged by a disaster, and on the other hand it represents the capacity of a society to face a risk, "*the capacity of a person or a group to anticipate, withstand, resist, and rebuild after the impacts caused by a disaster*" (Wisner, Davis, Cannon , & Blaikie, 1994) this definition refers to the notion of resilience which defines as the ability of an object to return to the initial state after a shock. In addition, the time factor as a key element of vulnerability definition, to identify the time that can take a company to get out of a crisis. On this basis, the feedback is a way to see to what extent the management policy has helped the company, all this is to clearly understand how a company faces a risk before a real examination, to improve the resilience of exposed issues, which is considered as the contribution of the feedback in understanding the flood vulnerability, that allow us to clearly define the issues, and their degree of risk exposure, this approach is built on the social aspect of risk which allows to reduce the vulnerability, this method is more relevant than flood risk prevention, so the vulnerability reduction depends on the risk degree diagnosis, and the means used in this operation.

This approach is based on the sectoral study of vulnerability to ensure a useful and sustainable flood risk management. In urban agglomeration, the vulnerability is different from one sector to another, so it is necessary to determine each sector separately, and it also differs according to the sectors, for example the vulnerability of communication sector can lead to certain imbalances in the alert. On the other hand, a good diagnosis of vulnerability can limit the modalities of the "prevention, prediction, protection" chain according to the determination of vulnerability classe: (material, structural, environmental, and social)

From this, and as an effective method of vulnerability determination, the direct consultation with the population by means of information collection, and opinions on the risk and sharing with other management actors. Therefore, it is a part of the risk memory, which can be documented with photography, the press, websites, water height surveys, expert assessments and others. The risk management policy can be divided into 3 stages: the previous risk period (forecast period, prevention, monitoring), crisis period (alert, evacuation,), disaster period (damage identification period, and consequences), following that the reaction phase as a crucial step to assess the risk of flooding, and build a policy adapted to the specificities of the field for aim to enhance the organization's capacity to mitigate the impacts of flooding by monitoring and vigilance.

5-8- Floods impacts on human health:

The impacts of flooding on overall health manifests directly during and following the event, due to drowning and the crises caused by the mental state of the affected inhabitants, especially those who have chronic diseases, where they have less endurance, and also the injuries caused by the stuff carried that affects people during the flood.

Its effect also appears indirectly on human health, in particular: Infectious and parasitic diseases transmitted through the untreated water, due to the disruption of drinking water supply and damage to the sanitation network during the disaster. Additionally, the psychological state of affected individuals may deteriorate due to the loss of their property and homes.

6- Flood types and aggravating factors in Algeria:

Algerian cities are highly susceptible to the risk of flooding attributable to the combination of various natural and anthropogenic factors, such as those of (eastern Algeria 1973, central Algeria 1992, western Sahara 1999, Sidi Bel Abbès 2000, Bab L'Oued 2001... etc). The effectiveness of management policy is contingent upon the thorough analysis of the components and the exacerbating risk factors, which leads us to an efficient risk forecasting, within which the history of events assumes a central role in this problem. The subsequent examples illustrate significant catastrophic events throughout history:

October 12, 1971: heavy stormy rains (182.6mm) which caused losses of 40 deaths, and a significant number of destroyed habitats. 27 to 29 March 1973: exceptional rains 166.2 mm, in Annaba.

March 28 to 31, 1974: exceptional rains 688 in 4 days and 381 in 1 day, in Algiers and Tizi Ouezou.

September 1, 1980: EL-Eulma: stormy rains, 44 dead.

November 17, 1980: Ghardaïa, (99.8 mm)

November 11, 1982: Annaba (167 mm)

August 22, 1983: Birine Wilaya of Djelfa, 10 dead.

February 03, 1984: the Algerian East,

December 29 to January 1, 1985: in Jijel, 250 mm

July 5, 1987: in Batna, 2 deaths, June 17, 1987: in Tiaret, violent thunderstorm,

September 1, 1989: in Biskra, 2 deaths.

6-1- The event of November 9, 2001 in Algiers (context and impact):

The floods that occurred in Bab El Oued, Algiers, from November 9 to 10, 2001, are regarded as one of the most persistent events in the collective memory of Algerians when discussing flood risk, it causes more than 270 deaths, and 100 missing according to statistics, due to a huge precipitation estimated at 263 mm, during the night of November 10 to 11, 2001, the circumstances prepared for the occurrence of one of the greatest catastrophic events in the history of this country.

On November 9, 2001, in Bab El-Oued, in the north-eastern part of the city of Algiers, an exceptional rainfall occurred in the Algiers region, a cumulative rainfall of 261.6 mm recorded in Bouzzaréah, and another of 207.9 mm on the port of Algiers. Despite the heavy precipitation that affected several regions of the city of Algiers, however, the damage was limited to only a few areas, and this is due to aggravating factors: which are often anthropogenic, such as that of development in a flood zone without being sufficiently protected.

Figure 13: Flood disaster in Algiers of November 2001.

(Source: News journal of L'EXPRESSION)

The precipitation extends over November 9 until the following day on November 10, 2001, causes a confluence of water amount that overflows in other places on the foot of the Wadi Koriche, causing flash floods of great brutality and devastating. The soil permeability is quickly exceeded because of the heavy precipitation, then the runoff speed is increased, a peak flow rate has been measured on the outlet of the Wadi Kourich of 730 m^3/s, and a flood peak of 143 m^3/s A state of alert was triggered by the Algerian government at the time, this government which never has an ORSEC plan for crisis management at that particular time, this plan which must define the responders and the means used, during the crisis management period until the lifting of the alert state, subsequently, it ends with a disaster recognition decree, to delimit the disaster zones, thus, this event constituted a major turning point in Algerian legislation in the field of natural risk management.

These floods are produced as a result of multiple factors, summarized in the floods of the tributaries of the Wadi Kourich, due to the heavy precipitation, This precipitation, along with the interaction effect of exposure influenced by the achieved density of 21360 Inh./ km2 in 2005 of Bab El-Wad district, provides a comprehensive explanation of the observed phenomenon, The consequences of this event were considerable, the damage affected most of the infrastructure, roads and various networks with significant destruction to the built environment, some buildings have completely disappeared, with human losses reached 781 dead and 115 missing, and many families affected.

The disaster event and subsequent failures:

The recurrent failures of management policies throughout history highlight enduring challenges in organizational decision-making, a total lack of technical solutions for risks prevention, the time of the alert which experienced a failure. The other element that would play a major role is the dimensioning of the sanitation system works, the reconstruction stage represents the period of returns to the normal after the disaster or resilience rate of the area. Reconstruction efforts should be informed by systematic feedback to ensure effectiveness, which illustrates the weak points as well as failure in system and crisis management plan, to improve the response of residents to the risk, among the lessons learned from this event is a lack of citizens awareness, the delayed warning was among the main cause of the significant number of victims.

The November 2001 floods remain deeply etched in Algeria's history, marking one of the nation's most impactful events, for the residents of the affected neighbourhoods was an event to never forget, from another perspective, it considers as the starting point of reconstruction for the management actors, and to determine exposed stakes and then the vulnerability.

6-2- The contributing factors of flood risk in Algeria:

Among the natural factors, we can mention the precipitation, the dominant type of climate in Algeria, it is the Mediterranean climate which is characterized by irregular precipitation and sometimes its intense and exceptional suddenness, and seasonal and interannual precipitation, The other factor is the geographical factor concerning the topography such as cities located on a watershed, or located on the foot of a mountainous massif such as the case of Annaba (our study area), Ain Defla, Batna, Medea ... etc. And the factors are: soil type, vegetation cover, and land use as an important element. Anthropogenic factors or attributable to human actions and their impact, which appeared in infrastructure state such as the sewerage and road networks, as the case of the city of Tiaret. Therefore, the most important reasons for flooding in Algeria are:

The meteorological situation: considered as an essential element in Algeria, the heavy precipitation, rains in the form of violent thunderstorms.

The anthropogenic factor, or the modification of the flow conditions, of water by development in flood-prone areas such as construction at mountain foot.

6-3- Risk management and assessment technique:

To this end, several ways exist to assess the risk, each according to the management policy and according to study area specificities: The definition of management policy from an institutional point of view and according to (Pierre , Bruno, & Yves , 2005) is *“all legislative and regulatory texts but also ministerial declarations, social partnerships, majority party leaders ...”* which concern a given sector", and the question is similar to the case of Algeria, because it follows a democratic system of government.

So, the public policy is centred on the prioritization of the application of decisions and measures taken by actors according to different scales, this policy is required to adapt with social and territorial changes to ensure its effectiveness, sometimes, the citizen as an actor and out of a sense of responsibility takes individual measures to protect his home. The risk management policy in Algeria remained for a long time based on technical action on hazard, and less on non-structural measures, this theme was the subject of a study firstly by the Anglo-Saxons, and exactly (WHITE, 1942), who made a comparison study between structural measures (dyke, dams, pipeline), and non-structural measures, which relies on vulnerability (risk information, alert) The risk assessment phase should take place after the disaster, comparing the PER guidelines and the recommendations of feedback, and the actions carried out by local actors. Issued in the form of a report, which explains all the details concerning risk and disaster management, and its consequences.

The consensus is that both parties, the population and local actors have the same objective, which is to bring security and stability to the life of population, but in the case of failure due to the sequence of events, the risk assessment has the role of correcting the imbalance in course of risk management. After the Anglo-Saxons in the 1960s and 1970s, and France, which introduced this concept in the 80s, after the catastrophic events that followed, through the establishment of regulatory texts and risk management plans. Each evaluation approach is useful for certain types of management policies; to establish the appropriate way it is necessary to observe some criterion:

Scientific approach: It is an experimental approach based on a comparison between affected cases.

Constructionist approach: The constructivist is the development of a society that observes itself, the way in which society articulates its own characteristics and relates to its future.

Temporal criterion: This approach is based on evaluation before and after public action.

Function criterion of the evaluation: To rely on the changes due to the initial reality and the new reality on the progress of the public action.

Destination criterion: This criterion concerning the possibility of change of action during its course.

Socio-economic approach of the evaluation:

The economic assessment is the monetary value to damage estimation (quantitative), on the other hand, the social assessment is the assessment of vulnerability of population to the risk.

The economic analysis is based on:

The "Cost-Effectiveness" Analysis (CEA): This analysis is based on the principle of taking measures for the lowest possible cost, without taking into account the measures relevance.

The "Cost-Benefit / Cost-Advantage" Analysis (ACB / ACA): it is an analysis based on the prioritization of choices to delimit the one that carries out the cost-benefit balance sheet.

These methods are often applicable in economic studies, and less used in geographical fields, because of the difficulty of data accessibility and actor multiplicity. On the other hand, we note that the feedback is done by direct damages calculation, unlike the previous methods.

A global vision for risk management methods:

In order to achieve a global assessment of flood risk management, several reference events must be selected to evaluate the effectiveness of measures and their resilience to risk.

The "Bottom up" approach, based on a sequence from the bottom-up scale, the performance evaluation of management methods (forecasting, prevention, protection) can be explained by the performance of local actors on the central policy of the State, this estimation is mainly related to structural measures, it takes effectiveness and efficiency, performance, relevance, and utility, as evaluation criteria.

Effectiveness: Is the difference between the objectives and the results obtained.

Efficiency: Serves as the ratio between the cost and the (economic) result.

Performance: This provides together effectiveness and efficiency.

Relevance: Represents the relationship between the objectives and the expected results.

The utility: Consists of the impact of the program on the issues.

The evaluation needs to take into account the variables of the different components such as: the geographical aspect (hydrology and topography) and the socio-economic aspect: the land, the land use, and the behaviour of the population.

Chapter Conclusion:

In essence, the key points highlight that to face the risk of flooding, the need is for a broad vision of the physical field of risk and, on the other hand, familiarity with management methods and strategies, taking into account the legal and customary framework of territorial regulation, so flood risk management is based on a thorough understanding of the hydrological, climatic and socio-economic dynamics of the region. The theoretical framework and the state of the art presented in this chapter show the importance of adopting an integrated and multidisciplinary approach to master all aspects of risk. The key concepts of resilience, vulnerability and adaptability are essential for developing effective management strategies. The management solutions, whether structural or non-structural, must be chosen according to the specificities of the region and the available resources. International examples shows that the combination of preventive measures, spatial planning, and early warning systems can significantly aid to reducing the impacts of floods. For Annaba, as a preliminary observation, the adaptation of these practices and the establishment of a solid local governance are significant requirement for a sustainable management of flood risks, because these measures are not enough to perfectly perform its function in all circumstances.

This theoretical framework provides a necessary reference to address the following parts, which focus on the vulnerability analysis, specific to Annaba and the evaluation of current risk management policies. By developing adapted strategies to analyse all risk factors and relying on better practices to improve flood resilience and effectively protect the population and its infrastructure.

CHAPTER 2:
BACKGROUND OF THE STUDY AND GEOGRAPHICAL OVERVIEW

Chapter Introduction:

For many reasons, the Annaba region has been chosen as a city located in the Eastern Algerian region to be our research topic, known for its susceptibility to moderate urban flood risk, due to the greater than 20% probability of a flood capable of causing damage. The management of this type of risk aims to reduce damage by taking into account the urban aspect and these specificities, by enhancing existing projects on the ground and by designing long-term resistant projects and by implementing adaptation and protection measures, this through studies on the physical environment and the environmental impacts of this phenomenon as essential factors to understand the causes and consequences of floods in our study area.

In this part of the research, we will address the geographical framework of the study by presenting the study area across many aspects, physical or climatic, and highlighting the interaction of these variables in the formation of living environment of the inhabitants of this area.

By exploring these interconnections, we seek to illuminate the significance of the geographical setting in shaping the adaptive strategies and local population resilience in response to environmental conditions. This comprehensive overview will formulate a solid foundation for subsequent considerations on risk assessment within this approach.

1- City of Annaba, geographical and historical review:

1-1-Regional situation:

The city of Annaba is located in the north-east of Algeria, it represents the capital of the Wilaya which is limited by El Taref to the east, and Skikda to the west, To the south, it is bordered by the Wilaya of Guelma, Situated about 150 KM from the city of Constantine and 570 from the capital Algiers, and 70 km from the Algerian- Tunisian borders, the Wilaya of Annaba has a total area of 1,439 km^2, the second smallest wilaya of Algeria in terms of area after the capital Algiers with 809 km^2, at a rate of 0.06% of the total area of Algeria. Given its location and its infrastructures, the metropolis had a great role in the national economy, as well as a strategic transit area, in addition to an important industrial base, in particular the El Hadjar steel complex which gave it a metropolitan function and a national and international reputation, in addition to many other industrial activities.

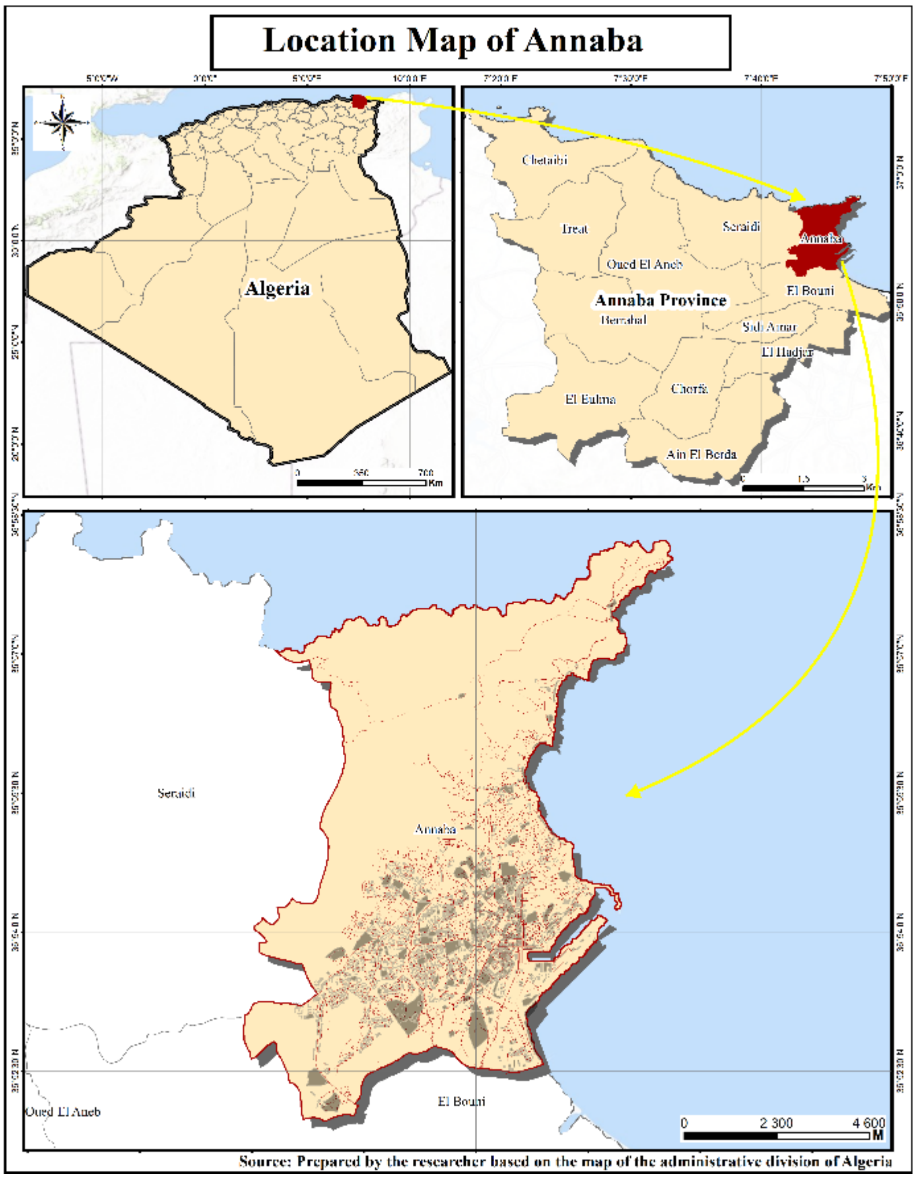
The geographical shape of the city of Annaba takes a linear from N to S, located on geographical coordinates, a Latitude of 36.9042, and a Longitude 7.75194 and 36° 54' 15'' North, 7° 45' 7'' East, on a total area of 49.00 km^2. The old town was built on a site near to the port on a variant altitude between 1 to 3 m, while the new town rises to an altitude of about 40 m on the plains and hills of the Edough.

1-2- Historical background of the city of Annaba:

Located at the foothill area of the Edough massif, and extends eastwards to the Mediterranean, the city of Annaba is considered to be a witness to civilizations during the history of the region, and one of the largest cities in the country in terms of size, which gives it an important weight, with a total of 500 thousand inhabitants, as well as the 2nd largest city in eastern Algeria after Constantine, The ancient site of Hippone, an ancient site of human settlement which later took its

name of Bouna, hereinafter now the city of Seybouse and then Annaba, the name of Annaba comes from the wadi Eunab, its site was attractive to the Phoenicians around the 11th century (Before Common Era), as a commercial area, and later by the Romans who dominate the Numidian city of Bone during the reign of Saint Augustine, then after the Byzantines and the Vandals, and in the Ottoman era, At that time, the leader Khayreddin Barbarossa undertook significant initiatives to make it an important site for the Algerian state.
All these potentials that the city has taken over time attracted the interest of researchers, which was worth paying special attention to during its urban development, this theme has become the subject of numerous studies at several levels.

Map 1: Geographical Location Map of Annaba



Source: (The researcher 2023).

1-3- Annaba and its metropolitan dynamics:

The wilaya of Annaba is divided into 6 Dairas and totally into 12 municipalities: Daira of: Annaba, Berrahal, El Hadjar, Ain El Barda, Chetaibi, El Bouni, shown in (Map 1). The urban area of the city of Annaba consists of the capital of Wilaya which represents the great urban pole, and the satellite cities with less size which surrounds and autonomous the main city with the widespread consumption of land, causing a need for new sites to create a new city, Where the choice came to a site in the town of Wadi El Aneb, this selection took place to create the new town of Ben Mostafa Ben Aouda (Draa Erich).

1-4-Exploring morphological characteristics:

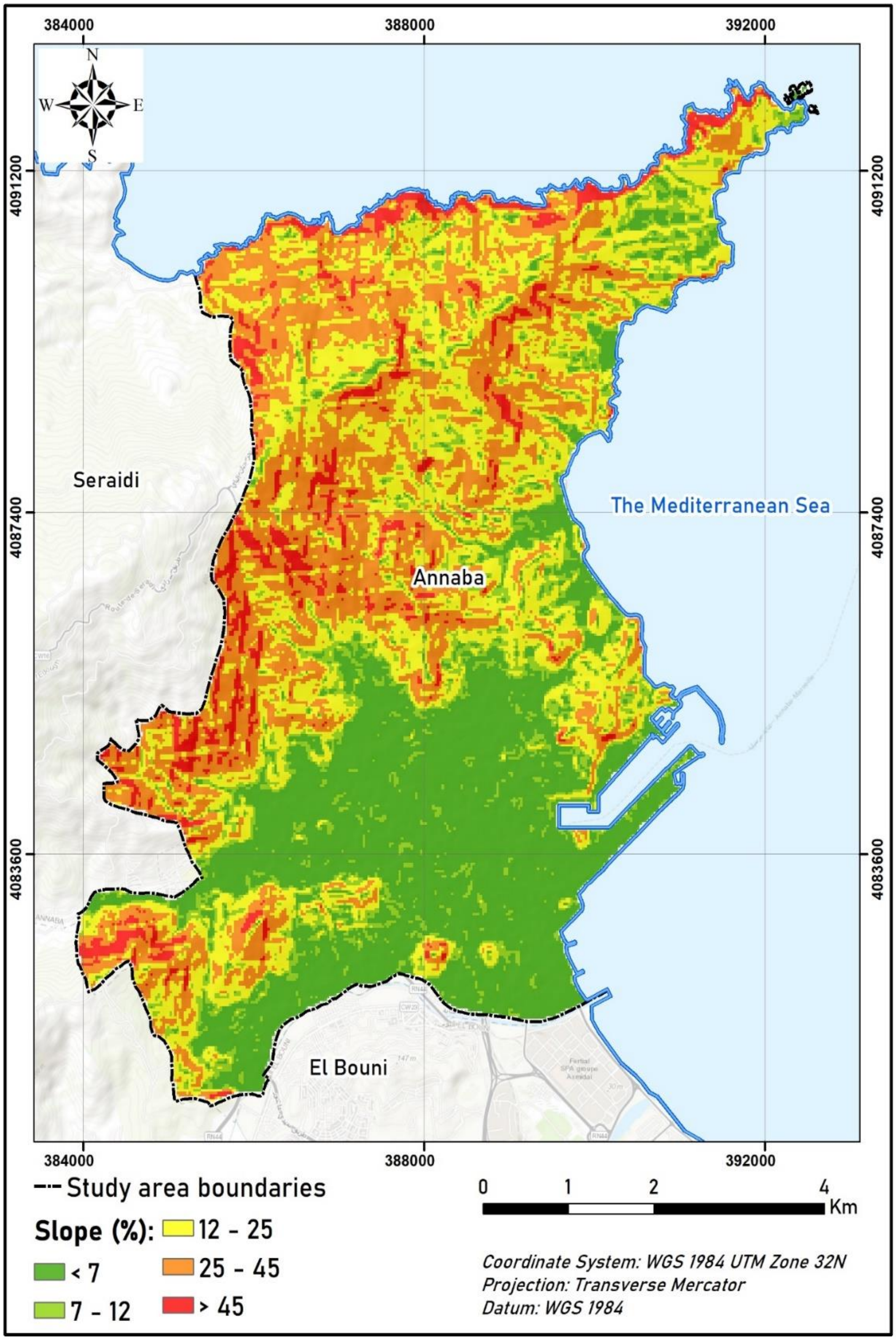
The morphological study serves as a foundational element for any examination of flood risks, particularly in terms of functionality, and the quality of life in general, this theme requires a preliminary reflection and action for the development of space. This approach allows us to determine the shape of the earth, in particular the altitudes as the main factor in flood genesis, because the speed and flow rate are linked to rainfall, it occurs depending on the steep slope. In this perspective, the major topographic units have been described as being located at the foot of the Edough massif and its extension towards the Mediterranean Sea is varied according to the site topography, by morphological units such as hills, plains, the site of Annaba city has known rugged terrain in the northern part of the city. And the rest of parts are distinguished by site diversity, such as the western plain which represents a large part of urban perimeter, in addition to the foothills which represent water accumulation surfaces with a small area.

Annaba region is characterized by its diversity of topography which knows a mountain massif (the Edough) and a large plain towards the sea which represents most of the site of the city of a more elongated shape and gently sloping. The topographic map of the Annaba region of 1/50000 shows the topographic variation on the slopes of the Edough up to the Mediterranean Sea with a low slope up to 2% and hills with a high slope up to 40%, and convexity, illustrated in (Map 2). The city is crossed by a hydrographic network which spreads out in a parallel way with the littoral with a relatively low gradient, in the part of the waterway system which drains the east of the massif by these catchments.

1**-4-1- Relief analysis:**

The relief of the terrain plays an essential role, because it controls to a large extent the capacity of runoff. The city rises at the base of a bay towards the open sea to the east on the Gulf of Annaba. It is limited to the west by the crystalline mountain range of the Edough, reaching a height of (1008 m) with an area of 47350 hectares. The reliefs of Annaba are the result of the structural movements to the soil formation, due to the climate with a significant impact on hills which represent the morphological unit where the city is built on this geographical sphere which spreads between the Edough massif and the Mediterranean Sea, on the coastal plain and the hilly zone located just next to the mountain massif, the western side of the city being characterized by its rugged site. The relief units in Annaba are divided between the Annaba Massif which spreads over 20 km, and 500 m above sea level in the middle, and a Full one with low altitude values. On this basis, the hydrological study was established taking into account the relief as an important element in the hydrographic study, the relief characteristics are studied through:

Map 2: Annaba province (slope map).



overall slope index: It can be understood using the global slope index via the equation (2.1):

$$\text{Slope} = \frac{Rise}{Run} X100 = \frac{y2 - y1}{x2 - x1} X100 \tag{2.1}$$

Where X and Y are the coordinates of two points on the line.
This index can therefore give us a classification of the relief of the study area.

1-4-2-Slope classes:

The slope is the factor that ensures the water runoff, because it represents the force of gravity, the slope inclination is the element that determines the speed of hydrological response during rainy events, and there are other phenomena such as the rate of water erosion, and deposits that can affect the relief of a region over time. On the other hand, an area with a flat topography, for example, the water will not be hindered in its ability to flow and will be more likely to spread further into the area, resulting in a higher flood level. In our study area, we can demonstrate 5 classes of slopes that express the inclination of the terrain where the stakes are located:

Table 1: Slope classes and its characteristics.

Slope class	Characteristics	Advantages	Disadvantages
< 7 %	Gentle slopes	Ease of construction, good drainage	May promote the water accumulation in some cases
7% - 12%	Moderate slopes	Good drainage, less risk of erosion	More complex construction, requires more stabilization
12% - 25%	Steep slopes	Good drainage of surface water	Increased difficulty for construction, risk of erosion
25% - 45%	Very steep slopes	Excellent drainage, good view	Very difficult construction, high risk of erosion and landslides
> 45%	Extremely steep slopes	Beautiful panoramic view, less risk of flooding	Extremely complex and expensive construction, major risks of erosion and landslides

Source: (The researcher 2024)

A low slope of up to 7%: Need for adjustment by gently sloping: most of its areas fall within the urban perimeter (Western Plain and Kouba) are areas that can promote water accumulation in some cases, and highly exposed to the risk of slow-type plain flooding, these areas require protective measures to reduce the risk.

Average slopes: 7 to 12%: represents the dominant category, this category represents an ideal buildable site with less risk of erosion, but with a more complex construction, requires more stabilization.

The steep slopes of 12 to 25%: are buildable land but with a high development cost, with good drainage of surface water with a susceptibility to the risk of erosion, its areas are located west of downtown (Beni M'hafer), the advantage of this category is easy maintenance, and the management of runoff.

Very steep slopes from 25 to 45%: the advantage of this category is the strong drainage, on the other hand a very difficult construction, high risk of erosion and landslides
Slope more than 45%: it falls into the category of extremely steep slopes, with a panoramic view from buildings, less risk of flooding, and extremely complex and expensive construction constraints, major risks of erosion and landslides, this category represents a very small percentage in the study area.

1-4-3-Vegetation cover:
The vegetation cover of the Annaba region is classified within the plant regions of northern Algeria, the forest mass of the Annaba region consists mainly of Eucalyptus, Cork, Oak and Carob. The vegetation cover of the region is also associated with another type of natural risk, specifically the risk of forest fires, with a total of 67 h, were affected by the fires. The relative effects of permeability are a result of the function of vegetation cover and erosion rates, were analysed over time under multiple soil conditions. Vegetation has an influence on water conductivity, some plant species have a great role in reducing conductivity, especially since it is considered as a barrier and an obstacle that limit the process of conductivity.

1-5- Geology and lithology:
Geology constitutes a significant theme in geographical studies, encompassing aspects such as lithology, to master the geological characteristics of a region, with the aim of determining the natural risks to human settlements, through the ground characteristics analysis. and to delimit runoff parameters, infiltration, as well as the definition of patterns and erosion., and the monitoring of groundwater tables through the identification of groundwater quality, moreover, physical and hydrogeological processes of functioning of hydro-systems.
The Algerian north is characterized by a complex geological structure, composed of large substantial geological entities arranged from north to south as follows: the Tellian Atlas, the Highlands and the Saharan Atlas (Justin, 1931). This research on the geological characteristics of Algeria is often based on the characterization of various geological entities for understanding the geodynamic evolution.
Morpho-structural units: Present a great diversity in the north (internal zone), bordered by the submarine reliefs to the north, and by the Saharan Atlas to the south, the shields, the ancient massifs, (external zone), as well as other geological entities. Following the geodynamic evolution of the Maghreb chain. The North of Algeria has undergone important geodynamic transformations throughout its history, which can be broadly classified into three periods:
The initial phase, known as the rupture period (Triassic-Lias), marked the beginning of these geological changes. Subsequently, the post-rupture period (Middle Jurassic to Upper Cretaceous) ensued, introducing other remarkable modifications of the geological landscape. Finally, the inversion period at the beginning of the Tertiary era and persists until now, exerting a continuous influence on the geological structure of the region.

Paleogeographic evolution: the North Algerian region has undergone an evolution throughout its history, characterized by the events of the Hercynian orogeny, and alpine, which results in the appearance of the structure of current reliefs.

Geological context of the region:

The geological evolution of the study area falls within the regional geology of the north-eastern Algerian sedimentary basin. The rock belt represents the geological evolution characterized by the formations of magmatic origin, and also sedimentary which constitutes the majority of surface of the plain of Annaba (Table 2). As we mentioned earlier, the Edough region consists of metamorphic rocks towards the NE-SW orientation, granitic rocks placed in the pan-African orogeny.

Local geological context:

The Edough massif has been the subject of numerous studies in terms of its geology, where it can be described as a plot rising abruptly above the coastal plain; it seems to be the most individual of the small cores of African fringed pearls. It consists of the superposition of different geological units: a core of Jebel Edough gneiss strictly speaking, and a central mass. In the Pliocene, the Edough massif was an islet. But the contribution of sediments led to the gradual filling of the areas to the south and east of Edough, which thus found itself connected to the mainland (François, 1977)

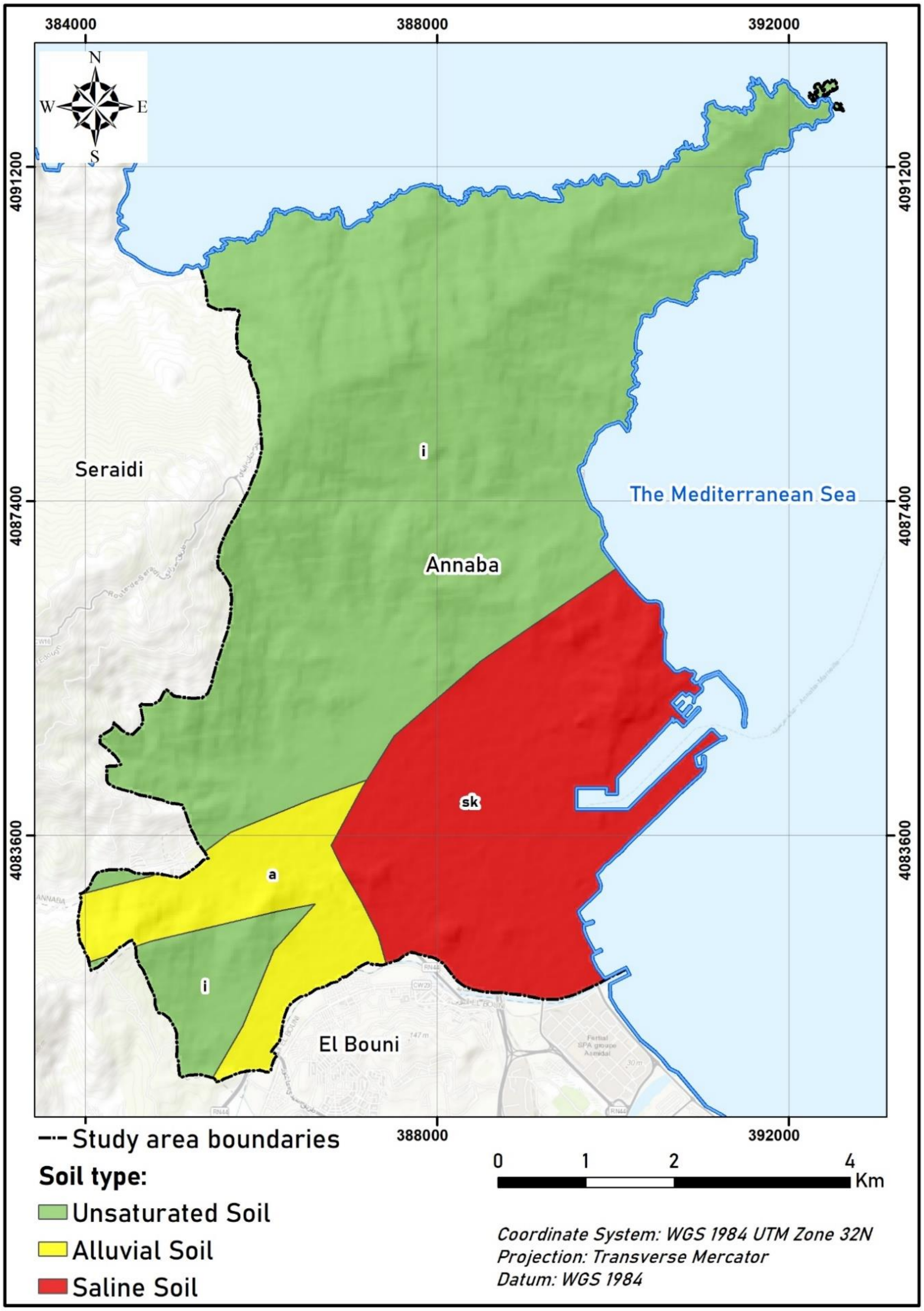
This evolution has been marked by a superficial and dynamic geomorphological formation, given that the Edough massif has undergone a strong erosion process, which has given it its current shape (Table 2). The precipitation is at the origin of floods which plays an important role in water erosion, contributing to the supply by solid transport, thus, aggravating the situation (Fadel, Boughambouz, Djamai, Laifa, & Oularbi, 2009). With one of the varied litho-stratigraphic characteristics, according to the literature, among the best-known studies carried out on the Annaba region is that of (Justin, 1931) which illustrates that the geological description of the region of Bône (Annaba) is quite extensive, involving the crystalline rocks of the Edough and large quantities of iron ore, magnetic in most cases.

1-5-2- Key soil characteristics:

The study of soils plays a pivotal role in flood risk analysis, being the former is directly in contact with the surface runoff, so it is a partner of hydrology in the context of large-scale environmental management, because it represents a factor that defines the distribution of stakes throughout space. The type of soils is formed directly on the geological substratum. as a result, the geological substrate has a major effect on the drainage properties of the soil and the structure of the stand.

Unsaturated soils are generally characterized by a low water retention capacity, resulting in higher infiltration rates and greater runoff resistance. These soils can hold limited amounts of water, which can increase infiltration and reduce the risk of flooding, this type represents the most part of the surface covering the study area, as can be observed in (Map 3). On the other hand, alluvial soils, composed of sediment transported by rivers and streams, are often highly fertile and have a high drainage capacity. However, their permeability can vary based on sediments composition. Whereas, saline soils often contain a high concentration of soluble salts, that can affect its structure and reduce the permeability. These soils require a specific treatment process to prevent salinization and maintain its effectiveness. Each soil variety presents unique requirements in terms of water management and urban development, demanding adapted approaches to ensure sustainable and efficient use of soil resources.

Map 3: Soil typology in Annaba region.



Source: (The researcher 2024).

Soil permeability overview: The characteristics of watersheds, as determined by the components of the soil, are presented in the table below:

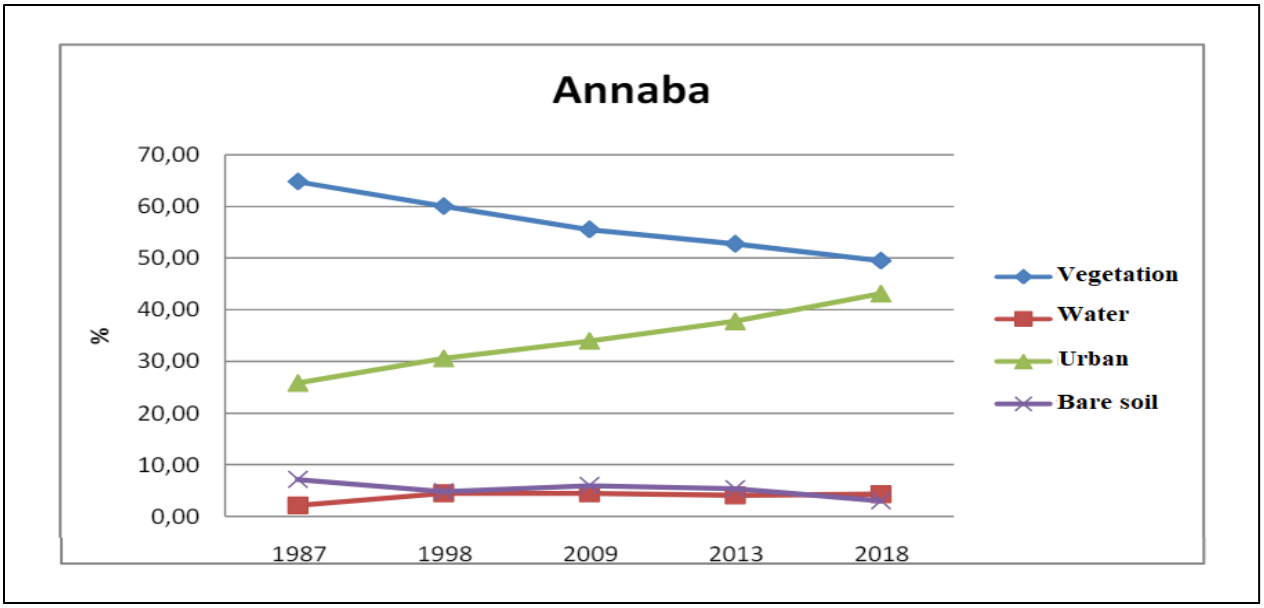
Table 2: Soil characteristics according to geological and lithological formation

Geological formation	Lithological formation	Erosion resistance	Permeability
Quaternary	Alluvium, recent sediments	Low to moderate	High (in alluvial zones)
Miocene	Sands, sandstones, marls	Moderate	Variable (permeable sands, less permeable marls)
Cretaceous	Limestones, dolomites, marls	Variable (resistant limestones, less resistant marls)	Variable (permeable limestones, less permeable marls)
Jurassic	Limestone, dolomites	High (for limestones)	High
Triassic	Evaporites, marls	Low to moderate	Low to moderate

1-6-Land use:

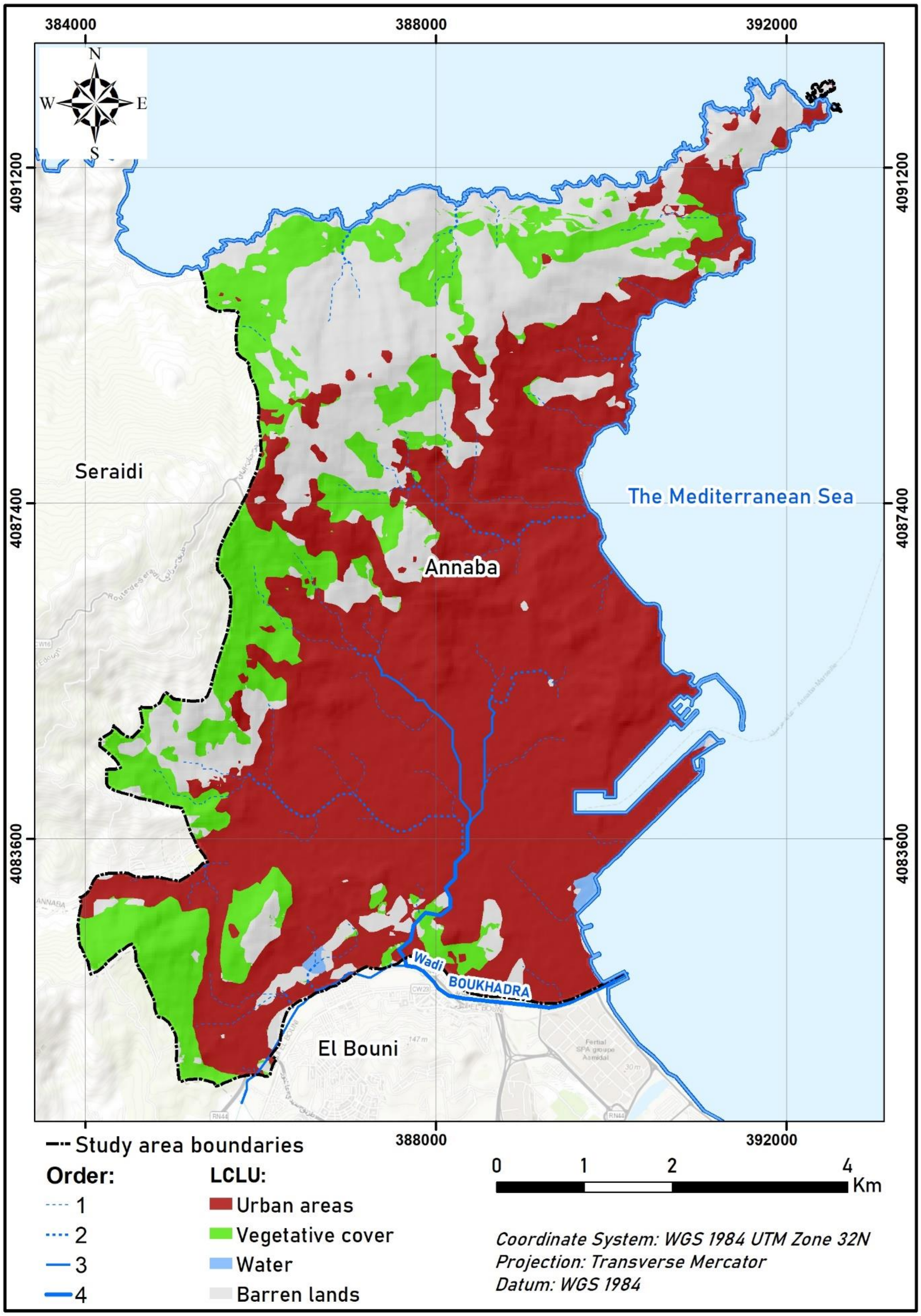
Given the repercussions of anthropogenic actions on the environment, it is essential to consider their impacts, an international scientific program has been dedicated in this regard, named LUCC (Land Use and Cover Changes) (Junye , Michael , M. Ali Akber , & Mojtaba , 2022) with the aim of improving the understanding of the evolution of land use dynamics, to predict these tolerances. Like the other Algerian metropolises, Annaba has experienced an evolution of a complex urbanization over time. Changes in land use have produced an urban fabric that has given an important density of housing in the capital of the Wilaya.

Figure 14: Land use evolution in Annaba region between 1987 and 2018.



Source: (ZENNIR, 2019)

Map 4: Land use map of Annaba.



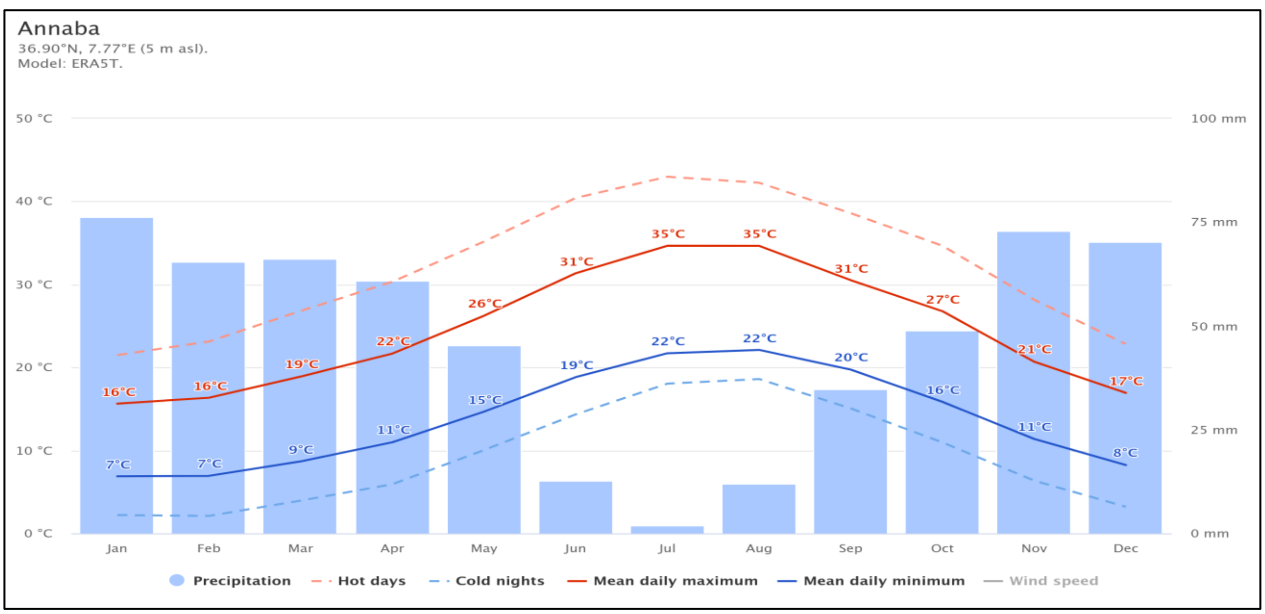
Source: (The researcher 2024)

The study area has been subject to significant development over time, characterized by a significant loss of vegetation, on the other hand, a significant concrete invasion as shown in graph (Figure 14), and an increasing sprawl at the expense of agricultural land and forested areas, that are supposed to constitute easements where construction is prohibited.
This classification was made on the basis of data from the National Statistics Office, in addition to field data according to areas with a high concentration of population and the type of housing (collective and individual), including areas with high commercial activity and administrative facilities with a significant polarization shown in (Map 4).
Densely populated areas automatically lead to an increase in exposure to the risk, which increases the presence probability of a larger vulnerable population group, consequently, the increase in social vulnerability to the risk of floods, because there the latter is depends on the number and not on the proportion.

1-7- Climatological features and trends:

Climate dynamics serve as pivotal factor in the assessment of flood risk, providing essential insights into patterns of environmental change, given its important role in the process (Mahmoud & Yew Gan, 2018). Climatic variations, such as the increase in heavy rainfall over short periods of time, exceed the infiltration capacity of soils and urban drainage systems, moreover, climate change that is usually controversial about its role in the increasing of flood-related hazards. It is therefore essential to integrate climate data into flood risk forecasting models. This approach makes it possible to better anticipate events, develop adaptation strategies and set up resilient infrastructures to protect populations and property. An accurate study of climate and its effects on hydrological conditions is therefore essential for an efficient flood risk management.

Figure 15: The Climograph of Annaba region (monthly average temperature & precipitation).



Source: (Meteoblue, 2024)

1-7-1- General characteristics:

Annaba region is characterized by its Mediterranean climate which is marked by substantial seasonal rainfall over a given period of the year, depending on the monthly precipitation, the rainy season is from September to March, and the dry period is from April to August according to the annual average, and by a high temperature amplitude in the summer which is relatively warm temperate by 43 °, which causes a fairly significant evapotranspiration which increases the humidity rate and hence the precipitation process, and with an average of 5 ° in winter, the latter is with heavy precipitation. This climatic region of the study area is characterized by hot summers and mild and rainy winters, the months of December and January show the maximum rainfall, through the representation of interannual precipitation which makes it possible to demonstrate the periods of heavy precipitation at the beginning of each decade.

1-7-2- Climate variables and data:

The primary data required for this review are rainfall-related, temperature and evapotranspiration, these are the data corresponding to the climate, and the flow rate of the flowing water slides in the outlet relating to the hydrological behaviour of the watershed, knowing that these data are always subject to uncertainty. The climatic data of the wilaya of Annaba are acquired from national meteorological office, and ANRH of Annaba.

According to (Seltzer, 1946), the annual average temperatures vary between 15 to 20 ° C, which reaches its maximum in July and August, and minimums in the month of January and February, in a paper entitled "Climatology of Algeria" in 1946, published in the “ANNALS DE GEOGRAPHIE”. This article is considered a classic reference in climatological studies of Algeria. Generally lower rainfall in summer and significant in winter. The prevailing sirocco and mistral winds are often the cause of extreme weather events.

1-7-3-Evolution of climatic factors:

These variables are used to provide a comprehensive overview of the prevailing climate conditions within the study area, through identifying the rainy season, that in turn helps in flood prediction process.

Precipitation analysis:

In Annaba region, rainfall is a key factor in climate studies, significantly influencing environmental patterns, it is estimated by the annual average of each month of precipitation over a given area, it is commonly represented by an Ombrothermic diagram (figure: 15).

Annual precipitation: This city, similar to the broader Algerian coastal regions, is marked by the distinctive characteristics of a Mediterranean climate which is characterized by a high rainfall in the winter season, and its scarcity of rain in the summer season, and by a disturbance of precipitation in the intermediate seasons,

Precipitation evolution: As a result of climate change, due to anthropogenic elements, this operation requires comparing rainfall data for a sufficient period to demonstrate the climate evolution during the period from January 1981 to December 2022. As part of our data processing, we have noticed that there has been an irregularity in rainfall which inevitably leads to and increases the risk of flooding, therefore, the wettest period is from September to March, on the other hand, note that the dry period is from April to August, hence, the number of rainy days is reduced.

Interannual variability: This fluctuation is identified through the coefficient of variability, this coefficient is obtained by the ratio of the standard deviation to the average of monthly rainfall in percent, this type of analysis is used to determine the return periods, in order to predict the occurrence of floods by the interannual variation.

Seasonal regime: The intent of this parameter is to identify the precipitation distribution through the seasons of the year, it has a direct impact on the vegetation cover, and flood genesis.

The rainfall altitudinal gradient: In its standard state, the rainfall varies according to the altitude, it varies from one region to another, and according to the slope-by-slope exposure, intermittently up to 40 mm more in the altitude of 1000 m (Seltzer, 1946), as shown in (Map 5). Precipitation is increased on exposed slopes to wet winds compared to sheltered slopes.

Rainfall map: This map is based on the rainfall values, marked in the different weather stations, (Table 4), the establishment of this map is based on long-term precipitation.

Measuring stations:

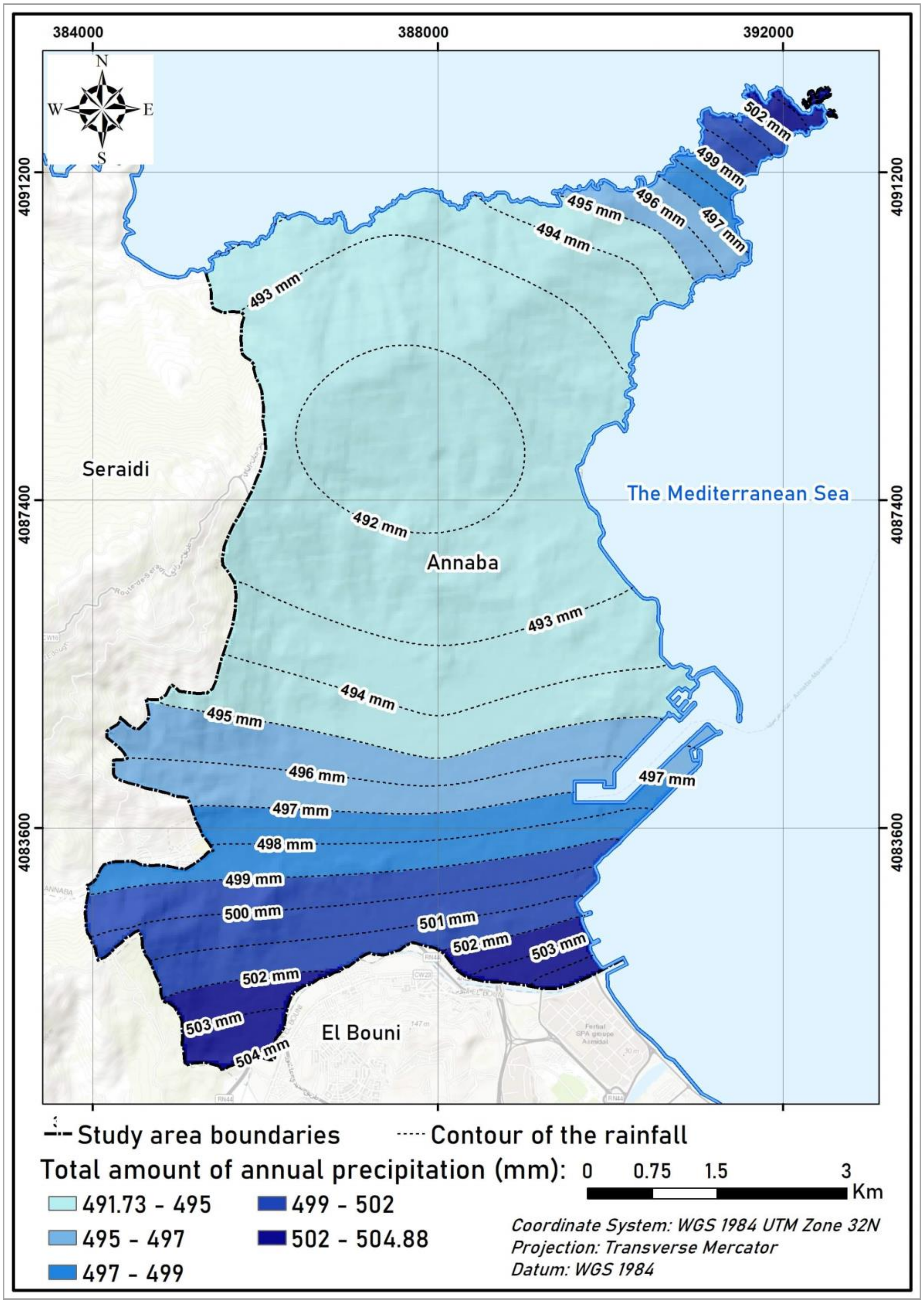
Precipitation can be also measured via Radar System stations, where weather radars can detect large-scale precipitation by sending radio waves and measuring the return signals of raindrops. Or via satellite sensing systems, where satellites provide large - scale data on rainfall from space, providing global coverage.

Table 3: Stations coordinates and recorded precipitation.

Station	Y	X	Precipitation
1	36,7346	7,6209	683,835
2	36,7676	7,7349	494,412
3	36,7984	7,5852	494,412
4	36,8078	7,6196	494,412
5	36,8078	7,6965	494,412
6	36,832	7,8654	575,415
7	36,8358	7,6196	494,412
8	36,8776	7,4548	494,412
9	36,8913	7,6642	494,412
10	36,9006	7,7432	494,412
11	36,9061	7,805	494,412
12	36,9467	7,693	494,412
13	36,9528	7,7699	494,412
14	36,9643	7,7349	494,4117
15	36,972	7,463	494,4117

Source: ((LaRC), 2024)

Map 5: Climate map of Annaba region.



Source: (The researcher 2024).

The X and Y coordinates denote the locations of the stations, while the last field contains the amount of precipitation during this period, as determined by GIS tool, in the form of points representing each location and the rate of precipitation in study area, then this is confirmed by depositing the points on the map, Then, using the interpolation tool of the set of spatial analysis tools, we can generate a precipitation map in several ways, the most appropriate of which is the Inverse Distance Weight (IDW) method, in which the map is divided into categories that vary depending on the amount of precipitation.

1-7-4- Rainy season determination:

Determining the rainy season is a complex undertaking that requires a thorough study of precipitation and hydrological models. There are a wide range of methods to determine the beginning of the rainy season, such as the analysis of climate models, the application of regional climate data alongside rainfall observations is fundamental. The climatic approach consists in using spatial and temporal characteristics of precipitation to determine the beginning of the rainy season. It can also be useful to take into account meteorological parameters, such as wind speed and direction, atmospheric pressure and relative humidity, to determine the start of the rainy season. Other methods, such as remote sensing and analysis of geographic information systems, can also be used to determine the onset of the rainy season.

Temperature variations:

Temperature occupies a critical role as a basic element in climate research, for their effect on evapotranspiration and the control of vegetation cover. The thermal altitudinal gradient: Is the inverse of precipitation, the identification of this gradient is made by the correlation coefficient for example 0.84 per 100 m altitude. And so, the higher the altitude, the lower the temperature and the oxygen level in the air.

Prevailing winds:

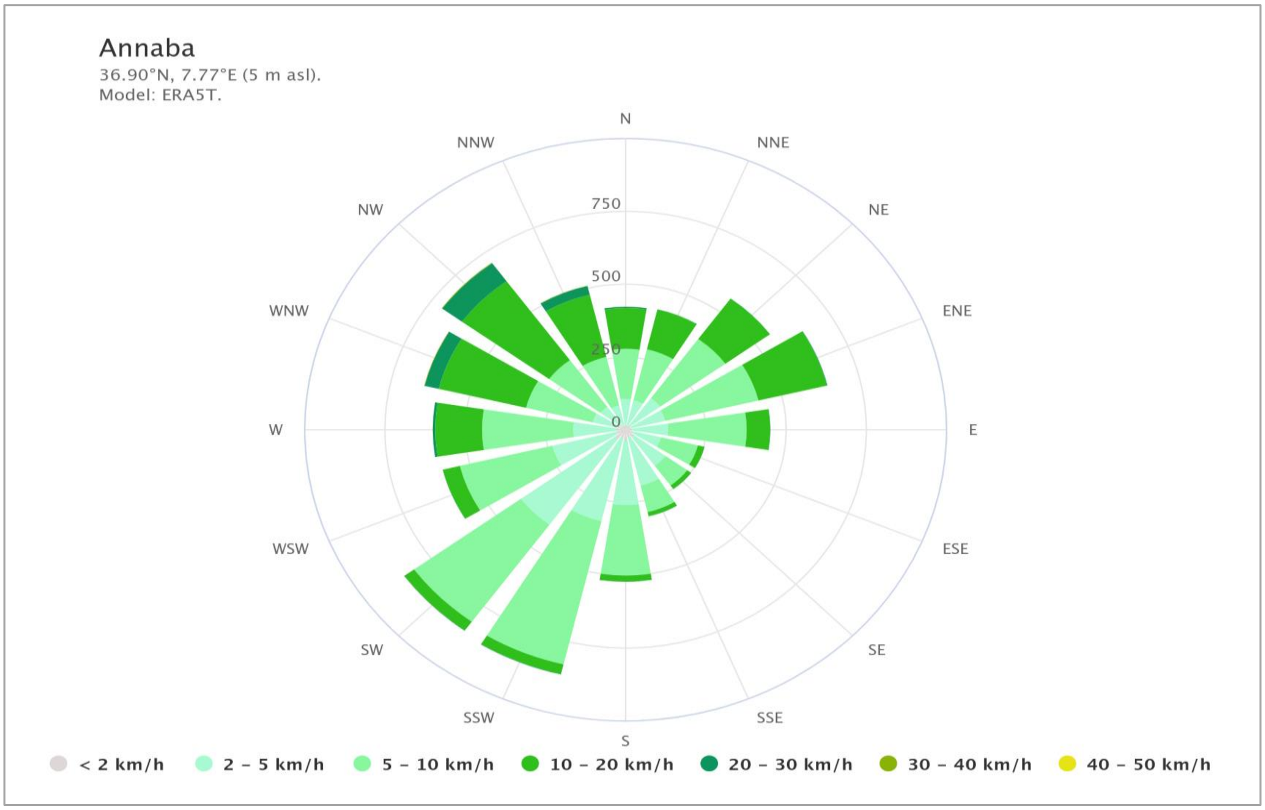
Wind is a critical variable that affects temperature, humidity and precipitation, because it considers as an engine that transports its different elements, the behaviour of the winds, through the prevailing winds in each region,

Types of winds: For this part of the geographical elements of the study area, there are some types of wind as dominant trends, in particular "Local winds" hot winds, off the desert, this wind occasionally blows towards coastal areas. On the other hand, the westerly wind or "out of breath", and the north-westerly wind as shown in (Figure 16), which brings rain, these winds blow especially in winter and spring. The easterly and north-easterly winds, which carry little moisture to decompose into such desirable showers, and also the "sea breeze" felt on the coast between the sea and the edge of the coast as endemic.

1-7-5- Intense weather events:

The high rainfall that characterizes the dominant Mediterranean climate in Annaba region causes intense weather events, due to the proximity of the Mediterranean Sea which represents a source of humidity, and depending on the winds, it makes Annaba prone to this type of rainfall, which can cause violent flooding in the urban environment or the waterproofing of the floors can aggravate runoff and consequently play a role in flood likelihood.

Figure 16: Wind rose of Annaba region.



Source: (Meteoblue, 2024)

Variation in annual and monthly totals:

The study of the annual and monthly precipitation averages was based on the analysis of rainfall data from the city of Annaba, with an average of the annual rainfall of the cold season (December-January-February) is humid, with a total average rainfall of 263 mm, and 25 mm in the winter period (June-July-August), The choice of season to make an intra-monthly analysis, rely on a season which constitutes an intermediate rate, in our case we chose the autumn season which represents 45% of precipitation, and also constitute the period most affected by short-term events and an intense character. By observing the variation in rainfall data in the Annaba region over the past several decades, it has been found that rainfall events are of reasonable frequency, and the high annual rainfall indicates that the Mediterranean climate is a generating factor for weather events. Rainfall data shows that exceptional rains are marked by a regular character every beginning of the decade, most of its events are marked during the autumn period, such as stormy rains. To this end, numerical modelling makes it possible to determine the potential sequence of the risk occurrence, for example, Gumbel's law to estimate the return period based on the data recorded on the Annaba region:

Rainfall and flow data:

This type of data is used for event preparation, through the determination of the rainfall event which is responsible for exceeding a certain precipitation threshold in a period during the year as an initial parameter. The identification of a rainy event does not depend solely on the rainfall intensity, but also on the basis of these hydrological consequences, despite the rainfall being at the origin of these events. The rainfall distinguished according to some variable is: the duration, the height of rains, and the flow coefficient (measured by the volume runoff on the precipitated volume) of each event. (Lower a 1) for the purpose of calculating the terrain permeability.

2- Hydrological processes and evaluation:

The hydrological study is conducted to ascertain point flows of different rivers and the return periods, and defining all the flows that modifications will have a direct impact, sometimes by the malfunction of the hydrological system, and then the probability of occurrence, the literature shows that through a series of peak flow data and with a static method, and then an analysis of the results by adjusting either by the log-normal law, or Gumbel's law, in case of unavailability of the series of flows, the method based on empirical formulas is applied. The most used method is to evaluate past events, their magnitude and their frequencies, in order to determine future events, (return period). This method is based on the analysis of data through past events: A series of point flows recorded at the level of Annaba stations, and their prioritization and analysed, to delimit the returns periods (laws of Gumbel) to predict the level of floods through the flow measurements in a period of 10 years which represents the ten-year return period of the study area.

2-1-Return period characterization:

The most common method consists in using Gumbel's law, this law was created by Gumbel in 1958, law of continuous probability for the purpose of determining the return period of a meteorological event, it relies on the modelling of the extreme values of the phenomena through the distribution of the maximum values of the flood levels, the prediction of extreme events probability, and the characterization of the return periods through the rainfall series, of 100 years to obtain related results, and then the assessment of the notable events of (*6 years: normal, 10 years very normal, 30 years exceptional, 100 years: very exceptional*) For this purpose, the intensity, duration, frequency (IDF) are key factors that help in the risk assessment and the potential impact of flood risks in the study area. This is used evaluate the peak flows for hydrological modelling, and when the rainfall data record is missing in the Annaba region. (Beloulou, Guechi, & Moguedet, The Assessment of Heavy Rains in the Region of Annaba (NE Algeria) to Improve Extreme Flood Forecasting—Use of Depth-Duration-Frequency Curves, 2015).

2-2- Hydrogeomorphology of Annaba region:

Hydrological runoff refers to the water flow or a fluid material on the land surface, especially that of soils. It is a form of superficial and rapid flow that can affect human life, and that can cause damage to the environment, in particular to fauna and flora. Runoff can be amplified by factors such as intense rainfall, insufficient vegetation cover or the presence of impermeable soils. And can also vary depending on the hydrographic conditions of the watershed which represents the main spatial unit for hydrological analysis, with a specific topography and known limits, the function of the watershed is to evacuate the water to the lowest part, with the exception of the infiltrative part and the evaporation part, the water flow to gather in a downstream point which is called the outlet. The characteristics of a watershed are identified through the hydrological behaviour such as: flow velocity and maximum flow rate, and the concentration time of flows.

2-2-1- Geometric structure of flood-prone watersheds:

Physical factors are considered to be one of the essential factors to flood generation, the relief of the watershed is flat in the urbanized part. Depending on the tributaries of this basin which transfer the waters rapidly downstream because of its steep slope, thus, the characterization of the rain runoff, as stated previously, the hazard depends on the criteria of land use, altitude and slope. The physical aspect of a watershed plays an important role in the flood behaviour, because it represents the first generating unit of surface runoff.

a) Surface: The catchment area is calculated numerically in km^2.

b) Reliefs and slopes: The flood behaviour is generally linked to the characteristics of reliefs; the slope delimits the flow velocity as well as the hydrological reconsideration time. The slope represents the inclined part of the land, it can determine the runoff characteristics (speed, flow rate, response time)

c) Shape: The shape of the watershed affects the hydrological characteristics of the water line at watershed outlet, this shape is varied according to the types of existing watersheds: elongated shape, and circular shape. The elongated basin is characterized by the production of less intense floods with a longer hydrological response time. In this type, the water takes a long time during its path to downstream, and thus, the point flow is relatively low, or rather the short concentration time is directly related to the power of the flood.

Using Caquot formula, the parameter which determines the shape of the watershed defined according to the elongation coefficient E, calculated as:

$$E = \frac{L}{\sqrt{A}} \tag{2.2}$$

L: Is the watershed length measured from the farthest point of the basin to the outlet (in km or m).

A: Is the area of the watershed (in km^2 or m^2)

The shapes of the Edough's watersheds are compact-shaped watershed, so the runoff in this case is quite important, because this type of watersheds reacts differently to precipitation than an elongated basin, even in the presence of the same weather conditions, the latter takes a shorter concentration time (Kerboub, 2022).

2-2-2- General characteristics of watersheds in the study area:

The hydrographic network of the study area exhibits a drainage pattern that flows from West to East, which represents the general orientation of the runoff with minor changes depending on the situation. the literature shows that the underground hydrology of the study area indicates that the region consisting of 3 aquifers, through the geological formations of the region, The aquifer of our study area is part of the coastal aquifers of the Annaba-Bouteldja region, the Annaba aquifer system "Mafragh", this system consists mainly of a surface layer of dune sands, altered gneiss, clay sands, and a deep layer in plio-quaternary (Kherici, Messadi, & Kherici, 1991)

The study area shows the presence of 4 watersheds diverted from the upstream of the Edough, towards more than 1008 m above sea level, the surface waters could flow from the West to the East, from the upstream and drain the streams passing through the urban area to the sea.

We can divide the watershed into 3 parts according to their role: Production zone, transfer and flood expansion zone.
The information pertaining to watersheds characteristics is presented in the table below:
Table 4: Geometric, orographic and hydrographic characteristics of the main basins of the southern slope of the Edough.

	Parameter	Boudjemaa	Bouhdid	Sidi Harb	Forcha	Kouba
Geometric and orographic characteristics	Area: A (km^2)	50.000	19.23	5.88	8.81	6.25
	Perimeter: P (km)	32.150	19.13	10.5	11.75	10.2
	Compactness: C (sd)	1.27	1.23	1.20	1.11	1.20
	Basin length: L_{bv} (Km)	11.100	6.68	3.0	3.0	3.6
	Maximum altitude: Z_{max} (m)	586.0	1008	855	749	525
	Minimum altitude: Z_{min} (m)	2.0	6	6	4	0
	Basin rise: D_{bv} (m)	584.0	1002	849	745	525
	Basin slope: I_{bv} (m/km)	46.7	365	280	200	210
	Urbanization rate: T_{urb} (%)	13.36	14.1	9.01	14.44	12.8
Hydrographic characteristics	Drainage density: D_d (km/km^2)	6.0	5.0	4.2	4.3	2.9
	Main course length: Ltp (km)	11.130	9.000	5.000	5.250	3.825
	Coast to the source: Z_{tp} (m)	26.0	980	855	470	415
	Coast to the outlet: Z_{min} (m)	2.0	6	6	4	0
	Rise of the main course: D_{tp} (m)	24	974	849	466	415
	Slope of the main course: I_{tp} (m/m)	0.0022	0.077	0.140	0.062	0.160
	Concentration time: T_c (h)	8.5	2	1	1	0.50

Source : (Beloulou, Thèse de doctorat, Vulnerabilité aux inondations en milieu urbain cas de la ville de annaba (nord est algerien), 2008)

2-2-2-1- Comprehensive presentation of watershed systems:

The study area comprises 5 watersheds that are integral to the management of water flow, and hydrological regulation (Map 6). Within each watershed, there are specific geographical patterns, such as main streams, tributaries, varied landscape characteristics and specific vegetation. These catchments interact to control the regional water cycle, pollution and water quality. They are therefore essential for the sustainable management of natural resources and natural risks prevention, such as flooding and soil erosion.

***Sub-watershed of the Forcha Wadi*:** The topographic delimitation of the drained surface by this watercourse represents a relatively small area of 881 ha (Table 5), the lithology of the basin is characterized by the dominance of metamorphic Gneiss rocks, The basin is partially urbanized, so the hydrology of the basin and particularly the drained surface is modified due to the presence of artificial lateral inputs, such as the road and mixed sanitation network, this limits the possibility of exposure to hydrological hazards, in this context, a crossing work has been carried out, a section of some 500 m of canal which passes through the main course of Wadi Ed Dahab through Shabat El-Mukawama.
In this sub-basin, the most remarkable tributary is Chaabat Zaâfrania, with a surface area of 78ha fromwatershed area, formed from soil that is less permeable than that of Kouba Valley, with three types of land use divided into three zones: the downstream part is urban, the middle part

agricultural, and the upstream part is covered by sparse vegetation consisting of scrub and wild olive trees. After crossing the western bypass, the Oued Zaâfrania flows through an underground gallery beneath the city of Annaba, ending up at the Sidi Brahim rainwater pumping station as a structural measure for flood control.

Sub-watershed of Sidi Harb Wadi: Represents another tributary of the D'heb Wadi, which covers an area of 588 ha, The basin is characterized by the decrease in vegetation cover, which affects the permeability of the soil, and thus increase the susceptibility to flooding.

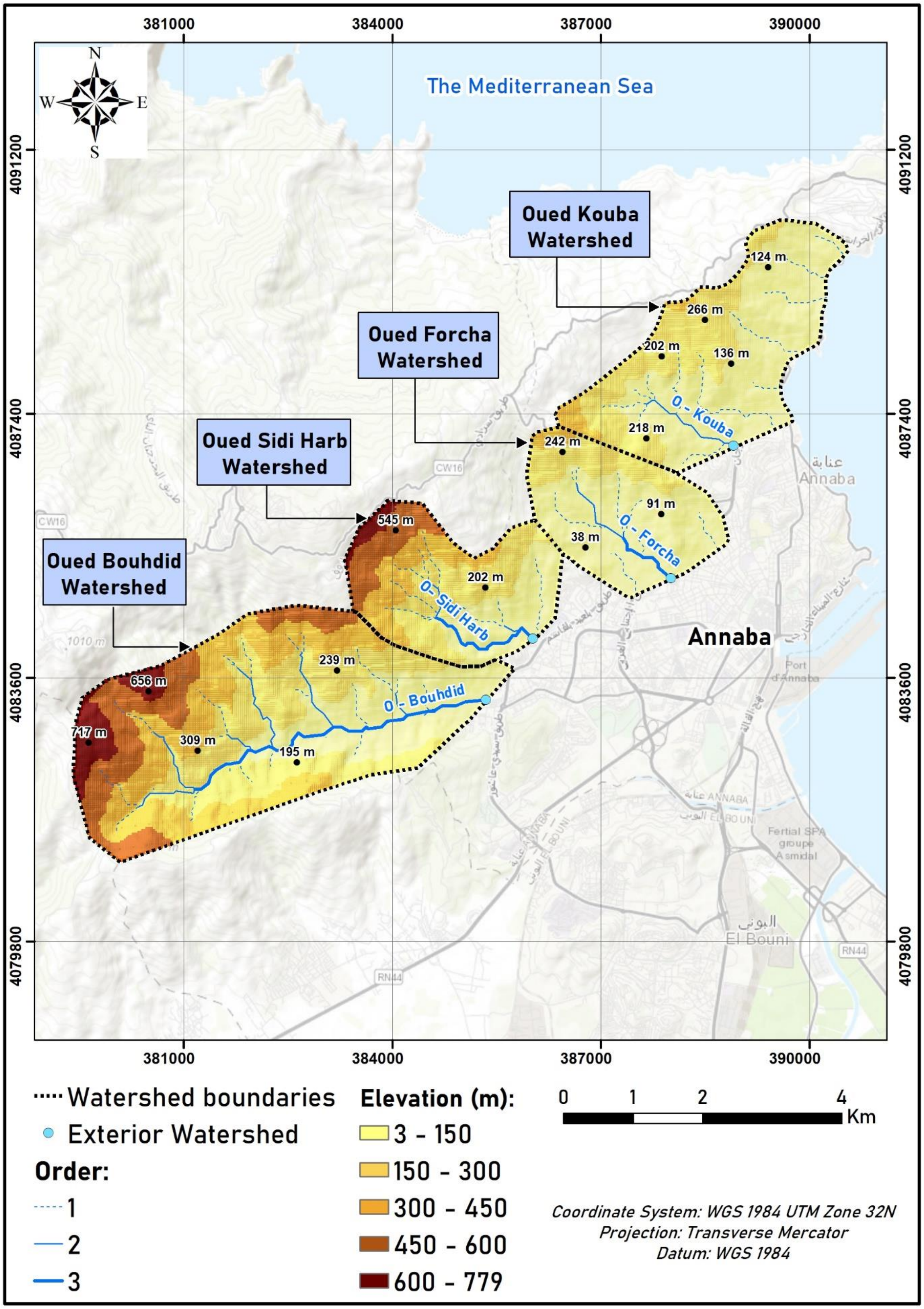
Sub-watershed of Wadi Bouhdid: This basin has an area of 1923 ha, and an elongated shape which reduces the peak flood flow, the main course of this wadi which extends from the heights of Seraidi, to the point of confluence with the outlet of Wadi D'heb, the overflow of this Wadi in many cases led to flooding the plain of the city.

The Forcha and Bouhdid Wadis are connected with S-Harb Wadi by the belt canal, these 3 watercourses come together and connect with the Boudjema Wadi by the Kef N'sour canal, and then it discharges on the Mediterranean Sea in the south of the city of Annaba.

***Sub-watershed of Kouba Wadi*:** Located on the north side of the Annaba city, which flows into the Mediterranean Sea, and exactly on Rizi Amor beach, drained by the unitary sewerage network (combined network) which collects both wastewater and rainwater. This sub-watershed is a part of the hydrographic network of the east of the Edough, it extends from the mountain watershed of the Edough from 800 m above sea level, with an area of 625 ha, it takes a collected form, with a stream length of 3.6 Km as shown in (Table 5), and characterized by its steep slope upstream and a low slope downstream, with an average slope of 0.160 m / m.

The Wadi Boudjemaa watershed: It refers to a watershed located in the southern part of Annaba, where it flows towards its outlet into the Mediterranean Sea, is characterized by its hydrological and ecological value, orographic characteristics are shown in (Table 5). The Oued Boudjemaa is fed by several tributaries that contribute to its flow, where the Bouhdid and Sidi Harb streams have been diverted to its main course by the Ceinture and Kefnsour canals, as a flood risk prevention measure. This watershed plays a major role in regulating water resources and flood management, and also as a source of significant biodiversity. Nevertheless, it faces challenges such as pollution from industrial and urban activities, which has inevitably contributed to the deterioration of natural ecosystem.

Map 6: Watersheds of Annaba region.



Source: (The researcher 2024)

The study area is included in the vegetation cover of the forests of the Edough National Park, which knows the presence of some trees of the Holm Oaks which still exist in the form of endemic vestiges, Zan Oaks and Junipers. There is also room for some Coastal Pines and Black Pines, the Atlas Cedar, it occupying an important part in the region, in addition to part of the vegetation cover in the form of brushwood. There is another factor that can play an important role in surface runoff is the dynamics of the outlet, where the alluvial plain is a kind of accumulation produced both by the lateral migration processes of water line, and on the other hand, by the accumulation during the overflows of the runoff from the watercourses. For this purpose, several techniques can be used to runoff control, for example, the development of banks, drains, canals, ditches and ponds. It is also possible to use specialized techniques such as the creation of buffer zones or erosion mitigation. These techniques can help to preserve the population living environment.

2-3- Morphometric characteristics of the hydrographic network:

The waterway system is a network of geographical lines that represent all the watercourses flowing in the study area, The plots of the hydrographic network are generally made up of line segments that represent the main watercourses, and their tributaries. The typologies of the aquatic system are a powerful tool to characterize the watershed and understand the potential of the resource and its vulnerability. Also makes it possible to identify areas at high risk of flooding, The hydrographic network of our study area consists of 4 watersheds Wadis, Bouhdid, Forcha, Kouba, and S.Harb. With a runoff direction from the West to the East.

This system represents a key factor for any hydrological analysis, because the watershed behaviour generates a comprising the runoff water that came from the tributaries of the sub-basins, and collected in the outlet which brings together all the watershed waters. With reference to the aforementioned factors related to the steep slope, in addition to the very dense hydrographic network that characterizes the study area because it comprises of 5 wadis, which gives a high density of drainage, and a relatively short concentration time depending on the precipitation that plays a main role in the surface runoff process.

The shape of the hydrographic network is influenced by several factors, including the geological factor by tectonic movements which play an important role in the formation of the network, as well as the climate by precipitation and prevailing winds, these factors that act on slope formation and the orientation of the inclination, and finally the anthropogenic elements and the modifications which follow it. The study of a hydrographic network requires a classification of the different types of networks, and its prioritization, and the confluence ratio, and the drainage density.

2-3-1- Flow regime analysis:

The flow regime varies depending on the type and component of a watercourse, these elements are important to control the spatiotemporal evolution of a watercourse.

Flower and river: This type of watercourse is composed by the low flow, medium flow, and floodplain, during the flood period the water rises to overwhelm the three parts.

Torrents and wadis: In this class, the runoff is generally limited to a specific period, which is the rainy period, with a single drainage flow.

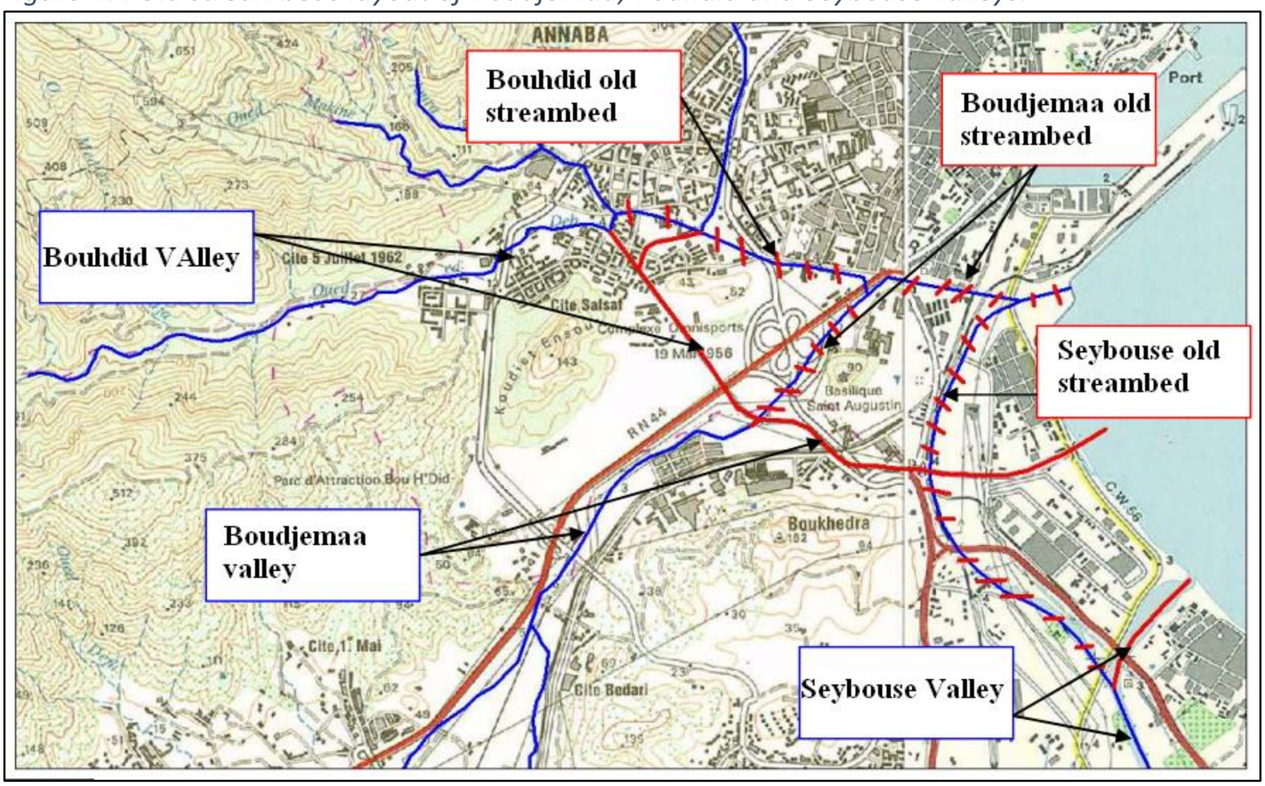
Diffuse flow: This category Is devoid of exhibit runoff flow; rather, the runoff in this class is uniformly distributed across the entire surface.

2-4- The hydraulic context of surface runoff:

2-4-1- Surface water dynamics:

Annaba region is defined by a sparse hydrographic network. it is about streams most of which are temporary in character, that receive several tributaries of the wadis, the most important of which are Wadi S-Harb, Bouhdid, Forcha and Kouba, the catchment areas of the wadi Bouhdid and S.Harb are connected by the belt canal, and also connected with the wadi Boudjemaa by the artificial Kef N'sour canal as previously indicated. The Wadi Boudjemaa and the Wadi Seybous are the only permanent rivers with a permanent runoff passed on the south of the city. We also note the presence of stagnant water bodies such as Fetzara Lake in the south of the city which reflects the nature of a wetland. Despite the measures taken to protect the city by diverting the waterways towards the Boudjemaa Wadi, it should be noted that many flood-related events have been recorded in previous periods. The slow floods by rising waters are known at the level of the western plain, due to the topography and site concavity, and due to the low slope, these parts of the city exhibit topographical depressions causing standing water that cannot take its course towards the sea.

Figure 17: Old streambeds layout of Boudjemaa, Bouhdid and Seybouse valleys.



Source: Annaba city protection against floods of Boujemaa valley -Hydraulics directorate-

2-4-2- Development of hydraulic conductivity:

The aim of the hydraulic study is to investigate surface flow patterns related to the presence of water slides, through dividing a volume discharged by the catchment area, to demonstrate the runoff amount by contribution to the precipitation. In addition to the factors contributing to flood genesis, there are also factors related to the nature of physical environment of each type of soil and rock, such as hydraulic conductivity, expressed as a function of intrinsic parameters of a porous environment, and this affects the occurrence and flood magnitude. Therefore, the possibility of infiltration is excellent in gravel, medium in sand, and low in the case of clay, according to (Musy & Soutter, 1991). Studies on silty sand columns indicate that the hydraulic conductivity retains 50% of the initial conductivity after a period of 40 weeks according to (Hatt, Deletic, & Fletcher, 2007), this indicates that rainwater management works can cause a decrease in conductivity.

To protect the city of Annaba against floods, a study of the protective measures in study area made it possible to note that the flow conditions in general are reasonable, therefore, we note in particular works already carried out like the Belt canal which connect the wadi S Harb with the wadi Bouhdid and Kef N'sour canal, (Figure 17) shows the diversion of the Boudjemaa, Seybouse, and Bouhdid streams, this modification of natural course of water by laying canals, this technique being considered to limit the risk of flooding, Some of the shortcomings of this approach include the impact on the environment by altering the natural aquatic and riparian species, weakening ecosystems and disrupting the natural water cycle. In addition, these measures can increase the magnitude of floods downstream, with devastating consequences in the case of overflow.

Retention dam of Bouhdid:

As a protective measure to mitigate floodings, authorities have instituted this dam as a key component of protective strategies for this end, launched in 2019 with a budget of 4.5 billion DA, as part of the national flood control strategy, with a global budget of 311,432 billion DA for this strategy, the works on the Bouhdid dam project in Annaba (Table 06), located in Bougantas zone at 3km from the city, the aim of the project is to slow the dynamics of flooding and protect the western plain against flood risk. According to the project owner (Ministry of Hydraulics), the Bouhdid flood control dam will have a collection capacity of around 59.800 m^3 of water, with a height of 29.6 m, and 260 m wide. It will retain the centennial flood at 10 m3/s downstream of the structure, with a completion deadline of 36 months, the rate of progress of work on the project has reached only 15% in 2021, The pace of completion has been accelerated until delivery of the project in the specified circumstances during the current year, pending a real test of its effectiveness in flood prevention.

Table 06: Description of Bouhdid valley retention dam.

Type of dam	Weight
Nature of materials	Roller-Compacted Concrete (RCC)
Maximum height above foundations (crest elevation)	29.6 m
Crest length	263 m
Crest width	4 m
Total volume of the dam	59.800 m^3

Source: Water Resources Directorate of Annaba Province.

2-4-3- The impact of works size on operational efficiency:

The hydraulic works can reduce the risks by limiting the floods, located along the main axis of the dry valley. In the form of a spillway or flood evacuation channel. It is obvious that there is a relationship between the size of watershed and that of structure, in other words, a small structure will reduce its conductivity because of the sediments that form a clogging layer, so this factor must be taken into account in the sizing of the structures. These works that have undergone rehabilitation it is about the works have affected on the Kef N'sour, Sidi Harb and Zaafrania canals where the retention dam have been built. This stream which passes through the districts of: La Colonne, Sidi Brahim and Cité Auzas.

3- Urban context of the flood risk in Annaba:

3-1- The landscape aspect of Annaba city: The city of Annaba is characterized by variability in urban styles, due to the multiplicity of periods of domination and civilizations that the region has known throughout history, and the evolution of the city through the variability of successive development policies in the city in contemporary times. The historical evolution and diversity of structural elements within the urban fabric, particularly underlying components such as road networks and land parcels have imparted a composite urban character to the city, accompanied by a varied infrastructure network, as observed in many Algerian urban centres.

3-2- History of urban development in Annaba:

As outlined in the literature review, the city of Annaba is a coastal city, built on the foothill of the Edough mountain massif, on the plain that extends from the latter towards the sea, its urban fabric spread over the coastal strip of the Mediterranean Sea. To meet its metropolitan status, Annaba is characterized by a complex road and rail network, and even an international airport, as well as the port which provides an important part of national maritime traffic, all these potentials make the city management a great challenge for stakeholders.

The city centre is characterized by an Arab-Muslim architectural style, like the rest of the ancient Algerian cities, which explains the multiplicity of the city's centres, each representing a certain historical era. The colonial period reflects a common architectural style of this period in Europe in the colonial core, it concerns the neoclassical style, this centre is characterized by their activities that represent the facilities and the luxury trade. Then comes a phase of transformation towards a contemporary style after independence, dominated by housing of collective character.

Therefore, the historical evolution of the city was varied in accordance with the periods:

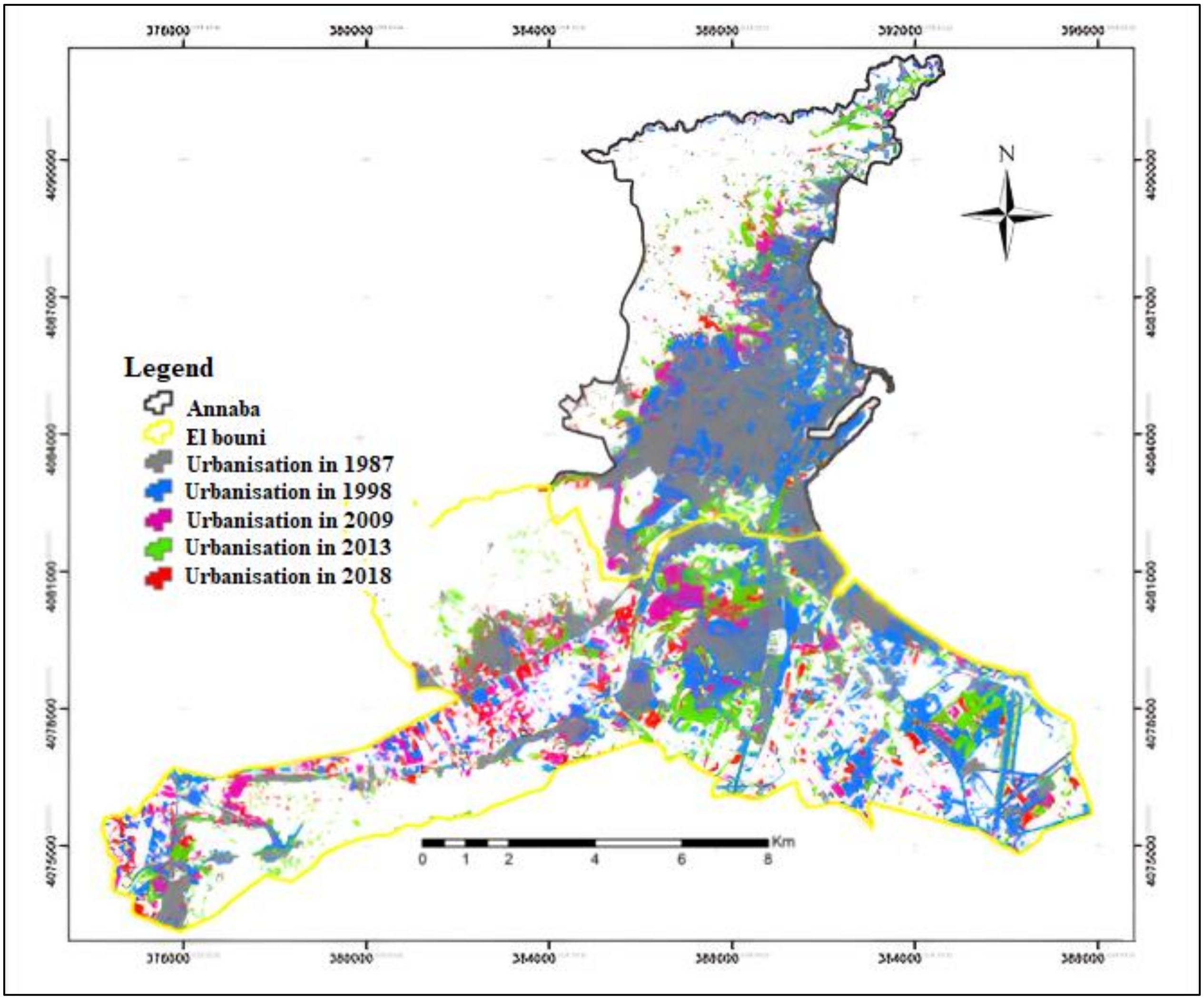
3-2-1- From genesis to 1830:

The city of Annaba has historically functioned as an economic centre, leveraging its strategic position as a port city, and because of its location that connects eastern region with the other Algerian territory, on the other hand, the countries of the eastern Mediterranean starting from Tunisia.

3-2-2- From 1830 to 1962:

Because of its site limited by the Mediterranean Sea to the east, and by the Edough massif to the west, the extension to the south of the city was inevitable, hence a widespread consumption of land, which affected even the agricultural lands known by its high potential. This reflects the problem of land in the city of Annaba, in this period the city underwent urbanization in areas near the port, which constitutes the colonial core. The period of French colonization came with many transformations in the urban fabric, and this reflects well the architectural style of downtown.

Map 7: Evolution of urban sprawl in Annaba between 1987 and 2018.



Source: (ZENNIR, 2019)

This period saw the emergence of classic models in the urban composition as part of the new development plan, improvement and extension of the city 1932-1933, which was made by a team of urban planners (Bensaâd Redjel & Labii, 2016) The urban development of this period is characterized by a striking effect on architecture and urban planning, characterized by rationality and symmetry. Unlike the following period when the authorities relied on new urban styles, which posed the problem of inconsistency in the colonial post period.

3-2-3- Since 1962:

Since independence, and to build the state and its associated institutions, the priority for the Algerian government has been for the development and spatial planning, because of the domination of rural population and the great abundance of housing left by the settlers, during the 1970s the extension of the city was to the west, due to the significant demand for housing and in accordance with the policies implemented by the state, which tends more towards selfconstruction and social housing, because the state was the unique actor in housing production, because of the lack of development plans, which leaves an anarchic extension, which often affects natural easements and non-developable land, and also the natural ecosystem deterioration . During the 1980s, Algeria, in light of the uncontrolled expansion of major cities, the state created the National Centre for Urban Planning Research Studies, (Centre National d'Etudes et de Recherches Appliquées en Urbanisme [CNERU]) to control urban planning by regulatory tools that organizes the extension of cities. This historical development of urban sprawl following this period is shown in (Map 07).

A)-General Organization Plan (POG): This plan was part of an ordinance in 1975, and limited to the capital Algiers, with the general objective of organizing urban spaces and extension of Algiers. In the context of the definition of the main axes of the urbanization strategy, this plan was doomed to failure due to the lack of implementation mechanisms.

B)-Master Urban Planning Plan: (PUD): After the decision of the Council of Ministers in 1997 to suspend the application of the POG, a new PUD plan was officially launched, based on a general planning system, for a new vision in the 80s, which also registered a failure on more than one level, among the criticisms addressed to this plan is the irrational consumption of agricultural land of high potential.

C)-Master Plan of Development and Urban Planning (PDAU): this plan was established within the Law 29/90, relating to development and urban planning, this new regulation considered as a revolutionary tool, for the purpose of continuing the activities relating to development and the orientations adopted at the interministerial council of July 14, 1984, the PDAU. Nevertheless, it is important to note that this new instrument is not without its disadvantages, primarily attributable to lack of experience.

D)-Major Urban Project (GPU): Two decrees of May 31, 1997 on the organization of the metropolis of Algiers and the emergence of status: Governorate of Greater Algiers. The metropolis of Algiers had a specific management system like the initiative at the time, this status was quickly cancelled and transformed into a wilaya like the rest. This experience had to be valued and generalized to the rest of the metropolises such as Oran, Constantine and Annaba. Article 84 of the law n ° 12-07 of February 21, 2012 relating to Wilayas, allows any Wilaya to take actions at the local level to control the risks of floods and drought.

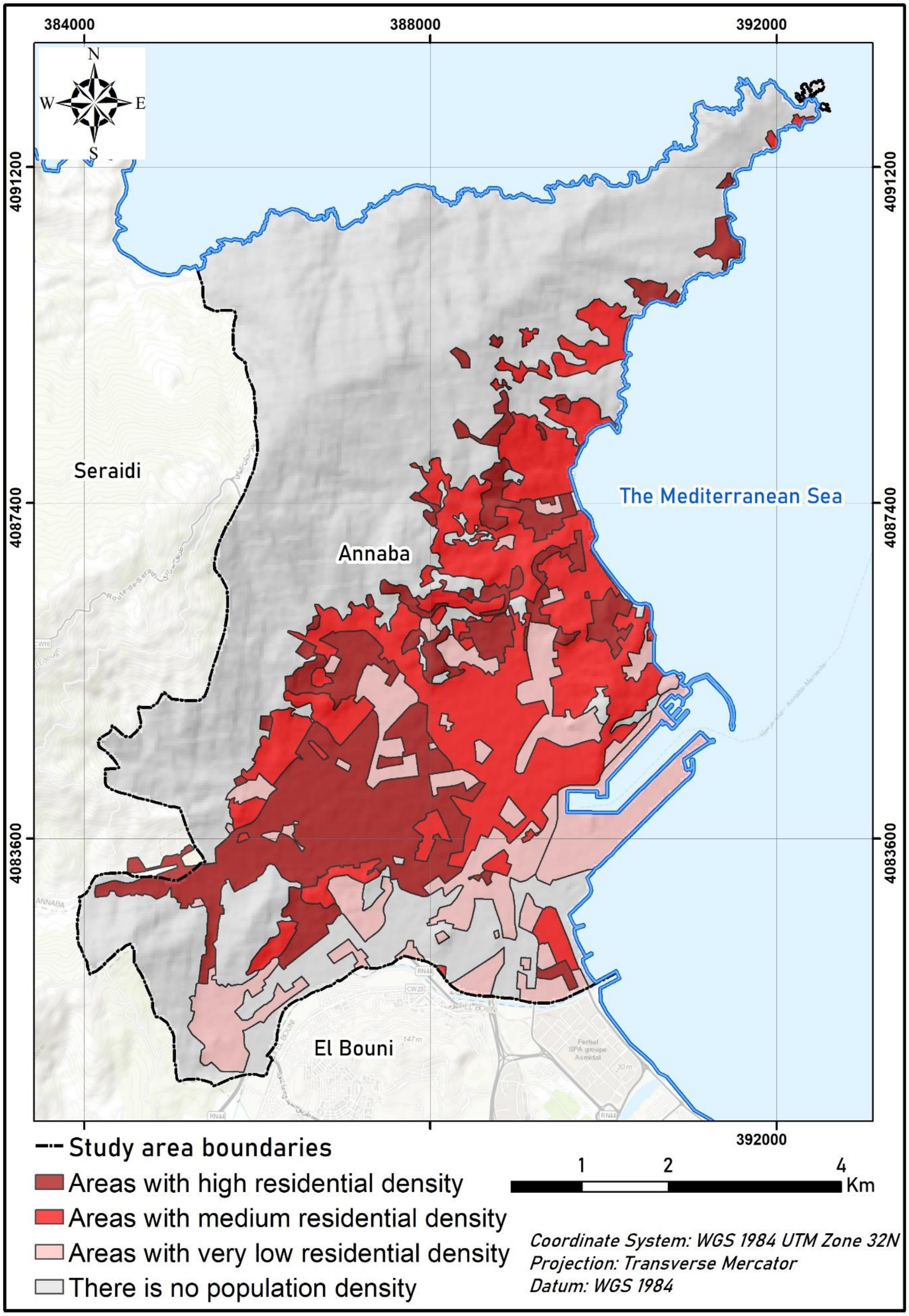
4- Demographic analysis:

The population of a territory is often susceptible to flood risks, which are frequently associated with anthropogenic activities and human interventions that can exacerbate the exposure, thus, worldwide, 1.81 billion people (23%) are likely to be exposed to this type of risk. In addition, there are other areas that combine this risk with other natural and even technological risks. Therefore, human geography is the basis of any risk management process, it ought to be based on population studies, and its distribution through the territory, the population density and the consequences that follow, for the delimitation of exposure and vulnerability diagnostics.

4-1- Population distribution:

The metropolis of Annaba serves as a representative example of other major cities in Algeria, where the population on the territory is irregularly distributed (Map 08). The Algerian land area has experienced a very high population concentration index.

Map 8: Population density map of Annaba province.



Source: (The researcher 2024)

About 90% of the population occupies only 12% of the area, rather, the coastal strip. The available population data (Table 07) explain a strong spatial imbalance due to the population repair on the territory of the Wilaya, with 640,050 inhabitants of Annaba Province, this high density explains the high *Urban Primacy* ratio.

4-2- Population and urban area development:

The urban evolution of Annaba has experienced an impressive pace, especially in post-independence period, which is experiencing a significant rate of increase, due to the political will for the development of the metropolis, and due to its significant weight at the regional level, represented in the realization of several industrial projects and superior equipment, reaching 609,500 inhabitants with an area of 1,412 km^2, and a housing density of 431.6 inhabitants / km^2. this data reflects the strong anthropogenic alteration experienced in this period.

Table 7: Demographic evolution in Annaba Municipality.

Pop. in 2005	Pop. in 2010			Pop. in 2015			Estimated population in 2025			Pop. Add 2005-2025
	Global	Addit	T.A.G. M.A	Global	Addit	T.A.G. M.A	Global	Addit	T.A.G. M.A	
278827	304434	25607	1.77	329194	24760	1.57	380745	51551	1.46	101918

Source: PDAU intercommunal revision 2008

4-2-1- Urban construction practices: In a territorial context, the elevated density of residential development signifies a substantial land consumption, and land scarcity that links them, this urban densification appears as an imperative to find constructive land. This high population number and the large urban footprint represent a direct correlation, which explains the amplification of the rate of space enthropization.

Landscape maps are designed to delineate spatial characteristics through systematic observation, and essential for conducting spatial analysis in order to facilitate decision-making, it is about examining and representing the components of space, and also useful for evaluating tourist potentials and preserving cultural identity on an urban scale. The map of the major State: a map for use for military purposes, contains a topographic information, road network, communication routes, and it also represents the hydrographic network and the reliefs in general, the map available in this regard is that of the MINISTRY OF WATER RESOURCES This is a topographic map of Bône made by the French Ministry of Public Works and Transport, by the Army Geographical Service at a scale of 1/50000e, in Paris by the National Geographic Institute, year 1958. 4fill in colour 56x79cm.

5- Overview of historical events in Annaba:

The physical environment can be an aggravating element of extreme events in the case of heavy rainfall, because of the exposure of the stakes in the floodplains, which causes significant human and material losses. Due to the amount of rain and its torrential nature, the period from mid-autumn to mid-winter is considered the most favourable for hydrological hazards., the large amount of running water overflows the floodplain because of the dimensions of the sections of the canals and the protective works and its inability to absorb the amount of water, this is what favours the flood occurrence.

5-1- Investigation and classification of events:

The findings relating to the return period and the determination of the precipitation season, according to the international classification of extreme events provided by the Royal Belgian Meteorological Institute, determining the events by the following classification: normal (if it occurs frequently in a region on a regular basis), very normal (more frequent and typical for the area), exceptional (a rare and noble event that occurs every 10 to 50 years), very exceptional (an extremely rare event, once every 100 years or more).

5-2- Limits and scope of event scenarios:

The anticipation of spatialized scenarios is considered to be closely linked with the reference hazard, which depends on the magnitude and the feared consequences, represented most by the return period as the average interval between two remarkable events, because the backup plans cannot be very practical for an event with a return period between 50 and 100 years. In France, the Specialized Environmental Inspection Mission (MISE) has established a scale of severity of disasters represented by a (Table 08) with a classification of natural events.

Table 08: Classification of natural events scales.

Class		**Human damage**	**Material damage**
0	Incident	No injuries	Less than 0.3 million euros
1	Accident	1 or more minor injurie	From 0.3 million euros to 3 million euros
2	Accident	1 or more seriously injured	From 3 million euros to 30 million euros
3	Serious accident	To 9 deaths	From 30 million euros to 300 million euros
4	Very serious accident	10 to 99 deaths	From 300 million euros to 3 billion euros
5	Disaster	100 to 999 deaths	From 3 billion euros to 30 billion euros
6	Major disaster	1000 deaths or more	More than 30 billion euros

Source: (MATE, 2002).

For ease of reading and a simpler understanding of the degrees of risk in terms of return periods, the 5X5 matrix shown in (Figure 18) is used to classify and manage the risks, the two axes contain the probability of occurrence (time) from low to high, and the other axis represents the potential impact (intensity) from minor to critical. By the combination of the two axes and each intersection of two axes gives us a certain degree of risk.

5-3- Significant material losses due to floodings:

The catastrophic events that have affected the city of Annaba have caused considerable damage to both infrastructure and in human losses. Given that its site in some neighbourhoods is situated at an elevation lower than that of the sea level, brutal floods have been recorded during the history of the city, with a ten-year return period, the most remarkable is that of November 1982, which led to significant losses and remained engraved in the memory of the inhabitants. These floods are often of the lowland type (slow) due to the floods of the different watersheds originating from the Edough massif: it is about the watersheds of wadis: fourcha, kouba, Bouhdid, and S. Harb.

Figure 18: 5X5 Risk level assessment matrix.

5X5 Risk assessment matrix

Probability of occurrence (Time)					
5	Medium/ High	Medium/ High	High	High	High
4	Low / Medium	Medium/ High	Medium/ High	High	High
3	Low / Medium	Low / Medium	Medium/ High	Medium/ High	High
2	Low	Low	Low / Medium	Low / Medium	Medium/ High
1	Low	Low	Low	Low / Medium	Medium/ High
	1	2	3	4	5

Potential impact (Intensity)

Source: presented by the researcher.

Specific material damage (Heritage):

The historical heritage of the city holds significant and irreplaceable value, particularly in the event of damage, the deterioration of heritage is concerning its symbolic significance, but also independent of its economic value. The United Nations Organization has adopted a special policy for the preservation of classified world heritage, through its representative, the United Nations Educational, Scientific and Cultural Organization (UNESCO), a strategy revolves around strengthening the governance of risks related to disasters, by the (Convention for the protection of the world cultural and natural heritage) of June 24, 1974.

5-4- Secondary effects on non-flooded areas:

The city of Annaba has experienced several catastrophic hydrological events during its history, the events have been devastating and cause the greatest number of human and material losses in the city, because it represents a space of high concentration of population and activities. The flood consequences can go beyond the territory boundaries, it may also exert indirect effects on specific areas or result in damage at a more extensive level, in particular on infrastructure, for example, the effect on the drinking water supply network, as in the case of Paris 1910 where the flood causes a cut-off for a large drinking water supply sector because of water pollution, and also the case of blocking of road networks that prevent citizens from accessing the facilities.

In the case of the city of Annaba, the reference events of 1973 and 1982 are the best known, caused significant damage and left a significant impact on the infrastructure, which disrupted economic activities and daily life during these periods.

Figure 19: Floods of November 1982 in the city of Annaba.

Source: National Hydrographic Basin Agency (ABH)

The flood of November 11, 1982 (Figure 19) in Annaba caused damage where the Edough massif experienced heavy rains of 167 mm on November 11, 1982 and intense at 35 mm, intervals of 40 minutes, causing sudden flooding of the wadis in Bouhdid and Forcha, which causes immediate and long-term disturbances on the environment and local communities.

The steep gradients of the thalwegs accentuated the violence of the floods, which caused significant damage. At the time of this flood, evidence indicated that a considerable solid transport took place from the main thalweg, with scree over 1m in diameter = (3 tonnes) being carried away, which suggests flow speeds of 5m/s, if the following formula is applied:

V= 45D

Where:

V: flow velocity.

D: diameter of debris.

For: D= 1m............V= 6.7m/s

The very steep upstream thalweg intersects with the downstream thalweg at the Sidi Harb cemetery and the confluence with the "URBAN" canal. At this critical point, the cemetery suffered some damage during the event of 1982.

5-5- Consequences on Annaba as a national metropolis:

In the case of Annaba, the metropolitan dynamics complementing the urban dynamics, in the case where the requirements are higher, from the point of view of reflection on the risk of flooding, it addresses the functions of commands at regional level, and polarisation facilities that extends to regional and national level, the value of the stakes there is greater. In other words, there is a direct correlation between the size of the city and the aggravation of risks, where risk is an integral part of the life of contemporary society. The feedback shows that the interruptions and the disturbances of the public services which depend on the central one, influenced either directly by the event or by its secondary effect, cause a malfunction of the management system and its logical sequence, which has a harmful effect for the environment and hinders economic development.

5-5-1- Economic sector implications:

According to World Bank estimates, floods cost the world's companies about 2 to 3 billion dollars a year, the heaviest toll compared to other natural hazards. The damaging effects in the economic sector can be directly quantified, either by the direct estimation of economic losses, or by the consequences due to the disruption of networks and infrastructure operation. The effects of the floods on the city of Annaba appear directly in the cost of reconstruction in case of damage to basic structures, and economic facilities, in addition to damage to the transport network, and this inevitably increases the costs of production of goods and services during and after the events.

5-5-1-1- Substantial impact on property:

The principal flood type observed in our study area is classified as a slow-onset flood typical of flat, low-lying plains, where the water rises more slowly over a relatively long period, this type is linked to the long-lasting rains of the rainy season. For instance, of the reference event of 1982, that affected a large part of the city, and causing considerable losses, and disruption of the supply of drinking water and electricity for days, in a fairly vulnerable area that requiring immediate relief. The material damage was considerable caused by flooding and rising water in lower parts of the city such as the western plain, rather the districts of: La Colonne, El-Nedjma, Zaâfrania, Oued Fourcha, and Oued Edheb, according to reports from the civil protection. The anarchic urbanization widely diffused on the territory at the time, which required the realization of the canals of (Belt, and Kef N'sour), However, several failures of these measures have been recorded, such as those related to the events of December 2005, where a flood was documented at the the Belt Canal, shown in (Figure 20) by civil protection agents.

Figure 20: Overflowing of the belt canal (Bouhdid valley) event of 12, 2005.

Source: Civil protection directorate.

Material loss encompasses not only the direct costs associated with infrastructure, but also indirect expenses represented by the cost of intervention and evacuation of the affected population, and consequently the transport and communication sector, within the largest share concerns reconstruction operations.

5-5-1-2- Impact of disruptions on the service sectors:

In such catastrophic events, the risk paralyzes daily life, affecting public networks (electricity, telecommunications, drinking water, roads) where things get complicated, because logistics work is the basis of any rescue operation. The sewerage networks that drain the running water are often located in parallel with the roads and lead into collectors in order to locally reduce the floodwater amount, according to our investigation conducted on parts of the city, this type of equipment is often denounced by citizens on its operation, due to poor quality or accumulated waste.

5-5-1-3- Implications on transport sector:

In some cases, the stakeholders are compelled to adhere to the principles outlined in the plans, this is the official followed course of action by local actors to minimize the negative impact of an unforeseen event, based on real-time warning systems and the improvement of the plans and its response to the circumstances that threaten these operational capacities during the disaster, and its interventions are faced with uncertainty and the compatibility of all cases, (a plan for certain types of events, E.g. decennial, is not effective in the case of a centennial flood). The transport problem in the case of floods can go beyond the local stratum to the regional level, because the city of Annaba represents a road and port transition zone.

Chapter conclusion:

In conclusion, Annaba region as a study area, represents great importance due to its distinctive geographical characteristics and the environmental and socio-economic issues that it presents. The exceptional biodiversity, the composition of the relief and the general landscape of the region coupled with the challenges of deforestation due to the risk of forest fires, which has led to a significant reduction in forest area and, and soil degradation, makes this region a perfect terrain, and an ideal natural experimental field to explore conservation and sustainable development strategies.

By analysing the existing infrastructures, the demographic dynamics and the economic activities of the region, it became apparent that flood risk management in Annaba is based much more on purely technical solutions.

This section has thus laid the groundwork for addressing flood risk management strategies in the following chapters. The remainder of this thesis will explore the various issues related to flood risk management in Annaba in order to minimise the impact of this natural risk on the population. The research carried out in this area will provide valuable insights for flood risk management and the development of more sustainable management practices, with potential implications for other similar regions.

CHAPTER 3:
METHODOLOGICAL FRAMEWORK FOR FLOOD RISK MANAGEMENT EVALUATION

Chapter introduction:

The primary aim of mitigating the flood risk devastating impacts is for ensuring the safety and well-being of local populations, as well as the protection of infrastructure and the environment, this chapter presents the Materials and Methods used to flood risk assessment, with particular emphasis on a multicriteria analysis approach to assess the physical and social aspect of the risk.
In this section the model development is a process where multiple models are available, and just one meets the desired criteria and being practical. Modelling process are commonly need to start from the basic model rather than the advanced form (McGahey & Cameron, 2002). This is frequently due to the new model's lack of accordance for reuse, often stemming from complexities of the evaluation process. In the case of our study, several models are available, but we believe that one of multi-criteria analysis model is the most relevant because the situation requires an approach based on a holistic analysis, given that the phenomenon is basically associated with the uncertainty.
This approach makes it possible to prioritize the different factors contributing to the risk of flooding and to integrate them into a detailed mapping, combining the Analytical Hierarchy Process (AHP) with Geographic Information Systems (GIS) enables a multi-criteria approach to flood risk assessment, to optimize the management of a diverse range of field and statistical data, thus, providing a visual and analytical tool for decision-makers. In parallel, the questionnaires allow qualitative and quantitative data to be collected on residents' perception of risk, their level of preparedness and their expectations in terms of risk management. This dual approach makes it possible to obtain a holistic vision of the problem, combining technical and social data for a more effective and inclusive management of the flood risk.

1- Research Design:

In order to obtain accurate results for our research, we resorted to the use two approaches, namely: descriptive approach in the phase of the collection and acquisition of statistical and cartographic data to describe the current state assessment, and then the analytical approach for the performance analysis of the prevention measures taken by local actors, through a field survey. And on the other hand, by identifying trends and patterns in the cartographic data obtained by our work to demonstrate the root causes of flood risk.

1-1- Environmental assessment by geomatics:

Geomatics, (GIS, and Remote Sensing) is a powerful tool for spatially assessing risks for decision-making support, especially in the case of flood risks. To conduct such a study, it is necessary to take into account all the variables that can have an impact on the components of the space. This implies the crossing of different geological, climatic, hydrological and topographic data, as well as the interaction of man with its environment. By taking into account these different factors influencing the hazard generation, it becomes possible to estimate the probability of occurrence of natural risks and their temporality. Indeed, the issues exposed and the vulnerability to risks that may vary depending on the increase in human activities in certain cases. Therefore, it is essential to understand the consequences of these interactions for an accurate risk assessment. By using geomatics tools and techniques, it is possible to gather spatial data from different sources, such as satellite images.

These spatial data can then be used to analyse and represent natural hazards in a visual way, which facilitates the understanding and results communication. On the other hand, by using geomatics maps, it is possible to estimate the risks probability of occurrence, and its temporality, as well as to facilitate the collection and representation of the necessary spatial data for this assessment, and this is the case in our study area.

The need for environmental assessment: This concept is also referred to as (geographical assessment), it represents a new concept that has been developed to answer the question of the effect of land use changes on the environment, its main objective is to promote spatial planning according to the principles of sustainable development, this concept was first initiated in the United States in 1969, and has since been adopted by several countries around the world. Where the United Nations demanded that all countries adopt an environmental protection program, which is supported by (Agenda 21), from (Rio Declaration). This evaluation must be at the national level, within the framework of sustainable development. These initiatives have reinforced the importance of environmental assessment as an essential tool for ensuring environmental sustainability.

To carry out this evaluation, geomatics is considered as a valuable tool for the establishment of this method, combines the technologies of geographical information systems with earth sciences, and the representation of human-environment interaction. The urban population forms about 80% of world population in 2008, the city has more than ever become a space that requires a management that integrates all social and economic components into a global system, that ensures the establishment of sustainable development principles. The aim of the environmental policy is the preservation of the citizen's quality of life, the prevention of natural and industrial risks, and the fight against pollution such as water management and waste management. In this regard, Algeria is trying to set up a legal framework for environment protection, to be applicable, it is about the National Action Plan for the Environment and Sustainable Development (Plan National d'Actions pour l'Environnement et le Développement Durable [PNAE-DD]) of January 01, 2002, is the most recognized in this sense.

1-2- Applications of geomatics:

Geomatics is a field that appeared for the first time in 1960 by the French scientist Bernard Dubuisson, according to Canadian Association of Geomatics Sciences (Association Canadienne des Sciences Géomatiques [ACSG]). Since then, it has experienced the development of Geographic Information Systems, which are widely used in various fields, including environmental studies. GIS can play an essential role by allowing the collection, representation and projection of different spatial data. This data may include information from surveying, geodesy, cartography, Global Positioning System (GPS), and remote sensing. By using this data, GIS facilitates reading and analysis of this information. These maps can then be georeferenced, which means that they are linked to specific geographical coordinates, which facilitates their use in decision-making and planning. In addition, GIS can also be used to establish statistical tables in relation to the environment.

1-2-1- Geospatial analysis by Geographical Information Systems:

Geographic information systems (GIS) are effective instruments that enable the, store, analyse and visualize spatial data. These systems make it possible to represent several spatial characteristics at the same time, using georeferenced cartographic data. They also offer the possibility of integrating theoretical or statistical data and overlaying them in a spatial context. The most well-known GIS software is ArcGIS, MapInfo and QGIS, which can gather different types of data in a one database.

The advantages of GIS are numerous. First of all, they make it possible to gather and manage several different types of data, whether geographical, demographic, economic, environmental data, …etc, that facilitates analysis and decision-making support. In addition, the data can be updated easily, which makes it possible to have up-to-date information in real time. GIS also offer a great ease of reading and information accessibility; it is possible to visualize the data graphically. However, GIS also has certain constraints, first of all, the cost of software and data can be high, especially for professional versions. In addition, the acquisition of precise geographical data can also represent a significant financial investment. Then the availability of data may present a challenge, because some datatypes is not easily accessible or is not available in all countries or regions.

1-2-2- Analytic Hierarchy Process (AHP): it is a multi-criteria decision-making support method, which is particularly effective for flood risk studies in a flexible way, by taking into account multiple criteria (hazard and vulnerability), with a relative weighting of these criteria, to bring it into line with the reality and the choices of the stakeholders, by integrating spatial data to associate it with the GIS tool, for an essential purpose is transparent decision support.

By applying this methodology, the desired objective is to identify the levels of risk in the form of a zoning which makes it possible to guide the spatial planning and the protection measures, taking into account the cost-effectiveness ratio in the framework of sustainable development. And based on this assessment, it can be adopted as a reference for development projects, and this is in accordance with the guidelines of the environmental assessment.

1-3- Field data and empirical research:

The type of the data whether it is be vector or raster, is a form of graphical representation for spatial information by a grid of cells (pixels), it is used to demonstrate the visual data. The vector data type corresponds to the geospatial data represented by points, lines, polygons, to represent several types of geographical objects such as roads, buildings, and waterways. This type of data is useful for performing several operations automatically in a GIS environment.

There are several approaches that can be used, Geographic Information Systems (GIS) and remote sensing have made this task easier and more accurate. To achieve this, a DEM (Digital Elevation Model) contains altimetric and planimetric information, it can be used to represents the physiographic, geomorphometric, geomorphological, hydrological and hydrometric characteristics of an area. This information is essential for hydrological simulation and watershed analysis. A commonly used method is the spectral method, which is based on the use of satellite images to extract the necessary data, as in (Figure 21), which shows a comparison between the images taken before and after the event of January 24 and 25, 2019 from Alsat-2 satellite imagery of the Algerian Space Agency (ASA), in (false colour mode). The Figure provides a graphic illustration of the impact of the floods on the region. The photo taken after the flood shows a transformed landscape on the black spots shown in the second photo, affected by the floods. The difference between the two images highlights the destructive force of flooding and the significant changes it brings to the local environment.

Figure 21: Visualization of the Annaba region before and after the flood of January 24, 2019.

Alsat-2B image: September 22, 2017 **Alsat-2A image: February 02, 2019**

Source: (Algerian Space Agency, 2024)

The following figure illustrates the disastrous magnitude of 2019 event, in addition to the deaths recorded, this occurrence resulted in devastating material and infrastructural losses, as the 140 mm of recorded rainfall, thus, 27 mm less than the reference event of 1982, which experts categorize as a centennial event, this prompts an inquiry into the reasons behind the severity of such events, and whether they can be attributed to climate change. This quantity of precipitation caused this extent of destruction, which calls for the adoption of more effective methods in flood forecasting.

Returning to the literature, we find that the classical approach based on historical events may lack effectiveness, as the 2019 event proved this hypothesis, supporting the possibility that the change in flood behavior is due to climate change, as the state authorities explained the rise of new black spots as an element of uncertainty in such phenomena, as the state authorities allocated an amount of 350 billion DZD for the crisis management, This event led to exceptional alterations to the rescue plan to adapt to new scenarios, which experienced the occurrence of coastal floods due to winds exceeding 90 km/h. This raises the question of finding an effective flood risk assessment method that takes into account all forms of uncertainty in the analysis process.

Figure 22: Floods of January 25, 2019

Source: (Algerian radio website).

Another method is the topographic method, which is based on the use of a Digital Elevation Model (DEM) itself. This method can be carried out using a geometric approach, which involves the data thresholding of the data to eliminate rare data and to obtain the network of the valley paths. In addition, there are dynamic methods that are based on the distribution of the amount of rain on each pixel and the calculation of the flow characteristics as a function of the slope. These methods make it possible to take into account temporal variations in the urban fabric and to simulate hydrological changes over time.

1-4- Vulnerability assessment by integrating land use:

As mentioned in the literature, the vulnerability can be defined according to several aspects, both sociological and construction. On the physical level, it is about the exposure of inhabitants, buildings, and infrastructures in general to the risks of flooding, according to their distribution in space. On a sociological level, it is about the ability of the inhabitants to cope and recover from the damage caused by the floods. To carry out our study, we used an approach that integrates data on land use which allows us to understand the effect of urbanization on flood aggravation. Since the first appearance of this perception, its principles have not changed, the concept was first introduced in 1993 based on the potential severity of damage, either economic or social. We thus distinguish between economic vulnerability (material damage, infrastructure, roads, …etc.) and human vulnerability (injuries, deaths, disappearances) But the problem remains in vulnerability estimation that is based on:

Damage evaluation and impact report: It pertains to the assessment of damage caused by the Hazard, by studying the history of previous events, (the return periods) this observation was aimed at: Determination of exposed elements to the risk, and then the assessment of economic damage. To do this, a topographic maps and aerial photos and maps at different scales are used that include buildings, infrastructure and agricultural lands. The assessment of natural risks is predicated on several essential elements and predetermined thresholds, and according to (Dauphiné & Damienne, 2001) in RISK AND DISASTER, 3 elements have been established to evaluate a natural disaster: The risk is only considered a disaster if it causes: Human damage (100 deaths at least) Economic damage ($10 million minimum) Ecological damage (10,000 Tons of biomass damage). The study area is significantly exposed to risk of flooding, and that is spread over the territory of the wilaya as shown in the following table:

Table 09: Historical flood events in the city of Annaba in the last decades

Dated	**Disaster scene**	**Occasional Damage**	**Observations**
11/11/1972	Neighbourhoods of: Oued Dhab, Seybous	9490 people and 1436 families without shelter and significant damage.	45000 stricken following the floods
04/05/1973	Neighbourhoods of western plain, Seybous.	Significant damage in crops and animals.	4870 families affected, 2126 cattle heads
11/10/1982	Neighbourhoods of December11, Oued Dhab	Large damage and blocked roads	26 dead, several wounded and several families without shelter
09/27/1995	Neighbourhoods of Sidi Brahim, 8 Mai	Significant damage on homes, schools located on Oued Kouba, and Rizi Amor beach	Affected homes and equipment And no human damage
04/04/2003	El-Hadjar, Sidi Amar, El Bouni (western plain)	Flooding of all single-floor dwellings and roads: R.N 44 East, R.N 21, R.N 16 A Blocked traffic for 48 hours	944 families affected. 4312 people affected.
12/14/2005	lower neighbourhoods of the of Annaba city.	Severe damage on roads and infrastructure	Affected homes
06/01 to 03 /2006	All the districts adjoining the main lifting station. - sidi Brahim-	Large areas were inundated with damage on buildings and vehicles, blocking roads	Several families affected
11/25/2013	Oued Kouba neighbourhood, Rizi Omar beach.	submersion of several neighborhood units in Oued Kouba. landslide	families and homes affected
01/25/2019	National road N44, Oued Dhab, Rym, July 5 neighbourhoods	roads blocking, damaging a large number of buildings, uprooting trees, Blackouts.	3 deaths, and a large number of citizens overnight in their vehicles

Source: General directorate of civil protection Annaba.

In our study, we are particularly engaged in assessing the vulnerability, therefore, the areas affected by floods are often the most vulnerable neighbourhoods, also called "Black Spots". Floods cause significant economic and social damage, particularly in at risk areas, which we will discuss in the next chapter. In addition, this identification of black spots must be supported by a hydrological Simulation. For the purpose of flood assessment, land use data are used for this purpose, provided by cadastre services which contain information on the nature of soils, their ownership and land use, whether built or not built. The objective of this simulation is to compare the effect of human activities on flood parameters in the same place, but at different times, this will help informed decision-making in terms of risk management related to flows, taking into account both the physical and sociological aspects of the stake's vulnerability.

2- Flood risk analysis approach:

As a first step in the risk analysis, the issues are referred to as the entire population at risk and their associated properties, from which we can determine its vulnerability. This situation requires a method to determine the risk spreading in territory through the establishment of the risk map through overlaying of the hazard and the stakes maps and their vulnerability by taking into consideration the protected areas. This process requires a preliminary analysis which in turn aims to identify all factors that can cause a risk, spatial factors and meteorological factors. The risk of flooding is the interaction of two main components: the hazard constituted by the often-meteorological event, this includes the physical conditions of the terrain, as well as the stakes such as human settlements in areas susceptible to risk and associated vulnerabilities.

Major risk Identification: Is the interaction of a large-scale hazard and issues, that undermines the capacity of the community to rethink in response to this event, which is often characterized by a low frequency.
Definition of hazard: Is the result of combining a rainfall phenomenon with the physical environment of a territory, this type of event is characterized by intensity, duration, and frequency, in the case of flooding the factors are more multiple they also depend on other factors such as protective measures.
Identification of issues: It concerns the exposed objects to the floods, such as the population, the built environment, and infrastructure, there are 3 types of issues (human, economic, environmental)
Delimitation of flood risk: is the possibility of hazard occurrence in a defined territory, it affects objects with specific characteristics such as vulnerability and exposure degree.
So, the general form of the natural risk equation is:

$$\text{Risk} = Hazard\ X\ Vulnerability \tag{3.1}$$

This equation (3.1) can be expressed more specifically in different ways, depending on the context and the aim of study. Here are some examples of the equation according to different authors:
(Crichton, 2005), suggests a triangle where risk is a function of hazard, exposure and vulnerability. The equation (3.1) is often represented in the form of:

$$Risk = Hazard\ X\ Exposure\ X\ Vulnerability \tag{3.2}$$

(Turner, B. L. , 2003), Turner suggests a vulnerability framework that includes exposure, sensitivity, and adaptive capacity:

$$Risk = (Exposure + Sensitivity - Adaptive\ capacity) \tag{3.3}$$

Here, sensitivity refers to the degree to which a system is affected by Hazard, and adaptive capacity is the ability to adapt to potential damage, take advantage of opportunities or react to the consequences.

(Wisner, Davis, Cannon , & Blaikie, 1994) In their book "At Risk: Natural Hazards, People's Vulnerability and Disasters" Wisner and his colleagues, highlight the social dimensions of risk:

$$Risk = Hazard\ X\ Vulnerability\ XCapacity \tag{3.4}$$

The United Nations International Strategy for Disaster Reduction (UNISDR) in 2009, defines risk as:

$$\text{Risk} = \frac{\text{Hazard X Vulnerability}}{\text{Capacity}} \tag{3.5}$$

Here, capacity refers to the ability to manage and responce to disasters, which can mitigate the overall risk. Capacity here includes the social, economic and political factors that influence the ability of community to cope with dangers.
The Intergovernmental Panel on Climate Change (IPCC), uses a similar formulation in its special report on managing the risks of disasters under the heading Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation as:

$$Risk = Hazard\ Probablity\ X\ Vulnerability\ X\ Exposure \tag{3.6}$$

This formulation highlights the probabilistic nature of hazards, and the importance of both exposure and vulnerability.

These equations show that the main components of risk are Hazard and Vulnerability, while the rest of the designations are integrated into the same concept, for example, we find that vulnerability is part of exposure (not necessarily the entire exposed population are vulnerable)

The risk pool: Is a spatial entity delimited by topographic, geomorphological, and hydrodynamic characteristics. The human implantation in the basin likely to create a risk of flooding, which varies according to the stakes and their exposure degrees and vulnerability, the factors which delimit the flow are physical factors such as the pedological factor (soils), biological (vegetation cover), topographic (slope), and anthropogenic (land use).

Scope of the study: It may include not only the issues directly exposed to floods, in exceptional cases, floods can overflow to affect other areas such as (middle flow and floodplain, and also the (alluvial terraces, slopes), its effect can exceed the areas directly affected by the flood on a larger territory, by indirect consequences which can reach the agglomeration sphere of influence.

Data extraction and application*:* To establish a more adequate analysis of the flood risk, it is necessary to rely on the most global and precise data possible. For an efficient diagnosis of the flood phenomenon, it is necessary to return to the history of past events and their consequences with feedback to come out with new data, that can facilitate the adoption of similar events, with new field data such as new challenges, and the transformations that occur due to multiple conditions including land use and climate change.

2-1- Informative mapping: The purpose of this step is to identify the hazard characteristics in study area, in order to show the spatial distribution of risk, in the form of quantitative data to establish cartographic information, for this purpose, this work is carried out on an analogical cartographic background (topographic). Otherwise, on the spatialization of data by the integration of theoretical evidence on cartographic data, and integrate it into a GIS project, and finally the establishment of a thematic map which groups all the data in several layers, tables, and graphs. This operation can offer more advantages such as the ease of data access and reading, along with the prompt spatial determination of risks, it can be considered as a practical tool by which local actors can support to inform residents in case of risk.

2-1-1- Map design and content creation: The primary advantage of cartographic synthesis is its ability to enhance the clarity and accessibility of information presentation, along with the reading of several variables of the issues and their vulnerabilities, on the other hand, the predictable elements of flood risk in a database which can represent the hydrological behaviour of valley, alluvial plain and slopes, where the hydraulic and hydrological quantitative information concerning the historical events of the study area such as the precipitation, flow velocity, peak flows, duration of submersion, and also the failures of structural measures. And even statistical information on the consequences due to the floods, in particular the human losses, the damage that affects the built environment, the structuring elements of the city and the infrastructures. The mapping can also take into account the anthropogenic action on the space, either appropriate such as structural measures like damming and canal construction, or by the inappropriate intervention such as the establishment in flood-prone areas and the degradation of the sewerage network by the solid load that impedes surface runoff.

2-1-2- Stakes determination and implications: The stakes can be described as any object susceptible to be affected by a hazard, the population comes first, then the built environment and infrastructure in order of priority. In this perspective, the issues can be classified according to their value and their vulnerability, therefore, the risk mapping is established on the basis of its components, namely the hazard, the issues and their vulnerability. Spatial issues are included in urbanized spaces, that corresponds to the entire built environment of the city, they are different according to their vulnerability, (housing, equipment). On the other hand, non-urbanized spaces like the free spaces in the city, protected natural areas, tourist areas, and infrastructures which are represented by all that is network, (energy, communication, roads and utilities). Three types of issues, social issue, economic issue, and urban or environmental issue. From a management point of view, the negligence of one of them can lead to domino effects between multiple stakes.

Proceeding from that, risk map establishment is generally based on the history of events, it also defines the probabilities of flooding and the associated events, taking into account climate change. From this point of view, the delimitation and risk zoning has helped to predict floods through the demonstration of flood zones in the event of a disaster, which can cause social and environmental consequences due to anthropogenic modification on space.

2-2- Flood hazard identification: From citizens point of view, the flood hazard is expected by the projection of climatic factors on meteorology for flood forecasting. This approach loses its utility for many factors, including climate change and anthropogenic action on space, which makes flood forecasting more complicated. The establishment of the hazard map is based on meteorological data acquired from the weather service, and also on the terrain data collected in a GIS project to delimit the areas, it should take into account the capacity of sewerage network to absorb such a quantity of water to determine a usual overflow on the Wadis flows, or a rise in water on the plain, all this to demonstrate the probability of occurrence of the flood hazard in the city of Annaba. In our case study, the hazard map shows that our study area knows 3 levels of hazard: a very strong, strong, medium, and weak hazard.

2-2-1- Pluvial flooding type: Floods are commonly induced by heavy local rainfall, it serves as a significant issue in hydrological studies, the rainy season in the case of the Mediterranean region usually starts from September until February as mentioned previously, the notion of floods often evokes the rivers overflows, which can affect large areas of the floodplain.
To determine the rainfall regime, the Ombrothermic diagram as a classic method of representing the climatic characteristics of the study area, among these parameters, it highlights the rainfall patterns of Annaba region, where the precipitation averages are varied during the year, indicating that period from November to February is the wettest.
This analysis of the climatic elements reflects the time scale in which the floods occur and gives a perception of its behaviour. The effects of the floods still remain on the psychological of the population, even are sheltered. This aspect of natural risks consequences can have detrimental effects on the psychology of citizens, particularly during the post-traumatic phase.

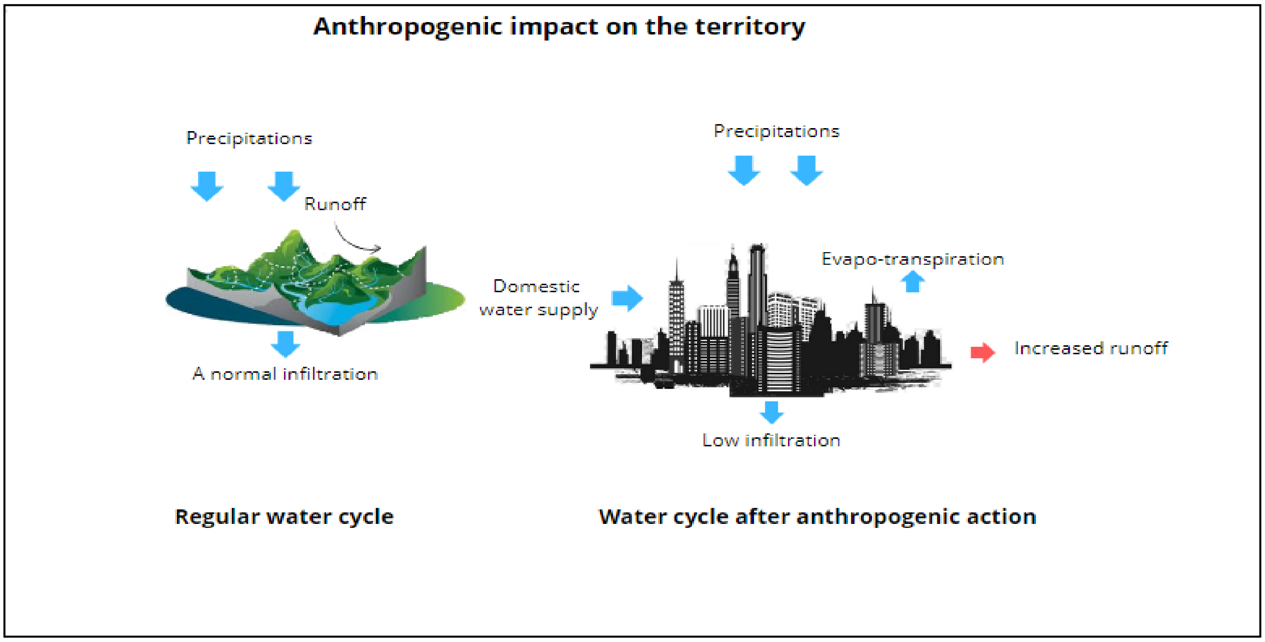
2-2-2- Water erosion by runoff on slopes:
From a theoretical point of view, the increase in flood point flows in the urban environment is generally due to a higher runoff coefficient, by modifying the flow conditions caused by land use modification, such as the example of a watershed located in Melbourne, it resulted in waterproof proportion of 70% more higher, and producing a volume of water 4.5 times than that before urbanization (Azzout, BARRAUD, CRES, & ALFAKIH, 1994). For this purpose, the vegetation plays a crucial role in minimizing runoff, to show this role there is the normalized vegetation index method: for any vegetation cover analysis, the most widely used index is the Normalized Difference Vegetation Index (NDVI), using digital data from remote sensing tools to distinguish areas with vegetation cover and its density. According to the red and infrared spectral bands:

$$NDVI = \frac{IR - R}{IR + R} \tag{3.7}$$

Its data are integrated into the GIS project to demonstrate the role of vegetation in runoff rates modification.

2-3- Land use alterations and consequences:
Before a site development, backfilling and clearing activities induce substantial environmental alterations, primarily through widespread asphalt or concrete coverage, which often encroaches upon low-flow watercourses via culverts or roadway, Such alterations, significantly reduce natural permeability, thereby intensifying surface runoff and altering hydrological dynamics, thus, increases the risk of floods and water scarcity, and in an indirect way the global warming, this situation requires a strategy that ensures sustainable solutions for water management in urban environment, which makes the risk assessment process more complicated.

Figure 23: The impact of human activity on natural flow conditions.



Source: (The researcher 2024)

Soil typology: In general, in the case of a natural environment, only 10% of the water flows over the surface, and most of the water evaporates and penetrates into the soil. On the other hand, in an urbanized space, on a perfectly sealed surface, the rate of evaporation and infiltration represent less than half, in other words, the rate of loss or runoff is reduced by up to 55% (Ugonna & Nkwunonwo, 2017). Therefore, land use is an important factor to floods genesis.

Roads as generator to potential runoff:

Generally, the sewerage network and the water drains needs be overlayed with the road network, it serves as a non-construction easement intended to facilitate maintenance in the case of potential disruptions occurring on the network. On November 21, 2020, and according to local residents, a heavy rain caused the collapse of parts of precarious habitats, these events affected especially the neighbourhoods of Sidi Harb, Oued D'hab, Bouhdid and Seybouse (Jouanouville).

3-Approach to questionnaire design and preparation:

In order to assess population vulnerability to floods, a social survey was carried out to describe the research work using a questionnaire based on a systematic approach at the end of an in-depth examination of previous studies, because the social vulnerability is devoid of a mechanism triggering hazard and it is different depending on the type of floods, physical characteristics and land use of the area exposed to the risk. A questionnaire of 45 questions based on socio-economic variables (type of activity, risk culture, standard of living), and biological variables (gender, age, number of children) in order to assess the living conditions, health of citizens and environmental policies in this regard.

3-1- Sample selection:

The questions were selected in alignment with the specific type of data intended for collection, and to avoid any irrelevant questions, to ensure the essential purpose of the study and correctly answer the survey objectives, so the sampling is based on geographical boundaries that delineate the population, so that the sample is representative, a random sampling "probabilistic method" was taken for this purpose, because it does not aim to show a specific social phenomenon that requires quotas to be taken with certain percentages of people and age groups, but it aims to analyse the risk that can affect everyone without exception.

Formula for calculating the sample size

$$n = \frac{Z^2 \times p \times (1-p)}{\mathrm{E}^2} \tag{3.8}$$

Where:

n: is the sample size.

Z: value for the desired confidence level (e.g., 1.96 for a 95% confidence level).

p: is the estimated proportion of population with the characteristic of interest, denoted as p. If the percentage is unknown, use 0.5 to get the largest sample size.

E: stands for the allowable error margin, which is, for a ±5% margin of error, 0.05.

3-2- Socio-Economic Profile:

Creating a socio-economic profile survey involves selecting questions that aimed to finding out a key demographic, economic, and social characteristics of your respondents. our case requires a design of questionnaire and some sample questions that include a part related to the social situation and another section is related to flood risk assessment and management.

The most targeted category is that of the elderly and the natives of the neighbourhood, because of their knowledge of flood history, and also their acceptability and cooperation, despite the lack of certain answers due to the ambiguity of certain questions in their opinion.

3-3- Conduct of investigation process:

Our investigative work was based on the question sheets: three types of citizen reaction: one category of residents was not even aware that they were exposed to the risk of flooding, due to their status as new inhabitants/residents, or they had never lived a flood experience. And another category of people cognizant of the risk of flooding, but they feel safe or sheltered from risk, explaining this by risk prevention measures. Unlike the other conscious category of risk consequences in the event. The main purpose of this questionnaire is to find out the level of structural and human vulnerability, the questions in this regard are focused on the following themes:

The situation of the building to the watercourse and its capacity for resilience, on the other hand, the identification of flood zones through the knowledge of the phenomenon to the citizen, (the history, the previous crisis management operations)

The opinion of citizens towards the relevance of protectives measures.

The social vulnerability of risk represented by the number of: elderly people, disabled people, children, people with chronic diseases, and with reduced mobility.

3-4- Processing and interpreting analytical data:

The analysis and processing of the data allowed us to interpret the areas of high vulnerability "building and population vulnerability" represented on a map containing the spatial distribution of the vulnerability, this analysis allowed us to determine the construction vulnerability index through this index we can determine the resistance of each type of building to floods in order to damage, On this basis, the development of the intervention is determined in each case to reduce the vulnerability.

3-4-1- Selected criteria for estimating the structural vulnerability index:

Table 10: Selected criteria for structural vulnerability assessment.

Selected criteria	Type of information
Building type Number of floors Condition of the external walls	Building Particularity
Wall covering Floor covering	Materials
Type of openings	Openings
Height of electrical sockets Circuit breaker heights	Electrical installation

Based on the analysis of the construction vulnerability, ground floor buildings are the most vulnerable. Therefore, measures to reduce vulnerability are cheaper with a positive efficiency ratio that can save human life.

3-4-2- Social vulnerability:

Table 5: Criteria used to calculate the human vulnerability index.

Selected criteria	Information type
Number of elderly people, less than 10 years old, and with reduced mobility	Particularity of people
Experience of a past event and how to deal with it	Information and risk memory
Safety and individual rescue measures	Building type
Building situation	Accessibility

The purpose of population vulnerability analysis is to demonstrate the number and location of vulnerable people, this category of population lacking either physical capacity or risk awareness even in rescue operations, on the other hand, the location and status of the building that can impact the easy access and helps the evacuation and rescue process of residents in case of flooding.

3-4-3- Welfare state and public awareness:

In the field of political and economic sciences, this concept refers to a system in which the state ensures the well-being of the citizen and protects him against risks, through socialization of risks. The State is required to invest in scientific research to better control the natural risk, and to build its strategic plans on this basis. In our case, a significant part of the population does not even have the susceptibility to knowledge of regulatory tools, in particular flood management, some residents report that they are implementing various measures at the housing level against floods, such as high construction. According to the inhabitants, the first person responsible for flood risk management is the State through their representatives, (the APC, the other sectoral services) through the different phases of the event, each in accordance with their respective roles to provide effective solutions to local development problems that aggravate the situation. But in fact, this is only possible by involving the citizen as a key risk management partner.

3-5- Socio-economic impact of floods:

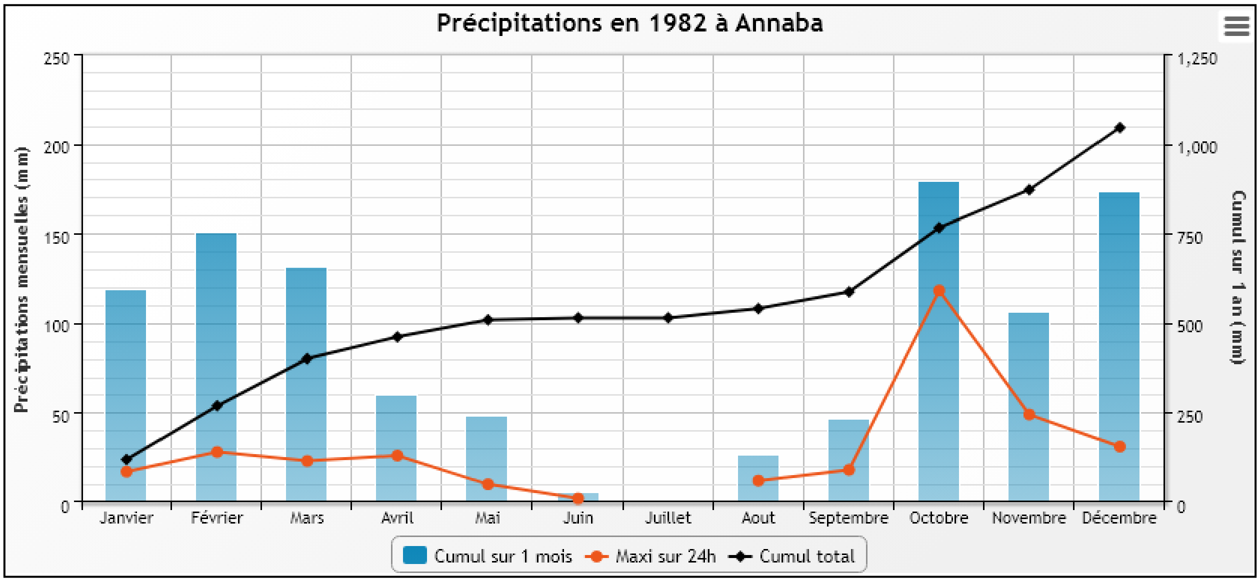
In addition to threatening the lives of individuals, floods also cause significant economic losses, sudden disasters cause significant losses on the contrary of slow-moving disasters such as pollution which has a long-term impact. The devastating effects of the floods that appeared in the subsequent damage, by the direct cost of the damage, and the reconstruction of the infrastructures, and also by the indirect effect that can affect a larger scale such as the interruption of equipment services. This explains the role of insurance culture on natural disasters among citizens.

3-5-1- Demographic groups involved:

Speaking of exposure to the risk of flooding, according to the World Bank, more than 2.2 billion people, or 29% of the world's population occupy areas subject to centennial events, with a probability of occurrence of 50% over a lifetime of a person aged 68 years. This event can cause significant damage beyond the ability of the population to respond, they can also influence the culture of risks that pass through the accumulation of historical events among the population, such as the example of Bab L'Oued floods in Algiers 2001, which remains in the memory of a wider category of population. In the case of Annaba, As mentioned above, the reference event is that of November 1982, because of the Accelerated and unplanned urbanization during the post-Independence period that the city experienced that amplifying the flood probability, with the return of precipitation, is the opportunity to demonstrate the failures related to the management of urban space, due to environmental degradation. After these floods, the project of digging the belt canal appeared as a protective measure against floods that has proven to be notably effective.

This event of 1981, and according to the Ministry of Planning was classified as "serious" considering the losses and the damages that it left. From a methodological point of view, these events are considered as a reference in determining the extent of flood risk as a classical approach.

Figure 24: Precipitation and cumulative total in Annaba region in 1982.



Source: (Cote & Camps, 1988)

The Red Cross ranks natural disasters, including flooding, on a scale of 1 to 7, this ranking is based on the cost and complexity of the company's response to the risk compared to the available means.

3-5-2- Current status of housing: The city of Annaba, paralleling other major cities in Algeria, which has the required characteristics to be considered as a regional metropolis, and in addition to these metropolitan functions, the high-level facilities, and their command function and national weight especially as an industrial hub, these factors considered as structuring elements of society due to its attractiveness. This situation has led to an increasing demand for housing, which in turn requires more land, which has forced local actors to program extensions to areas exposed to the risk of flooding through the historical evolution of the city. In addition to social vulnerability, it is important to complete a structural vulnerability analysis, that sometimes-called property vulnerability, either by professionals, or a self-diagnostic by the owner to demonstrate the degree of building vulnerability, using a guide to diagnose the resilience of its property against flooding, based on elements including the height of water, construction materials, age of the building and its condition.

3-5-3- Information and consultation framework:

Early findings from our research demonstrate that Effective outcomes require an active collaboration among local stakeholders and community members, to achieve effective management against the risk and its consequences. This proposal comes up against the reluctance of the individual to obtain information and, on the other hand, the lack of means to disseminate risk to local authorities. In this case, associations may serve as a viable solution to flexibility of the relationship between the citizen and public actors, although a large group is not interested in associative work.

4- Integrated flood risk management in urban environment:

As a solution to the problem of water management, structural measures are most common solution adopted by managers, however, this solution possesses a service life like the rest of commodities. A retention dam, in developing countries may be less than 50 50 years as a lifespan (Amzert, 1995). In an article titled (Water policies in Algeria since independence) The local management policy faces many criticisms regarding the management of rainwater in the urban environment, often, each failure is associated with a failure of the sanitation system. Urban management gives a great importance to the sanitation network, because it plays an important role in environmental protection, and this is done by collecting wastewater, and finally by a treatment before being released into nature, his research work supervises this process in the hydraulic sector in Algeria, by the National Office of Sanitation (Office National d'Assainissement [ONA]). This network needs significant funding for the realization and operation, and network maintenance to avoid failures that may result in public health issues.

4-1- Geographical distribution of flood-prone areas:

As is commonly understood, the classical approach is based on return period and the history of flood events, recorded by water markers on the walls, usually on historical monuments, by virtue of the duration of its existence. These flood haunts indicating the date of the event, these points contribute to strengthening the citizen's memory of the risks. The history of the floods shows that the areas illustrated from the hydrological analysis of the GIS tool are identical, with a simple difference due to other aggravating risk factors, such as the change associated with land use.

4-2- Protection measures and Urban Project:

More recently, the action on the urban environment is largely based on the urban project, as a means that ensures consultation between actors, including citizens. In Algeria, most urban development operations are based on the PDAU instrument at the municipal level, and sometimes on spaces located between two municipalities, and the POS tool which is linked directly with the PDAU but on a smaller scale.

4-2-1- Urban Project as instruments of urban management:

The urban planning and development tools are intended to regulate the land use, these tools must take into account the factors of aggravation of natural risk before any urban planning operation, in particular related to urban extension, which consists of new territory configuration, to an urban re-composition, which preserves the urban entity of each agglomeration, these tools are initiated by the Law 29/90 relating to development and urban planning, and the executive decrees of 177-178 / 91 of the 05/28/1991, yet the procedure for the elaboration of the PDAU and POS. These instruments required to take into account the state of the built environment, and this includes the role of adopting the urban project approach in defining the modalities of action on sensitive sites and intervention on at risk areas. The role of urban project is to correct the approach of *project control* to *work control*, as means to urban project actors, with the control of land which puts the managers in a challenge of the conservation of architectural quality with the city entity, along with avoiding new extensions marginalization.

4-2-2- Urban Project and supporting planning instruments:

After the great growth that Algerian cities have experienced, since the development policy has been limited to classic tools (PDAU and POS), to keep pace with current developments, there was a need to adopt new tools, such as urban project. The urban project in Algeria is confronted with issues related to natural risk, that pose significant challenges for urban planning and development. The risk of floodings in Algeria in general, and Annaba in particular, have caused significant damage through time, this situation requires the implementation of policies and practices for risk minimization, based on a risk zoning for urbanization management. Therefore, taking into account natural risks in the urban project in Algeria is a crucial issue for sustainable development and the safety of populations, which is likely to strengthening the resilience of society facing natural disasters.

4-3- Underlying reasons for managerial fragmentation:

In view of idea that the diversity of issues resulting in contributions to the fragmentation of management practices, considering that each actor takes responsibility for a sector according to his level and field, the multiplicity of actors is greater depending on the size of the city to a greater number of issues.

Table 6: Flood risk management actors and their respective roles

scale	**Actor**	**Task**
National	Ministries of planning, environment, water resources	(Crisis management, meteorology, urban planning, flood risk management plans)
Regional	Directorates: hydraulics	The implementation of policies and projects related to hydraulics, and the management of water resources.
Wilaya	APW	Flood risk management at the regional level. With the help of setting up emergency plans and coordinating actions in the event of a major event.
Municipality	APC	Local flood management through risk prediction and prevention. They can put in place preventive measures, awareness-raising and preventive information for citizens, and reaction in the case of events.
Higher education	Universities and research centres	Academic and scientific research institutions in Algeria are working on the prediction and hydrological modelling of risks, as well as on the development of solutions for the mitigation of flood impacts.
Local	**ONG**	Some non-governmental organizations focus on volunteer work and through awareness raising, and disaster relief.

4-3-1- Risk as an integral asset in state planning:

in Algeria, risk is considered as one of the factors of state control at local level. So risk management can control the decision-making circle, to impose an actor or delimit its tasks at the scale of a territory, according to the administrative and legal nature of the territory, in the city of Annaba, there is an overlap in the distribution of tasks at the local level, the action of the State is limited to the implementation of (structural) protection measures, the State takes advantage of compensation to improve its image among citizens, to obtain their confidence through solidarity in crises, (In the event of major disasters, the State can implement exceptional measures based on directives from senior state officials, which may extend beyond the established administrative and legal frameworks) The territorialization of risk leads to the creation of social groups under the state control, this creates solidarity between the inhabitants of at-risk areas, because they always feel like victims of the bad management policy led by the state in their opinion. The elected officials consider the risk as a "political headache" because the risk management is very costly, either by structural or non-structural measures, and in return its results are not visible, due to the temporal interval between the occurrences of flood hazards, and on the other hand, the uncertainty in results relevance of risk management policy to the citizen.

4-3-2- Public and private operator contributions:

In the management context, we can observe the important role of public or private operators, at the level of metropolitan area of Annaba, either in the communication or transport and also the economic sector, sometimes are connected to a central directorate in Annaba, these actors have an important role in social and political life in the city, which has an indirect effect on spatial planning orientations. The operators (technical and economic) are linked to the public power.

4-3-3- Socio-economic implications of metropolization:

More recently, an emerging class of private economic actors has developed within sectors such as telecommunications, housing production, and waste management. However, the emergence and the multitude of private actors indirectly participate in the management fragmentation. On the other hand, private operators required to ensure providing services in a disaster event, but they do not have sufficient means to ensure the protection and application of measures planned in management plans, therefore, public action is essential because it has the necessary means of intervention. The management problem between public and private actors is that the two actors do not have the same management logic, and their vision may differ. The process of metropolization leads to the emergence of new actors, with a new classification which obliges the State to review the positions of each actor, while the economic actors have an economic management logic built on (cost-benefit).

4-3-4- Risk management implementation on metropolitan scale:

In a wider context, urban management is based on the centre-periphery logic, starting from this logic, where the attention is more focused on the centre compared to the periphery, because of several considerations, consequently, as one progresses to the periphery, the capacity and effectiveness of management practices become increasingly impaired. To remedy this, the establishment of plans on metropolitan area scale can be a key solution, especially in disaster events (e.g., to accommodate disaster victims), A PPRI must be established at the Wilaya level, or at the regional level to control the situation or the parties which are against the PPRI orientations at the local level, to ensure consistency between other PPRI at the level of neighbouring municipalities.

Chapter conclusion:

This section provides a detailed overview of the approach employed to examine and analyse flood risk in Annaba region, by describing the geographical and social framework related to the risk, and the sample selection criteria, focusing on the high-risk areas identified by the preliminary studies and historical flood data, to describe the tools and methods used for flood risk assessment in Annaba, combining a technical approach by the multi-criteria method and a social approach by field survey.

Data collection was then detailed, outlining the used instruments, such as questionnaires, and interviews with stakeholders, additionally, by analysis of secondary data from official sources and local administrations. The procedure for processing the data obtained was carefully planned and executed to guarantee the reliability and results validity.

This integrated methodology makes it possible to obtain an exhaustive and multi-dimensional vision of the risks, thus facilitating decision-making for a more effective and resilient management in the face of floods. This will allow us to obtain reliable results, through which we will be able to discuss and analyse proposals that will contribute to the proper understanding of such issues, and thus to manage them more effectively. This research was designed to provide a systematic understanding of current flood risk management practices and their effectiveness. The following chapter will present the results obtained by applying this approach, which provides crucial insights for future flood mitigation and resilience strategies.

CHAPTER 4:

INTEGRATED RESULTS, DISCUSSION AND RECOMMENDATIONS

Introduction:

It's commonly known that natural phenomena remain ordinary until the interaction with human factor, as a consequence of this anthropogenic action, it become a disasters, So the need arises to protect human settlements, in the light of the important increase in population number particularly within large urban areas, and this highlights the significance of the risk assessment process. This chapter describes the results of our study on flood risk management in Annaba, using two complementary approaches: the Analytic Hierarchy Process (AHP) for risk analysis and mapping and a field survey to assess the social dimension of the risk. The combination of the approaches makes it possible to provide an exhaustive and multi-dimensional analysis of the flood risks. We start with the results of the risk mapping, by addressing the specific aspects of the vulnerability, exposure and resilience of infrastructure and populations to flood risk, and then a particular attention is paid to the effectiveness of the prevention and mitigation measures implemented in Annaba, followed by a detailed analysis of the perceptions and population behaviours in Annaba regarding the risk of flooding, with policy assessment of the current situation, and how effective it is, in risk identification and to mitigate the effects of floods on the population under regulatory and legal framework of management process.

This integrated approach allows to better understand the technical and social issues, and to formulate appropriate recommendations for effective flood risk management. This chapter concludes our study by giving an in-depth overview of the dynamics and impacts of flooding in Annaba City, while offering clear guidelines for effective and sustainable flood risk management.

1-Development of integrated flood risk management plan:

Flood risk represents a significant challenge within the context of urban management, giving that, in Algerian management system there is no explicit and applicable plan for flood risk prevention (Menad, 2013). In this regard, we trying to carry out a risk assessment plan, through a multi-criteria risk analysis methodology, and see if it is suitable for the current situation.

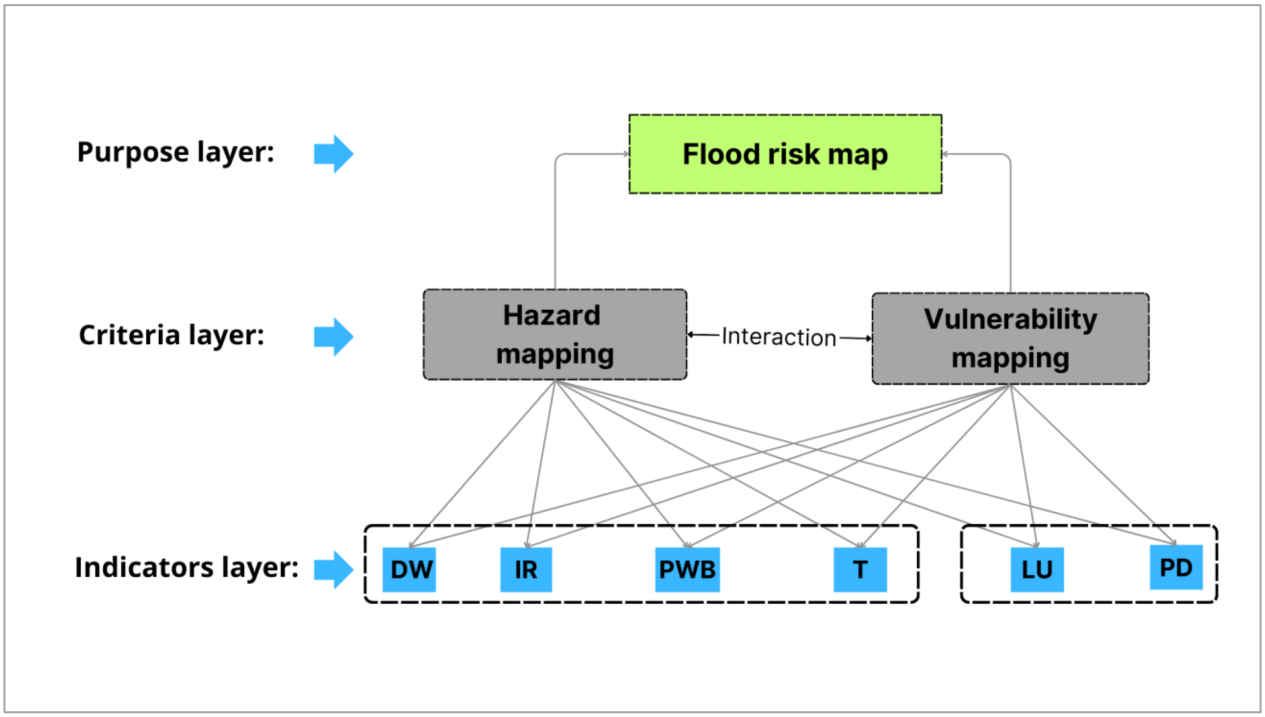
This approach represents the results of our study on the implementation of an integrated flood risk management strategy, using the multi-criteria analysis method supported by a field investigation to analyse social vulnerability. The results are discussed according to their relevance and their contribution to the effective management of flood risks.

1-1-Steps for AHP method establishment:

A hierarchical structure was established, with the overall objective being the flood risk map at the top level. Below this, two main criteria were identified: flood hazard and vulnerability. Each criterion was further decomposed into sub-criteria representing specific factors influencing flood risk.

This approach works by resolving a complex problem into a hierarchy of sub-problems that are easier to identify and evaluate. These criteria are defined according to the overall objective of the decision, each criterion is compared in pairs according to its relative contribution to the other criteria, and the relative weights for each criterion are calculated by mathematical methods, frequently employing eigenvectors, for optimized rational decision making.

Figure 25: Organizational chart of Analytical Hierarchy Process.



Source: (The researcher 2024)

These criteria are classified according to the contribution of each criterion to the flood risk generation, proceeding from this, the combined classification is as follows:

Hazard Criteria: Corresponds to: Distance to Waterways. Proximity to Water Bodies. Topography. Infiltration Rate**.**

Vulnerability Criteria: Land Use, Population Density.

1-2-Presentation of criteria and sub-criteria used in analysis:

The flood risk assessment process is impacted by a range of factors, the most prominent of which are factors related to the physical aspect of risk (Hazard) and others related to the social aspect (Vulnerability).

And after analysing the previous studies in the first section of the study (state of the art), The factors that affect the flood risk generation have been identified.

1-2-1-Criteria and sub-criteria selection and classification:

For this aim, the criteria selected are founded on its availability and relevance to Flood risk assessment, this could include indicators such as: Distance to waterways (m), Infiltration rate, Distance to the coast (m), Topography (%), Land use, Population density. These factors are sufficient for a multi criteria of flood risk analysis.

1-2-2-Pairwise comparison and elements weight:

The pairwise comparisons were predicated on gathered experts opinions, and the results were synthesized for determining the weights value of each criterion, to perform this operation a matrix was established for this aim, contain values of different variables based on their relative importance in contributing to flood risk in study area.

The Consistency Ratio (CR) is used to ensure the reliability of comparisons, a CR value less than 0.1 considered as acceptable consistency.

At this stage, the quantitative scale of significance developed by Saaty (1980) is adopted as:

Table 7: Quantitative scale for weights determination based on importance degree.

Importance	Numerical value
Equally important	1
Preference of one criterion over another	3
Strong preference for one criterion over the other	5
A very strong preference for one criterion over the other	7
Absolute preference of one criterion over the other	9
Intermediate values used between the previous weights	2 - 4 - 6 - 8

(Source: Saaty, T. L. 1980. *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. McGraw-Hill.)

Based on this, the pairwise comparison matrix for the criteria level is as follows:

Table 14: Pairwise comparison matrix for criteria levels.

Indicators	Distance to waterways (m)	Infiltration rate	Proximity to water bodies (m)	Topography (%)	Land use	Population density
Distance to waterways (m)	1	3	4	0,25	0,5	0,333333333
Infiltration rate	0,333333333	1	2	0,166666667	0,25	0,2
Proximity to water bodies (m)	0,25	0,5	1	0,142857143	0,2	0,166666667
Topography (%)	4	6	7	1	3	2
Land use	2	4	5	0,333333333	1	0,5
Population density	3	5	6	0,5	2	1
Total	10,58333333	19,5	25	2,392857143	6,95	4,2

(Source: Prepared by the researcher)

The resulting pairwise comparison matrices is used now to calculate weights for each criterion and sub-criterion, by dividing each of the pairwise comparison values by the sum of the one column, and then the average values are calculated to find the weights of the standards that have been worked on, which reflecting their significance in flood risk assessment, this is shown in Table 15:

Table 8: Calculation of criterion weights used in the analysis

Indicators	Distance to waterways (m)	Infiltration rate	Proximity to water bodies (m)	Topography (%)	Land use	Population density	Weight
Distance to waterways (m)	0,094488189	0,153846154	0,16	0,104477612	0,071942446	0,079365079	0,110687
Infiltration rate	0,031496063	0,051282051	0,08	0,069651741	0,035971223	0,047619048	0,05267
Proximity to water bodies (m)	0,023622047	0,025641026	0,04	0,059701493	0,028776978	0,03968254	0,036237
Topography (%)	0,377952756	0,307692308	0,28	0,417910448	0,431654676	0,476190476	0,3819
Land use	0,188976378	0,205128205	0,2	0,139303483	0,143884892	0,119047619	0,166057
Population density	0,283464567	0,256410256	0,24	0,208955224	0,287769784	0,238095238	0,252449
							1

(Source: Prepared by the researcher)

Weight (%)
11,06
5,2
3,62
38,19
16,6
25,24

1-2-3-Consistency check:

After calculating the weights, we must make sure that the weights are relevant and ensure consistency, by calculating the consistency coefficient, so that it does not exceed 0.1, and this is done by multiplying each weight and then extracting it from the previous (Table: 15), for weights in the values of all columns corresponding to it in (Table:14). Or by dividing this weight from (Table: 15) by all the values in the rows of (Table: 14), and inserting the obtained values into a new (Table: 16).

Then the sum values of the rows are calculated and divided by the weights calculated in (Table 15) to extract the Lmax coefficient.

Then the CI coefficient according to Equation (4.1), and then the RC coefficient is extracted through the data of the Saaty scale according to the number of criteria used in the analysis, then the RC coefficient is calculated by applying Equation (4.2) to confirm its value.

$$\mathrm{CI} = \frac{(\mathrm{Lmax} \; - \mathrm{n})}{(\mathrm{n} - 1)} \tag{4.1}$$

Table 9: Table of Thomas Saaty for Random Index calculation.

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: (Adapted from Saaty 1980).

Note that the consistency rate is a random indicator and these are constant values set by (Thomas Saaty 1980)

$$CR = \frac{CI}{RC} \tag{4.2}$$

Note that:

CR: Consistency Ratio

CI: Consistency Index

RC: Random Consistency

Applying the previously mentioned method, the consistency check table is as follows:

Table 10: Consistency check table.

	0,11068658	0,052670021	0,03623735	0,381900111	0,166056763	0,252449178			
Indicators	**Distance to waterways (m)**	**Infiltration rate**	**Proximity to water bodies (m)**	**Topography (%)**	**Land use**	**Population density**	**Total**	**Weight**	
Distance to waterways (m)	0,11068658	0,158010063	0,14494939	0,095475028	0,083028381	0,084149726	0,676299	0,110687	6,110038
Infiltration rate	0,036895527	0,052670021	0,07247469	0,063650018	0,041514191	0,050489836	0,317694	0,05267	6,031786
Proximity to water bodies (m)	0,027671645	0,026335011	0,03623735	0,054557159	0,033211353	0,042074863	0,220087	0,036237	6,073496
Topography (%)	0,44274632	0,316020126	0,25366143	0,381900111	0,498170288	0,504898356	2,397397	0,3819	6,277549
Land use	0,22137316	0,210680084	0,18118674	0,127300037	0,166056763	0,126224589	1,032821	0,166057	6,219689
Population density	0,33205974	0,263350105	0,21742408	0,190950055	0,332113526	0,252449178	1,588347	0,252449	6,291748

(Source: Prepared by the researcher)

Table 11: Values of previous indicators in the study.

Lmax	6,167384
CI	0,033477
RI	1,24
CR	0,026997

(Source: Prepared by the researcher)

The value of the CR coefficient in our case was equal to 0.026997, And it represents a ratio less than (0.1), therefore, the correlation has been confirmed through rigorous analysis, so the values of the weights can be relied on as efficient.

1-2-4-Processing of obtained criteria:

At this intermediate point, distance maps are derived according to development easements, and then the maps were reclassified according to a specific scale to determine the importance of each area in each criterion, through processing tools and represented by spatial analysis tools in ArcGIS program, where the scale adopted according to the importance degree of variables as: very low, low, medium, high, to very high. as shown in the table:

Table 12: Prioritizing categories by impact degree.

Distance to waterways (m)	From 0 to 5	Very high
	From 6 to 12	High
	From 13 to 20	Medium
	From 21 to 32	Low
	33 and more	Very low
Infiltration rate	Unsaturated Soil	Low
	Alluvial Soil	Medium
	Saline Soil	High
Proximity to water bodies (m)	From 0 to 20	Very high
	From 20 to 40	High
	From 40 to 60	Medium
	From 60 to 80	Low
	From 80 and more	Very low
Topography (%)	From 0 to 6	Very high
	From 6 to 12	High
	From 12 to 20	Medium
	From 20 to 30	Low
	From 30 and more	High
Land use	Urban areas	Very high
	Vegetative cover	Low
	Water	Very low
	Barren lands	Low
Population density	High residential density	Very high
	Medium residential density	High
	very low residential density	Medium
	No population density	Low

(Source: Prepared by the researcher)

1-2-5-Data sources for each criterion:

The map data was obtained from several sources, the most important of which is the preliminary map, which is the digital elevation model DEM, from the United States Geological Survey (USGS), with resolution of 30 m, which was adopted in hydrology, topography and slope study analysis.
After applying this approach, the maps for each criterion were obtained by combining the criteria taking into account the relative weight of each criterion according to the following equation (4.3):

$$\text{Main goal} = (\text{criterion}_{(1)} \text{ X weight}_{(1)}) + (\text{criterion}_{(2)} \text{ X weight}_{(2)}) + (\text{criterion}_{(n)} \text{ X weight}_{(n)}) \ldots \quad (4.3)$$

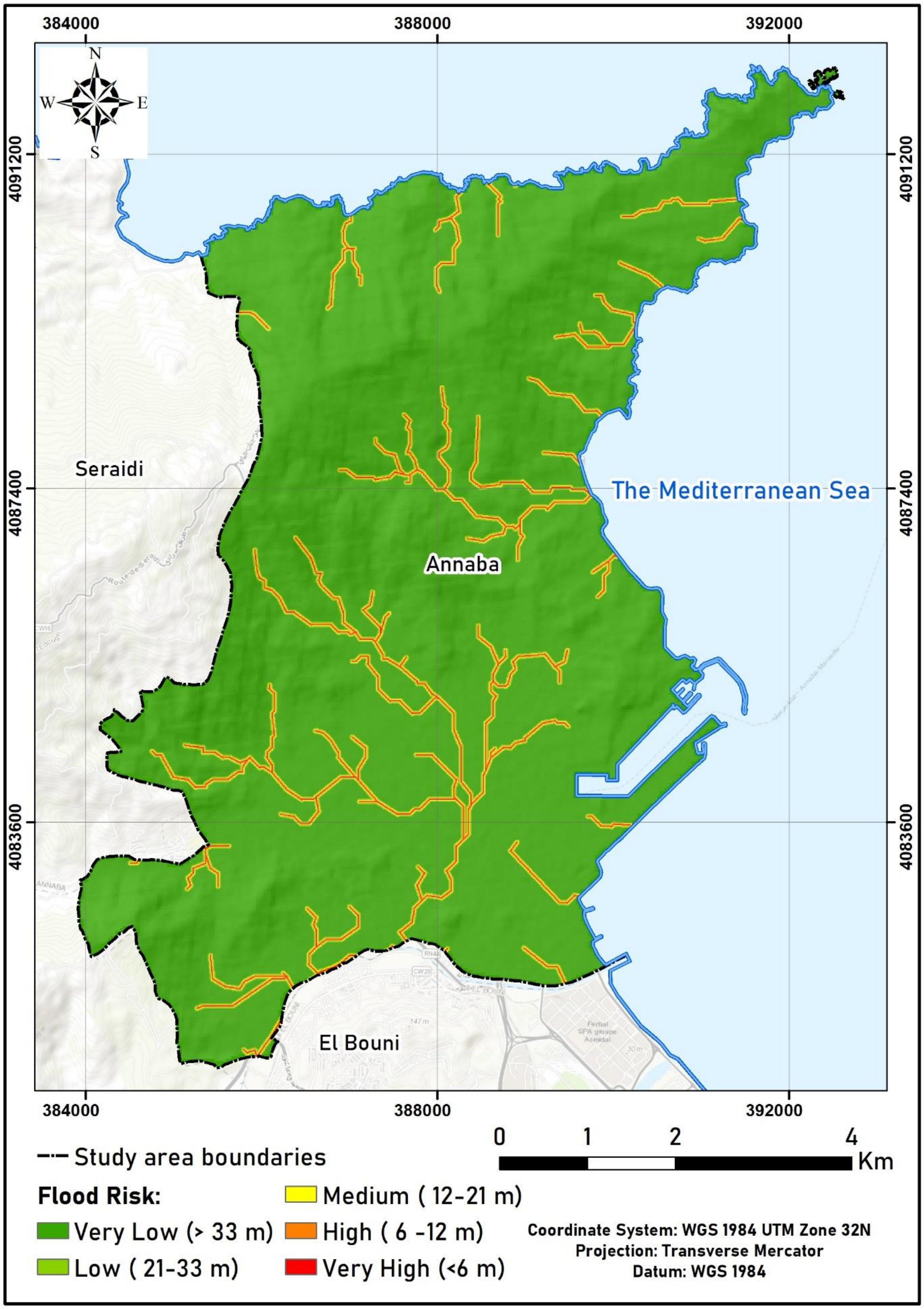
1-3-Flood risk mapping:

After the spatial analyst process, for the purpose of examining the hydrology and, consequently, the flood risk in the study area, and depending on the previous methods and stages, the final result was reached, that is the division of the area into sub-areas, each of which expresses a certain attitude towards the flood risk.

1-3-1-Distance to waterways criterion:

The distance factor to the watercourse is used as a determinant of the degree of exposure, therefore, it falls under the vulnerability category, these easements are often pertained to allowable distance between the buildings and watercourses.
These easements distance is typically depends on the Algerian legislature, this is subject to the law of easements, where it is determined the specific regulations and guidelines that dictate the legal distance for construction. Based on this, the distance map of the watercourse as represented in (Map: 9).
This spacing plays a significant role in flood risk prevention. Areas located close to streams may explain why they are generally more likelihood to flooding. As discussed, this is due to the fact that during heavy rains or storms, these waterways can overflow their banks, inundating nearby areas. The farther areas are from a waterway, the less likely it is to be directly affected by rising water levels and overflow. Nevertheless, even areas that supposed to be safe can be affected by floodings, if the overflow water accumulates in low-lying basins or travels down slopes. This is why studying the runoff behaviour and geomorphology is of a great importance in floodplains and drainage patterns for assessing flood risk, regardless of distance to a waterway.
This criterion is important in spatial and environmental planning to ensure that developments are sustainable and well-integrated into the existing environment. It can influence the environmental impact of areas close to watercourses in the city of Annaba, as these areas are often ecologically sensitive.

Map 9: Distance to waterways criterion map.



Source: (The researcher)

1-3-2-Infiltration rate criterion:

The infiltration rate serves as a key determinant in assessing flood risk, it controls the amount of water that escapes into the ground, and thus reduces the runoff. There are several factors that control the permeability ratio such as soil type, like sandy soil that increases permeability, therefore, this decreases the likelihood of floodings.
On the contrary, other soils types with a low infiltration rate in urban areas invariably results in significant acceleration in the formation of torrents. Regardless of soil quality, which already has a relatively low permeability coefficient, the most influential factor in increasing the speed and strength of runoff is the construction in urban areas, where the ground is covered with concrete and asphalt in most of perennial area as discussed previously.

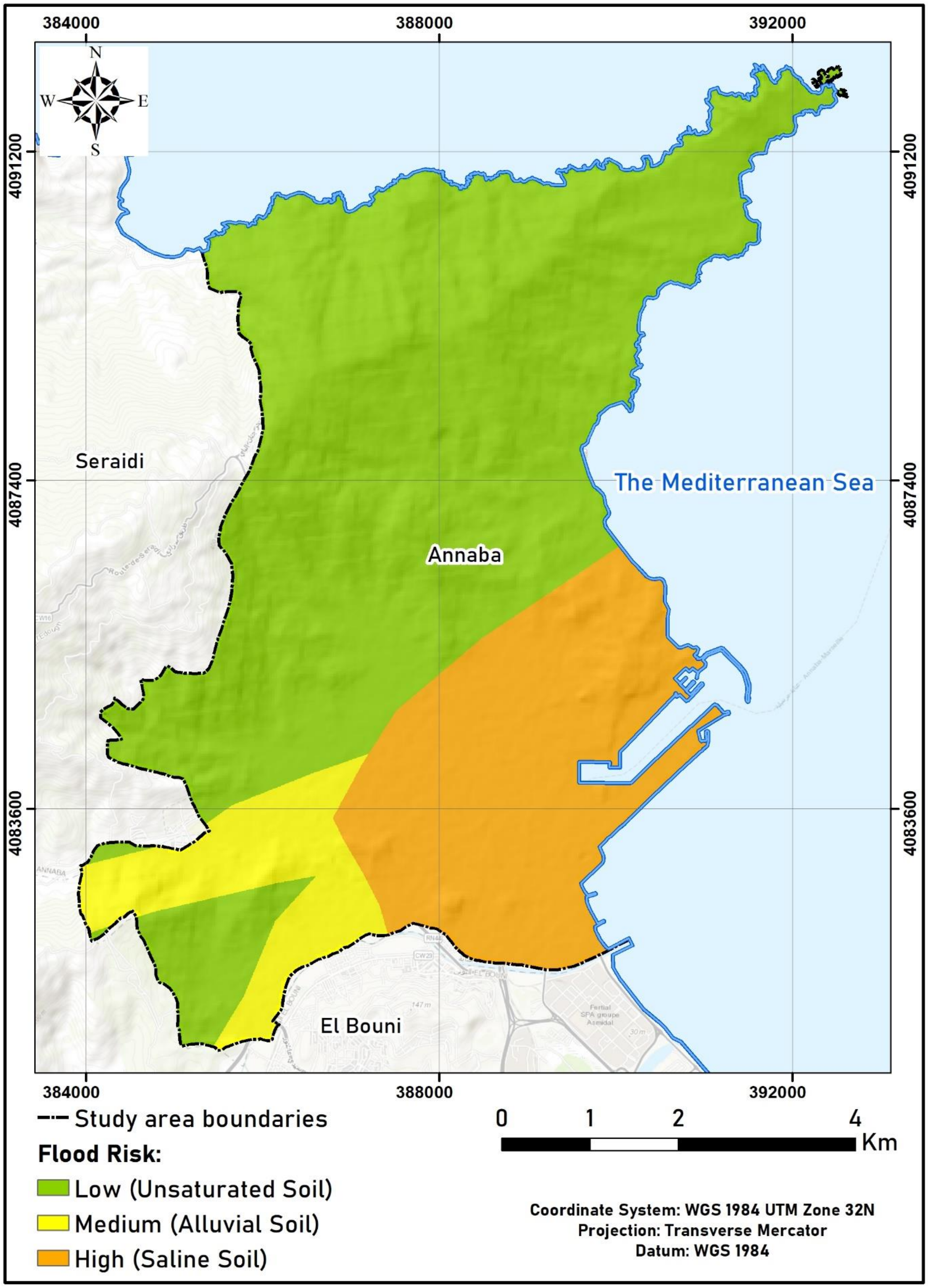
1-3-2-1-Mitigation and Adaptation Strategies:

In this instance, there is a near-total lack of green infrastructure and other means that raise the infiltration level, such as permeable pavements, rain gardens, that absolutely contributes to flood risk mitigation in Annaba City.
Considering the aspect of the physical environment, the risk map is made on a DEM background, and with the LANDSAT image, to demonstrate the characteristics and entities of watersheds, this type of data allows us to demonstrate the characteristics: topographic, (reliefs-slopes), land use, and vegetation cover, Therefore, there are three types of environments:
Stable environment: This upstream part has a good water infiltration, because of its relatively dense vegetation cover which acts as a runoff brake on the slopes of the Edough,
Medium stable environment: This medium corresponds to the watercourse or the runoff creating forms of erosion,
Unstable environment: In this type of environment the outcomes arising from the significant erosion rate are more visible on the landscape, this part represents a class of a large percentage, this class is located in the slope of the massif. The runoff effect causing the evacuation of a large solid load flows toward the collector.

1-3-2-2-The hydraulic control mechanisms:

It is important to emphasize that the hydrological and morphometric characteristics of a watercourse must be taken into account during any anthropogenic modification to avoid estimation errors. In addition, the management policy must be implemented at a more global level to improve its relevance, through the experiences exchange and the contribution to the financing of projects, such as the example of Europe (Flood Directive). With regard to flood risk management, it must be carried out at a watershed scale that passes through a complete region. However, in the case of Annaba, the establishment of policy takes place at the local level, because it pertains to a specific type of watershed (small) in Edough massif, according to history and particularly on the reference event, for example, that of 1982. This necessitated the development of canals (Belt and Kaf N'sour) to divert the course of the valleys as a strategy to flood prevention, and we have previously pointed out that these measures have failed on several occasions, most notably in the 2005 event.

Map 10: Soil types for Infiltration rate criterion.



Source: (The researcher 2024)

1-3-3-Proximity to water bodies criterion:

Since Annaba is recognized as a coastal city, this needs to be considered because it is an important element in flood risk analysis in coastal and near-coastal regions. As this factor affects several levels, most notably are: influence of sea-level dynamics, storm surge, tidal fluctuations, and coastal erosion. Due to the flat topography of the Annaba region, it is more threatened by this factor, because Low-lying coastal areas are susceptible to flooding from storm surges, as previously outlined, some regions exist at altitudes lower than sea level, it's about the neighbourhoods of southeast of the city such as: Oued D'heb that affects the vulnerability to storm surges and coastal floods, due to experiences from previous events, this demonstrates that the uncertainty factor necessitates consideration of all available options, due to exceptional events that are usually explained by experts as being related to climate change.

1-3-3-1-The efficiency in criterion selection:

This criterion has the potential to trigger coastal flooding when seawater inundates land areas along the coastal strip, primarily as a result of storm surges, high tides, and sea-level rise. Proximity to water bodies, such as the sea in our case of instance, as a possibility of increasing flood risk that should not be neglected in adjacent coast although, such event has never taken place in Annaba city, but it should be considered in the planning process because we are dealing with a non-stationary world. These floods can result of extreme events like heavy rains, which generate storm surges that leads to a rise in water levels. Moreover, climate change-induced sea-level rise exacerbates an increase in intensity of flooding and the convergence in return periods of coastal floods. Which leaves a huge impact on human settlements and ecosystems, necessitating adaptive strategies to mitigate such kind of risk and increase the resilience against this event.

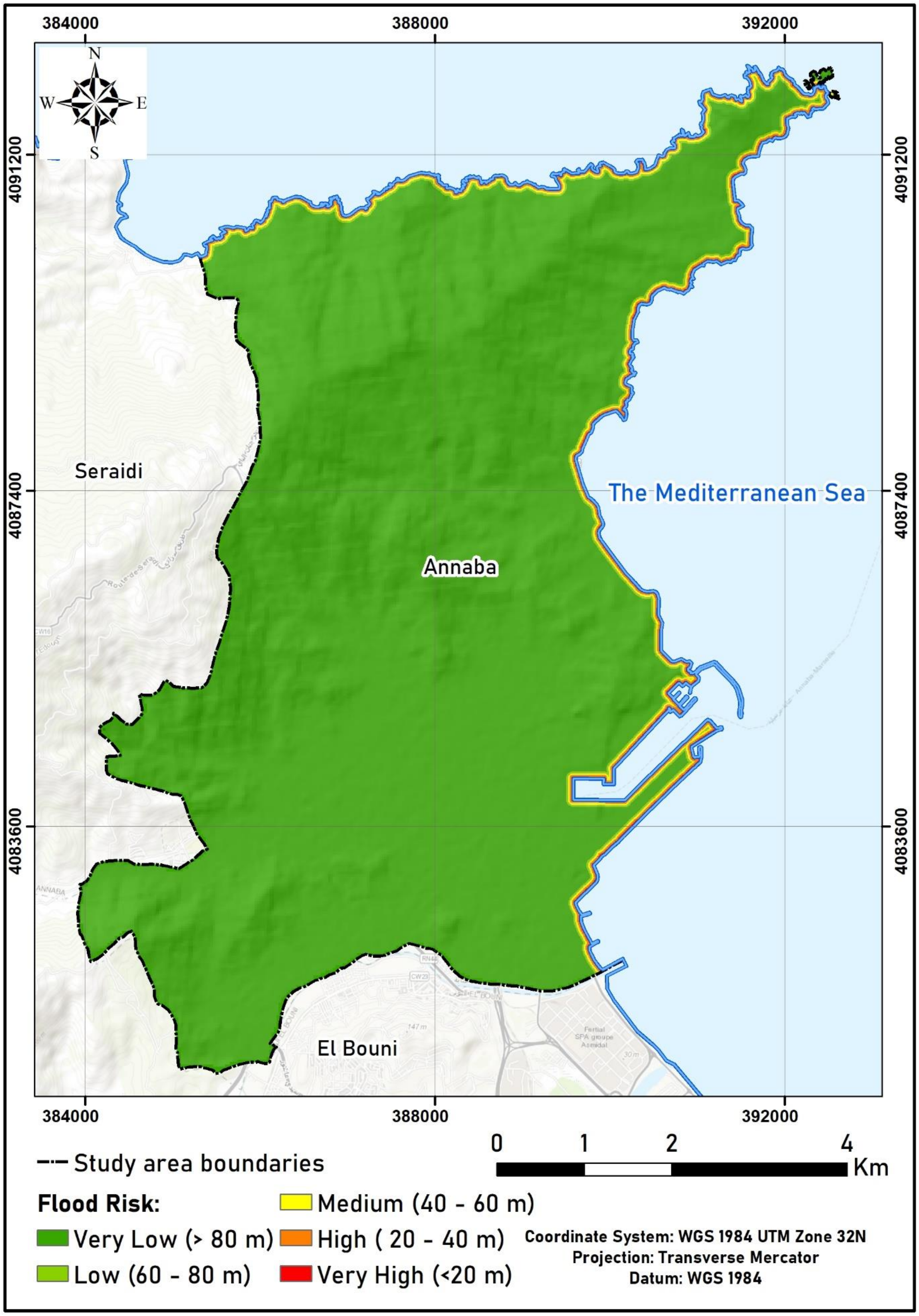
1-3-3-2- The weighting of criterion in evaluation:

The weights assigned to this criterion are subject to change depending on a variety of contexts, in our study on the flood risks evaluation, the proximity to water bodies was assigned a weight of 0,036237 out of 0.01, indicating a high importance in the risk assessment in the study area.

By combining this criterion with the other criteria, to obtain a more precise assessment (a total of 0,220087), it gives a relevant result in the flood risk assessment. in our case study, we used 6 criteria to assess the risks of flooding, including proximity to water bodies.

After pairwise comparison, the proximity to the water bodies is analysed alongside with other criteria using a pairwise comparison matrix. the assignment of relative importance values based on expert judgments and empirical data that demonstrate the absence of significant impact of this criterion in our case of study, and its weight reflects its relative importance in the overall assessment of flood risk, but this does not prevent it from being taken into account, because the risk assessment is always subject to uncertainty, this assessment will make it possible to prioritize at risk areas, and make informed decisions for flood management and prevention in our study area.

Map 11: Proximity to water bodies (The sea) criterion



Source: (The researcher 2024)

1-4-Topography criterion evaluation:

In the present case, the topographical factor plays an essential role in determining the risk of flooding, Due to the primarily flat topographical features that define the city of Annaba, as highlighted in the section detailing the study area, specifically in the slope map, which shows that most of the city's area falls in the weak slope category. Topography is a main item in flood risk assessment, in addition to many other various factors discussed in this study, which contribute to the overall flood risk. This factor is logically very high ranked and further evidence of this is that it has a weight of 0.3819 out of 1, the highest weight among the other criteria in our case study (Table 15).

This criterion can include several sub-criteria, the most important of which are:

Typically, the higher elevation areas obviously considered to have a lower probability of flooding, although have a higher construction cost. furthermore, the slopes increase the runoff, on the other hand, a less likely to standing water which causes the floods by water rising, occurs after the repetition of rainy episodes in a flat topography zone like the case of Annaba city. also, the slope direction plays an important role in the exposure to influential factors such as sunlight and wind, which control the evaporation process rates impacting flood potential.

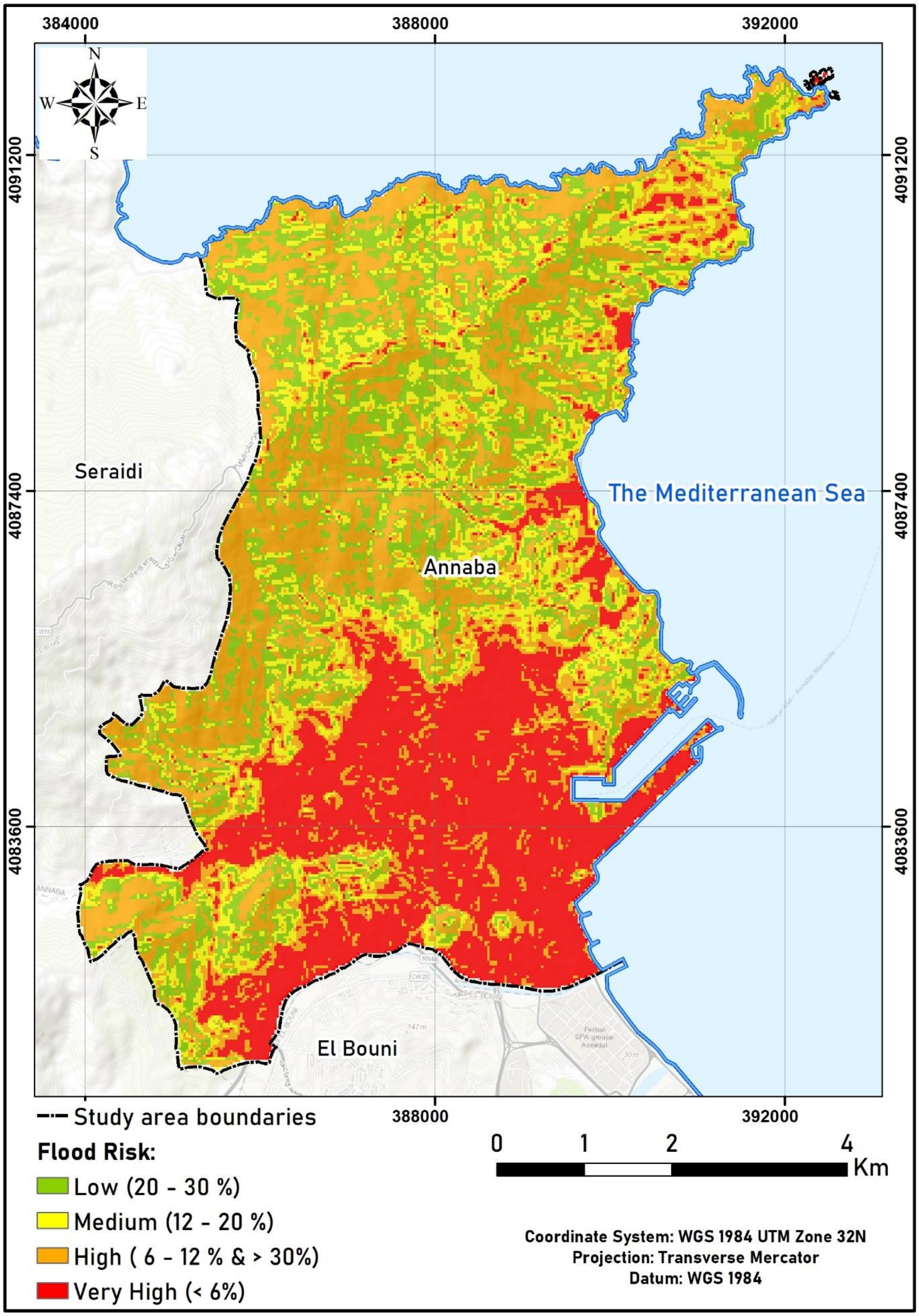
1-4-1-Need for topography in non-structural measures adoption:

Based on the topographical factor, preventive measures have been taken to prevent flooding, by making adjustments to the hydrographic network by diverting each of the valleys: Bouhdid, Boujemaa, and Seybouse, to take a new hydrographic network configuration, which poses the possibility of overflowing in the case of exceptional events.

The topographic study contributes to the programming of structural measures such as Works of protection against the risk of flooding, in our case the belt canal which connects the wadi Bouhdid and S-Harb with the wadi Boudjemaa, is an open channel that runs through the entire Sothern west of the city, this work is in unfinished poured concrete with a roughness coefficient of (k) is on average 0.5 mm, it is intended to evacuate the quantity of running water from wadi Bouhdid and Sidi Harb to the wadi Boudjemaa. The hydrological behaviour of the wadis is calculated through flows and return period, besides the hydraulic behaviour through the speed and water level.

The topography of the hydrographic network that drains the city of Annaba is marked by a configuration of the watersheds that defined by a steep slope upstream, and with a low slope downstream, so it generates fast-type of floods on areas located in places where the dip is strong and the slow type downstream (the plains).

Map 12: Slope map and topography criterion.



Source: (The researcher 2024)

1-5-Land use as a determinant criterion:

As outlined before, the AHP is used to assesses and prioritize various variables contributing to flood generation, land use considered as a main factor in this process, that involves the confluence of the natural factor with the human factor, unlike other factors, so the land use has a dual effect when interacting with all other sub-criterions, this is shown in Pairwise Comparisons which reflect the hierarchy level.

In our case, the proportion of urbanized area represents the majority of Annaba province, which increases the amount of exposure, which automatically increases the vulnerability, and this is given in final score for weights.

Where its effect is seen in contributing to higher runoff by lower infiltration, conversely in forest and agricultural lands where the probability of flood risk is reduced through water retention and high infiltration by absorbing floodwater**.**

1-5-1-land use dynamics in the Edough massif:

Subsequent to land use evolution mapping within Annaba city, this map serves as a significant source to make a numerical floods simulation. And the spatial modifications on the water flow conditions. The hydrological analysis of Annaba city is based on the GIS tool. Through a Diachronic Mapping of land use, which shows the dynamics of land use in Edough massif, this mapping is one of the essential elements in the management development and urban planning tools, in our case, we used this map in the identification of historical evolution of flood risk in the city of Annaba, to be taken into account in hydrological analysis of the study area,

The analysis of land use map of the territory of Annaba shows that throughout its recent history the urbanization rate has been high compared to national rate, on the other hand the development policy was opened after independence, and this explains the gravity of the events affecting the city. After the city extends to the west. An urbanization that follows the road axis to the south-west, the rest of the map represents bare soils that are at the massif foothill and vegetation cover (trees, and brushwood) where all types of land use are delineated according to the map**.**

1-5-2-Land use contribution to vulnerability assessment:

The vulnerability can be explained on two contexts, physical (structural) and socio-economic, it depends on exposure degree of stakes to the hazard (social), therefore, the representation of vulnerability is closely linked to the land use, whereas, the hazard potential damage varies according to the specificity of the area most likely to be affected by floods, that can be high in a dense urban tissue, and medium in an industrial area, and low in open and green spaces.

We relied on the changes that occurred on the territory of Annaba agglomeration on its history according to the available land use maps, to analyse the strategic orientations of urban territory management in Annaba city. Based on LandSAT images from two different periods. The purpose of this operation is to obtain the contents of the maps in the form of data representing a comparison of territory state, studied during two specific periods, which shows the modifications that have occurred on the space and the distribution of the stakes and occupation of land (vegetation cover, urban areas, bare soil).

Deforestation and vegetation loss of cover around Annaba reduces the ability of the soil to absorb water. The roots of trees and other plants play an important role in water absorption and soil stabilization (Hartmann, Slavíková, & McCarthy, 2019). Their loss increases erosion and faster runoff, thereby, increasing the likelihood of flooding.

We can classify the land use formations into:

The land use map Shows the changes that have occurred on the space including the degradation of vegetation cover and urban expansion on spaces often containing natural easements. The vegetation cover is distributed in (forests and scrub, clear and dense and in reforestation).

1-5-3- Spatial dynamics of agglomerations:

The urban increase known in Annaba agglomeration during the last years was in the form of urban extension on spaces often containing natural easements, because of the need for land for construction. This intervention on the space and the modifications that follow, due to installation of infrastructure. The period that knows the greatest rate of increase is that of the 70s and 80s, and this explained by the attractiveness of Annaba city, due to the functions and activities of the city, and the high natural growth rate, therefore, in Annaba, urban expansion towards risk areas should be carefully planned and regulated.

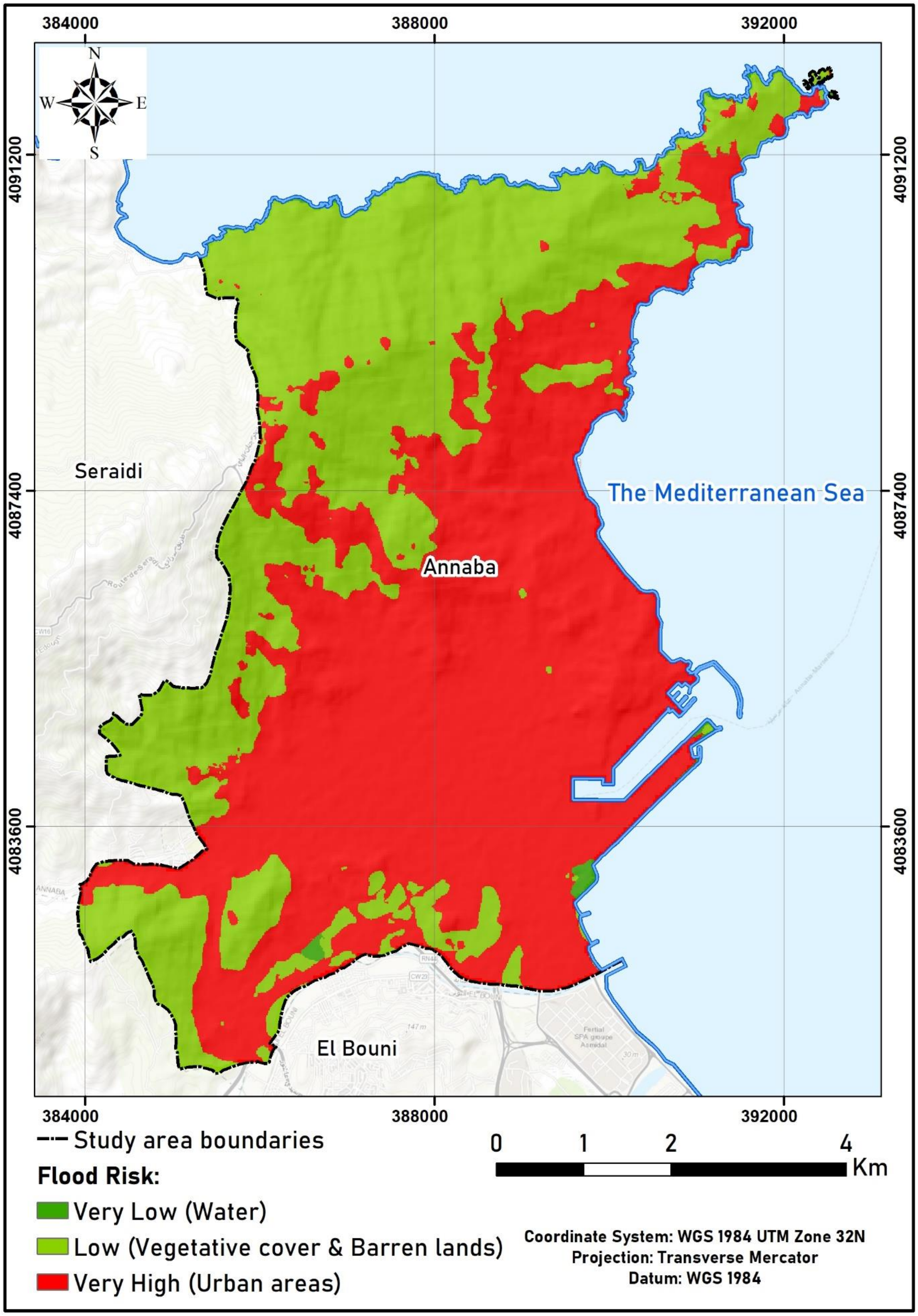
Within the scope of our study, the findings from the survey revealed that 91.1% did not know about flood susceptibility of their place of residence, a clear indication that the local authorities who gave the permission to build in these areas are primarily responsible for this, while 8.6% were aware of the exposure of their neighbourhoods to this risk, which is evidence that this group is aware of the risk of flooding while they still occupy these areas. Human-induced geographical change must be subject to planning controls, and any construction in areas at risk of flooding must be subject to serious consequences in the case of exceptional events.

1-5-4-Asymmetrical deployment of urban fabric:

An examination of land use distinctly reveals a defined functional and structural asymmetry, with urban development that is more compact in the north, with more spread out in the south. This asymmetry is reflected an urban development in the western part of the site which are considered as more susceptible to risk of flooding, such as the neighbourhoods of the western plain, while the eastern part, dedicated to industrial and airport activities, appears relatively empty.

This asymmetrical and eccentric distribution results in a lack of cross-connections between east and west, in a marked contrast to the densification of links between north and south. This leads to a phenomenon of polarisation and the lack of ring roads on the outskirts. This configuration can exacerbate the risk of flooding, as the urban areas, which are particularly compact in the north, increases the soil permeability, as well as water run-off. On the other hand, the less dense areas to the south, despite their apparent dispersal, may lack the infrastructure needed to effectively manage the rainwater, thereby increasing the flood vulnerability of the whole area.

Map 13: Land use map (Anthropization criterion).



Source: (The researcher 2024)

1-6-Population density criterion:

In this study, population density is identified as a pivotal factor in shaping flood risk dynamics, the impact of this criterion is evident throughout the overall decision-making framework. and this is systematically giving a broader view and a relative importance of flood risk management process.

Based on the zoning on the map, highly populated areas density has impervious surfaces than increases the runoff and foldability, Additionally, a high population density which leads to a significant vulnerability level, these areas are concentrated in the city centre and neighbourhoods with a collective character of housing. Another category includes areas with low density, and it concerns suburbs and peri-urban areas.

This weight in AHP method indicate the relative impact of human factor in likelihood of casualties in the exceptional events, due to high exposure and thus the vulnerability.

1-6-1-Population density and flood risk generation:

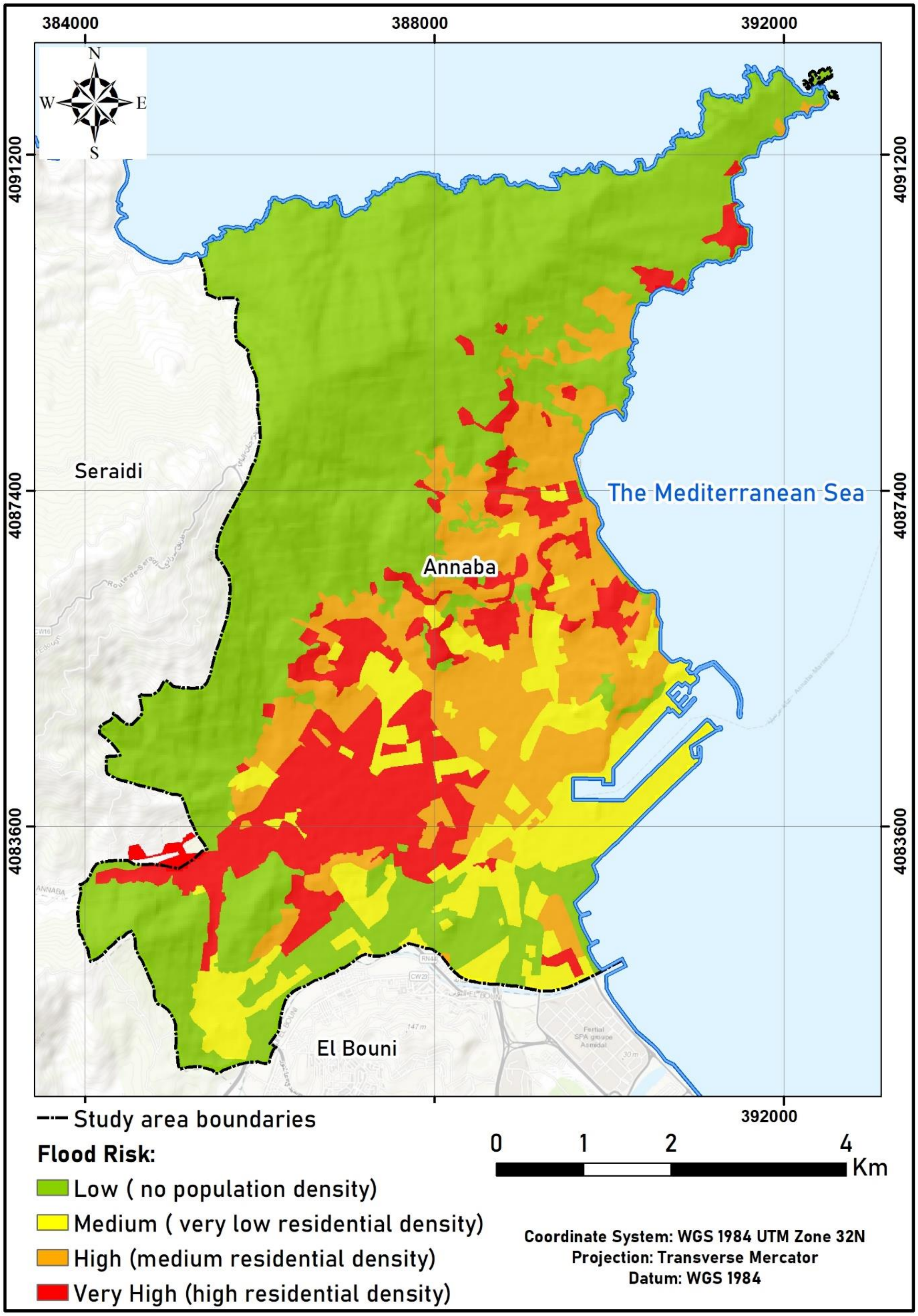
With a high population density, the drainage infrastructure and the water evacuation systems are overloaded during rain events, In Annaba, the drainage infrastructure in several parts of the city is poorly maintained and lacks the capacity to effectively manage water flow, posing risks to public safety, so the network will quickly be overwhelmed by intense rainfall, resulting in flooding with urban expansion to at risk areas without adequate planning could increase the social vulnerability. on the other hand, the high population density also led to inefficient waste management. waste materials in most cases have been the cause of clogging drainage systems and waterways, preventing the water flow and exacerbating flooding. moreover, due to the high population density, the evacuation operation and emergency interventions in case of flood disasters is more challenging because of the congestion of roads and the infrastructures are saturated in this case, this situation hinders the rescue efforts and increase the risks for the population in Annaba city.

1-6-2-Using exposure data to vulnerability mitigation:

This analysis is used to determine the feedback from these events in order to identify the exposed issues to the risk of flooding. Assuming that all the issues are linked to the set of exposed inhabitants to flood zones, so in the case of Annaba city, it represents the working-class neighbourhoods with a significant population density, such as the low-lying areas of the Western plain, Wadi Dhab, La Colonne, and the 1 May neighbourhoods, and the National Road n ° 44 connect Annaba to Barahal, with the equipment and infrastructures of significant value, this type of data must be integrated into a Master Plan for Flooding.

The purpose of this scheme is to delimit the flood markers as historical level witnesses as well as the date of past major floods, in order to improve the studies of the expertise on the floods, and to transmit a collective memory of risk to the citizen and convince them to know how to live with the floods, and the slowing down of flood dynamics, and also for the realization of PCS (flooding).

Map 14: Population density map (exposition)



Source: (The researcher 2024).

1-7-Flood risk map establishment:

After synthesizing the various determinant factors to the risk of floodings, the overall approach to undertaking this task is executed through the use of the final scores for different criterions weights, along with the necessary geospatial data. using ArcGIS software to superimpose and analyse the different maps that represent the intermediate variables that contribute to flood risk genesis. We getting the final map that indicates the risk areas with different levels. this method of creating the flood risk map allows a structured and multi-criteria risk zoning assessment, with the integration of expert judgments with geospatial data to obtain a reliable and efficient map for flood risk assessment. that can guide mitigation strategies, prioritizing areas with higher combined scores.

1-7-1-Stages of determining the flood risk mapping:

This operation is done by overlaying the maps of the human material stakes, and the assessment of vulnerability to obtain the maps of the material and human damages, and ultimately, a composite risk map. According to this map, 3 levels of risk have been identified in the study area:

Red zone: A high-risk area, these areas are highly exposed to the risk of flooding, where catastrophic losses can occur, these areas are theoretically considered unsuitable for development, it represents a vast portion of the total area of the municipality.

Blue zone: This area is less exposed to the risk of flooding, or with a medium risk, this area is conditionally buildable.

Yellow zone: this zone is with a low risk, viable for development, this category is the most dominant territory of the city.

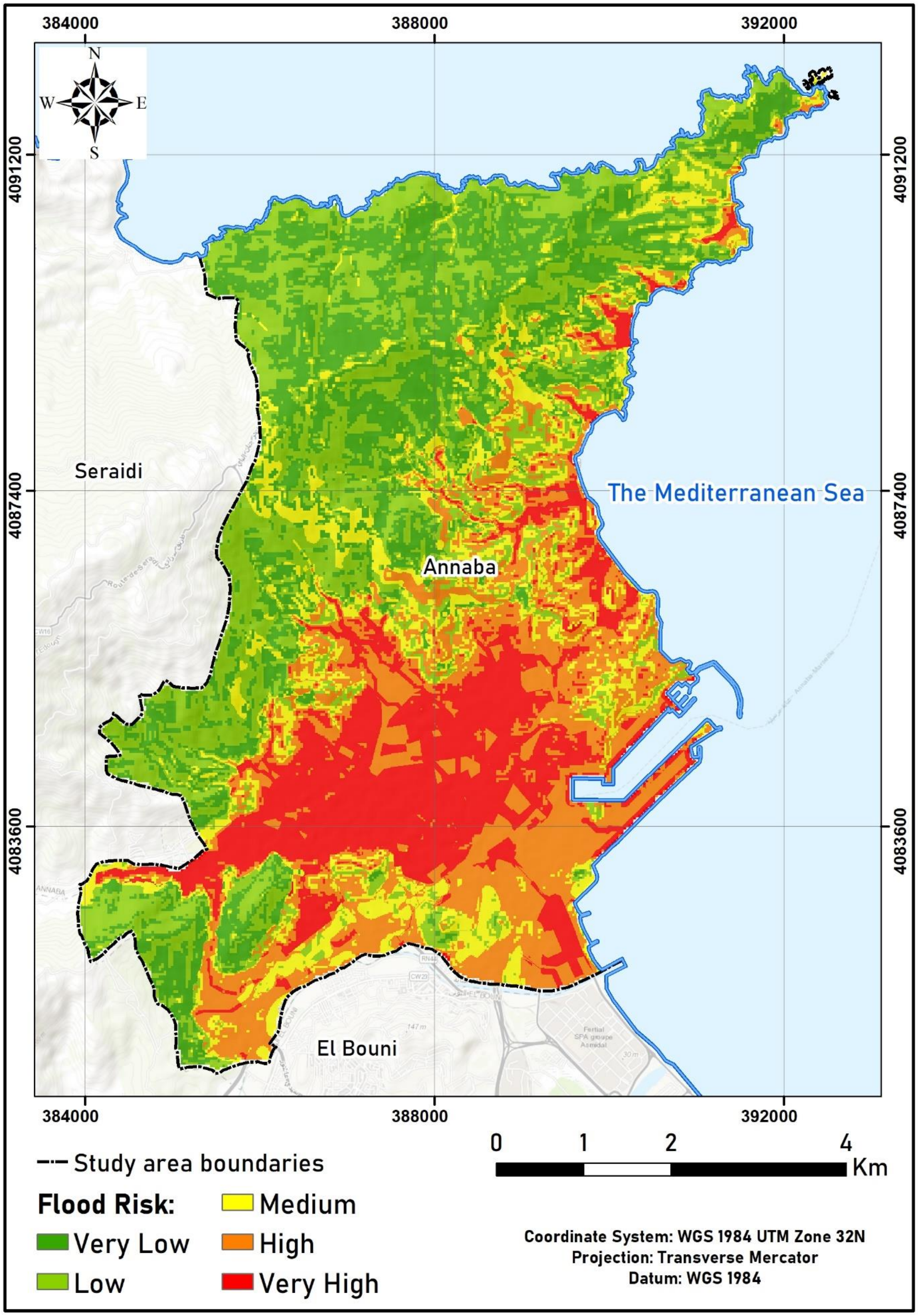
1-7-2- Delineation of flood risk zones:

As is widely recognized, the flood risk map is a result of overlaying of hazard maps created using geospatial data from the AHP analysis, with vulnerability mapping to obtain a map by which we can distinguish the areas where the risk of flooding has 3 main levels: very low, low, medium, high, and very high.

The classification of hazard levels and vulnerability has been distinguished as a very strong flood hazard at the level of Wadi Dhab, and the western plain, while the vulnerability is increasingly concentrated in, and exacerbated within, the areas of Wadi Kouba and La Colonne, the channels of the wadi Bouhdid, S-Harb, and Wadi Forcha, and these tributaries have undergone modifications due to urbanization causing overflows and anomalies due to the inability to evacuate quantity of water from the canals and drained surface.

In addition to the landscape anarchy, several settlements with a dense urban fabric have not taken into account the hydrographic network easements, which represents a risk to human life and property and has a negative impact on the environment. The map also represents places with a low risk corresponding to the non-urbanized areas (urban pockets, green spaces ...) and also the buildings located on non-flood zones. With the help of the GIS tool, a flood simulation was established, to demonstrate the valleys overflows (natural and artificial) and furthermore the known failure in sewerage network.

Map 15: Flood risk map based on multicriteria method.



Source: (The researcher 2024)

2-Findings from the field investigation

The aim of this initiative is to understand the risks perception and the effectiveness of management measures via a questionnaire contains closed questions for quantitative data and open questions for qualitative data. The sample selection is representative of the population concerned and determine the mode of distribution in person. Collecting the responses and analysing the data is done using statistical tools to identify trends and dominant opinions. Its purpose is to evaluate the current policies in flood risk management, after assessing the risk using the hierarchical analysis method AHP, which has proven to be effective in assessing the risk by integrating several criteria, including demographic and not only natural hazard as a reference.

2-1-Data processing in research:

To obtain reliable results, non-responses must be ignored during the survey development and processing phases (S. Roux, Jimmy Armoogum 2008), the data processing was done according to the objectivity of the answers, then the classification of the answers according to the questions that has a typical answer, (closed question) and the other of the open questions that offers the advantage of breaking down the typical responses to use as testimonials.

Table 20: Survey question and targeted parameters.:

Variable	Question
FR in neighbourhood	your neighbourhood, is it concerned by the risk of flooding?
Worry of FR	do you think the risk of flooding is a matter of concern?
FR awareness	have you been warned of flood by local actors?
Flood behaviour	in recent years, have you noticed a change in flood behaviour?
Exposure plan, and rescue plan	have you heard of a risk exposure plan, and rescue plan?
Risk information	have you been alerted to FR by authorities?
Alert evaluation	how do you rate the alert?
Vulnerable persons	do you have vulnerable persons in your household?
Sustainable development	have you ever heard of sustainable development?
Emergency numbers	do you know the emergency numbers?
Lived events	have you ever experienced catastrophic events in your city?
Construction vulnerability	have you ever done a building vulnerability diagnostic before?
Liability for damage	who is responsible for the damage in case of flooding?
Evaluation of measures	What do you think the risk prevention measures are?
Evacuation	do you think that the evacuation of inhabitants is necessary?
Cleaning of drainage canals	are the drainage canals cleaned before the rainy season?

Source: (The researcher 2023)

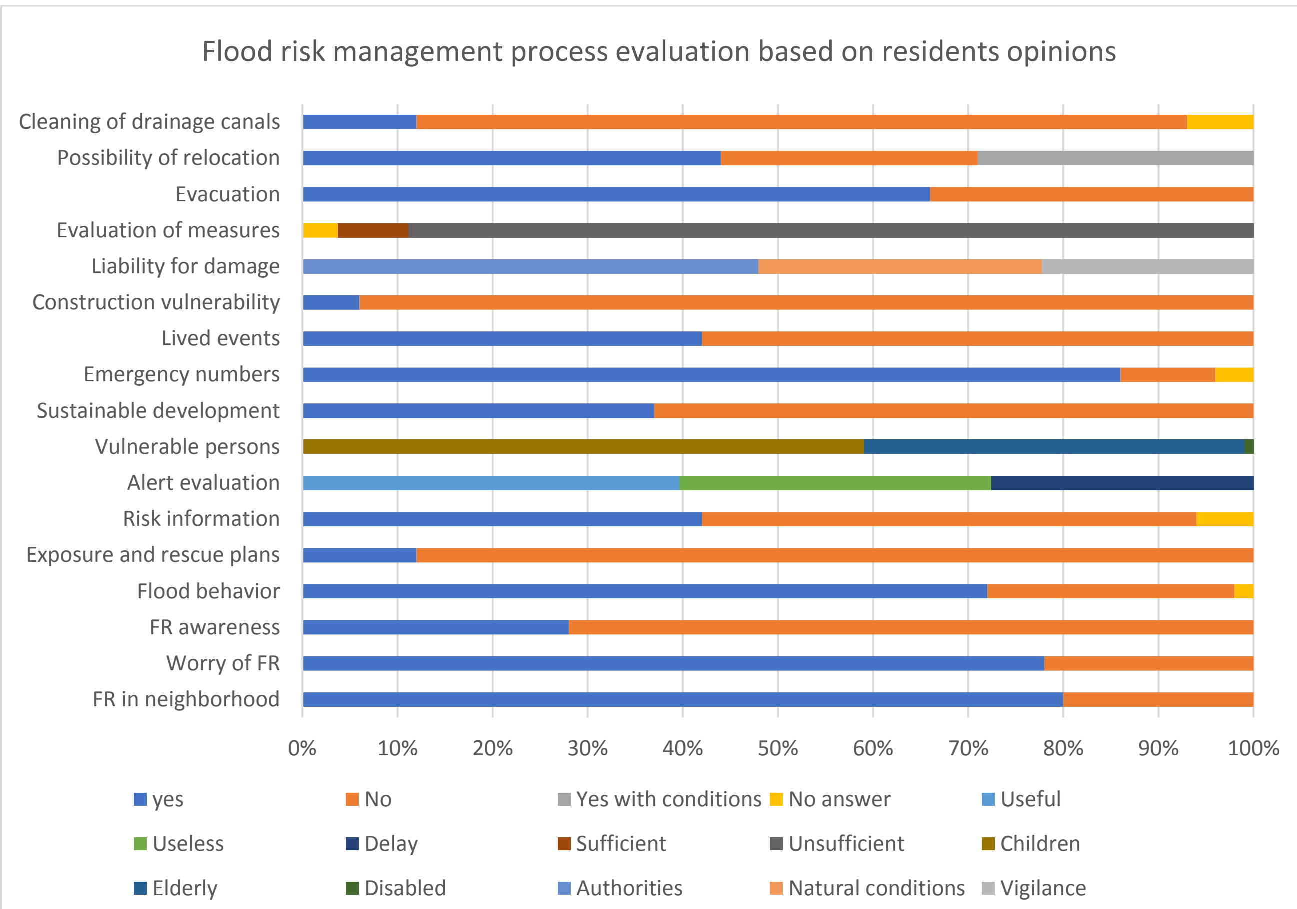
2-2- Lived perception and memory:

Considering that risk assessment is a multifaceted and interrelated process, since the conditions surrounding events are not the same in all cases, even in the same territory, we structured our questionnaire upon the last phase of risk, it is about direct contact with citizens, and its vision of the hazard. This survey is based on the knowledge of risk culture level to the citizen, and its acceptability, and his perception on the risk memory, only a small percentage feel that they are threatened with a feeling of insecurity.

As a preventive measure, a substantial segment of residents answered by going upstairs to protect themselves from the rising floodwater, and this is what is recommended as a precautionary measure. As a result, the responses show that residents of upstream neighbourhoods have less experience of handling risk than those who live downstream.

An open-ended question may lead to numerous varying responses, and consequently, multiple possible points of view which translates into artificial texts, and must therefore be treated and analysed in order not to deviate from the objectives of the survey which is the estimation of risk culture to the citizen (LEBART, 2001)

Figure 26: Stacked bar chart of flood risk management based on field survey.



Source: The researcher 2023)

A significant number of the population occupying the risk areas consider the risk of flooding as a source of concern that can lead to social repercussions and potentially result in economic issues, certain ones may have already experienced events, and this is explained by the acquired confidence and the ability to live with the risk. Along with other respondents which believe that the floods of 2012 are the most aggravating, but the older category cite the event of 1982 as the most devastating with bad memories on it. The vast majority of citizens do not have insurance against natural disasters, and they do not accept the idea of moving to other safer places, because of the attachment of these places of residence and a fairly developed sense of belonging.

2-3-Synthesis of technical and social results

The synthesis of the technical and social outcomes serves as the foundation for a mixed approach between a multi-criteria analysis and a field survey, for a decision support in flood risk management. The integration of this analysis and the social survey offers a holistic approach to flood risk management, this approach allows technical and social priorities to be combined in order to select the most appropriate management measures, to improve the decision-making process and promote community resilience.

2-3-1- Evaluation of authority performance in flood risk management:

Preventive risk information is a fundamental aspect of risk management strategies, it enables to reduce and addressing the maximum potential damage, it represents a fundamental right that should be guaranteed by law, because poor risk information increases destructibility during an event (National Research Council, 1989). Our questioning was about the knowledge of preventive risk tools and their applications by local actors, and the knowledge of the actors involved in relief, most think that civil protection is the only risk management actor in their words.

The findings of the survey now provide evidence that a large portion of the population does not know where to find out in case of potential risk due to the lack of risk culture,

Generally, it is also the local authorities who are responsible for the risk prevention action, because of this, a large part of the population is dissatisfied with the way the APC is conducted for flood risk management. Whereas, a small category of respondents to this topic in the survey suggested some measures addressed the development of banks and valleys damming, and by retention pond in upstream and the maintenance of existing structures, this issue is unknown to some people who do not know the protection measures.

2-3-2-Analysis of qualitative results:

The review of the survey findings reveals an exploitable outcome, extracted from raw data in the form of a statistical analysis sheet. After highlighting the main explanatory variables, the native responders know better the details and the flood risk behaviour in their neighbourhood and its intervals of occurrence during the year, especially the elderly compared to the young people have less awareness of the risk and vulnerability.

2-3-3-Perception and feelings explanation:

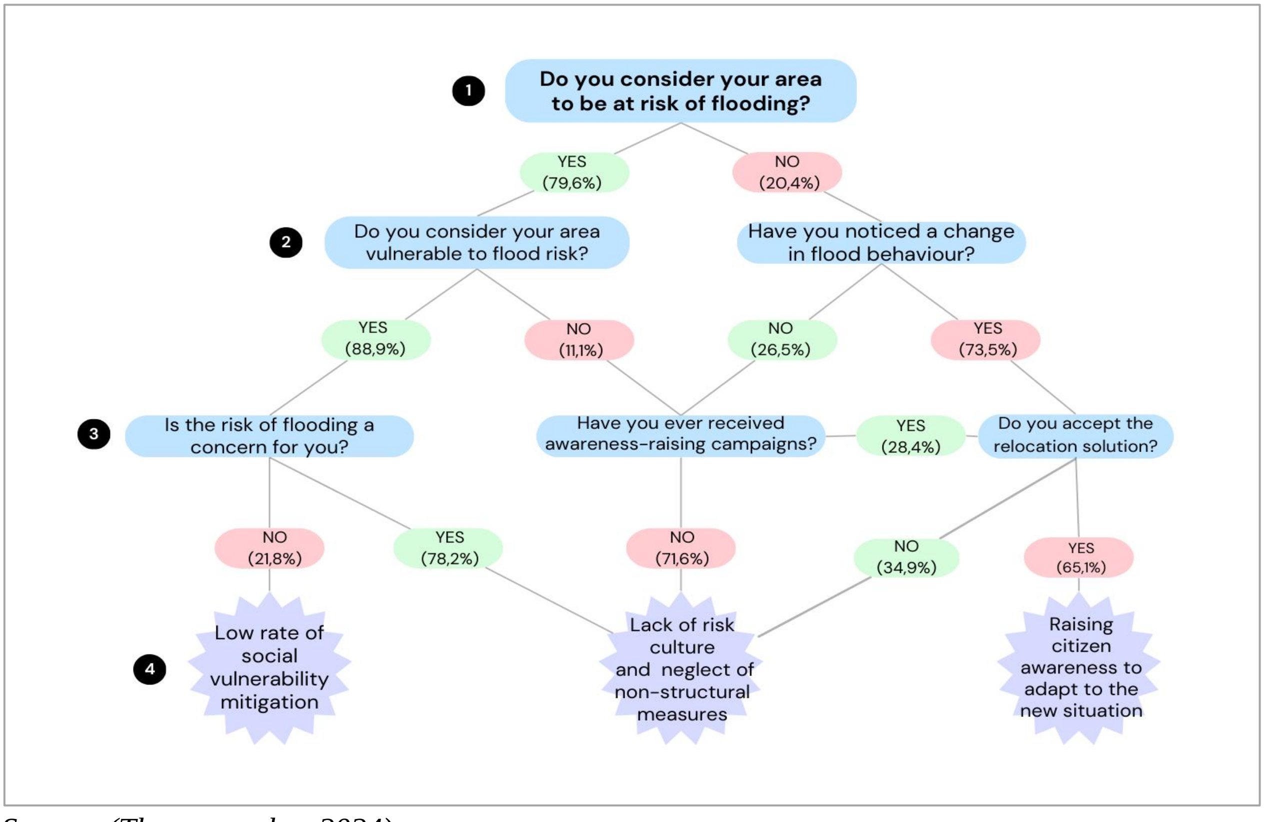
The risks perception is intricately reflected within the reaction in the disaster event. This risk perception is based on the flood risk identification and assessment. It depends on their distribution over the territory and the age of the people exposed to the risk, young people see it as a threat, on the other hand the category of elderly people sees it as a natural phenomenon.

The majority of respondents replied that floods probability of occurrence is higher in the months of September until January, because of the characteristics of intense rains type during this period, this explains the vigilance and the good knowledge of the temporality of risk.

Almost half of the exposed population have a poor acceptability of answering our questions, among the causes that create this feeling of insecurity is the comfort and the standard of living that make the population more sensitive to natural phenomena, which makes the comparison between historical events more difficult because the stakes and vulnerability are perpetually subject to change. On the other hand, this phenomenon is less common in neighbourhoods where there is a lack of services.

Although, the floods leave a bad impression for the memory of population, especially for those who have already experienced major natural events, it is worth discussing these interesting facts revealed that this population is poorly prepared for catastrophic events, and they do not accept the idea of leaving their homes, because of the commitment to their neighbourhood. From the question of responsibility risk, most of the answers were focused on the state and the municipality as those directly responsible for the risk due to the flood.

Figure 27: Decision tree for role of risk culture in mitigation.



Source: (The researcher 2024).

To present the survey results, we have opted to implement a decision tree as a tool used in various fields of statistics as a visual representation like a mirror of decision-making support processes, based on data by modelling the relevance between variables. (Figure 27) represents an illustration of a decision tree representing a portion of the survey findings regarding the correlation between social vulnerability and awareness. The questions are arranged in a logical sequence that ensures an effective analysis of the reality of risk management in the study area. The findings confirm the idea that when citizens are actively involved in the decision-making process, it can effectively mitigate the negative impacts of flood risk. This technique serves as a comprehensive method for controlling such natural disasters.

2-3-4- Critical analysis of structural measures:

Since the 1970s, hydraulic modification works have been programmed, this policy has been adopted with the aim of protecting agglomerations located in areas exposed to flood risk such as the belt canal, and Kef N'sour. after the evaluation of the structural measures taken by the management actors in the framework of the fight against the risk of floods, the relevance of these works depends on floods degree of resistance with regard to these infrastructures, and the measures adopted in its realization to be resistant to the most frequent hazards. The major events, in other words, the reference events represent an element through which an evaluation of the measurements is made, in the case of failure, a new intervention is necessary to address the issue.

2-3-4-1-Structural measures in face of large-scale events:

Focussing on the current management policies, these measures should be designed to adapt as much as possible to major and exceptional events, whose hydrometeorological characteristics are extreme, this can be determined by examining the history of past events, characterized by its return period, generally centennial, (the chance of occurrence is once in 100 years). In our case of instance, the hydro-geomorphological method and the Highest Known Water Method are used in the identification of flood zones, the first method allows the creation of a map of flood zoning, the first method is influenced by anthropogenic intervention on the ground, by development (the building and the hydraulic works) which affect the force of event, in this case, the second method give more accurate results. In addition to the water level, there are several other factors that must be observed in the process such as the speed of the floods and the duration of submersion.

2-3-4-2- Territorial exposure to large-scale hazards:

According to the above, large parts of the city are exposed to flood risks, The diversity of issues revealed is explained by the variation in urban fabrics, which is influenced by the historical evolution of the city of Annaba, and the social specificities of each part of the city. The identification of the current issues exposed to the risk of flooding is based on the initial degree of material vulnerability, and the social vulnerability as a complement. Our method to identify the issues was based on simulation using a GIS tool and field surveys, and subsequently, overlaying flood zones with land use map, the issues exposed to risk of flooding are varied, the road network as an example represents a vulnerable issue if we talk about its role in crisis management and thus, disaster evacuation, so the natural phenomenon is not the only causes of disaster occurrence, but also the issues and their exposures and therefore vulnerability, the present study confirmed the findings about the increase in the number of victims in the most populated areas shows that randomness is not the single factor behind the disaster.

The population evolution of Annaba city has gone through several periods, the scarcity of land pushes local actors to meet the need for housing by occupying flood-prone areas, therefore, our material vulnerability assessment is based on a qualitative character, this assessment is measured by the type and construction materials, and the number of floors for the shelter, because in certain events the buildings are submerged at a height of 2m, so homes with a shelter floor have more chances of survival than others of the same type., this protective measure is among the most effective in this case. In the event of a flood, local authorities through the media recommends residents to avoid movement during likely events., therefore, victims recorded is due to the irresponsible and inadequate behaviour of the population in the face of risk, this explains the difference between social and structural vulnerability, because anthropogenic action increases the hazard consequences on exposed issues, because they represent a barrier to the natural water flow, and this makes the territory complex and difficult to manage.

2-3-4-3- Structural measures effectiveness in addressing flood disasters:

The attention is generally paid to protective measures analysis and evaluation to flood risk mitigation, generally, a civil engineering works such as dykes, canals and weirs. The evaluation is conducted with regard to the effectiveness of performance and dimensioning of these measures to contain the amount of water, in order to avoid any failure or canals overflow, Therefore, some flows may exceed the canal size in the event of a centennial flood which requires maintenance and protection of these structures against erosion effects, it is important to understand that during the course of exceptional events, the failures of the measures are acceptable in the territorial context (the topography, the nature of soils) Therefore, in case of an occurrence stemming from a breach or overflow from floods, the consequences will be more damaging.

2-3-5-The drainage network maintenance as a protective measure:

This intervention type matches the recalibration or cleaning of the small hydraulic system, to increase the resilience capacity of the territory facing a flood risk, through the increase in the flow of runoff. For the case of the western plain, the structural measures show an efficiency of reducing the flooded area in the case of a large-scale event likely according to the simulation. In contrast, in the case of our analysis, the evaluation of structural measures for large-scale events in particular shows the failure of several of these measures, sometimes they increase the magnitude of an event, on the other hand, they give good results in protecting the stakes that facing the risk. The difficulty is listed at the level of evaluation operation, because the most of the measures have not yet been put into a real examination, and sometimes the lack of socio-economic and spatial data or the difficulty of acquisition represents a barrier to research. In our case the risk management policy is often based on the reference event and its details, however, in reality each event has its specificities and uncertainties, so its relevance depends on the course of events.

3-Flood risk management tools discussion:

Regarding flood risk management in general, various tools have been developed through Algerian legislation, many advances have been the basis for risk prevention, in particular by preventing the construction in floodplains. In that issue, regulations for the management of natural risks have been made, with specific laws for the protection of forests, urban planning, mountains, major risks (natural and technological) and insurance. Following Asnam and Boumerdes earthquake events, Bab El Oued floods in Algiers, Algerian government has begun to think about this problem and to develop techniques to better manage natural risks, the need for insurance legislation after the significant material damage from Bab El Oued floods, is a management solution for this type of hazard, before and during and after event in the post-disaster period.

We can cite the most important legal texts in Algerian legislation:

3-1- Relevant legislative texts:

After the Asnam earthquake in October 1980 in which it is regarded as turning point in Algerian legislation, so the legislative authority began to enact a total of legal texts related to regularizing natural hazards:

The Executive Decree 85/231: Of August 25, 1985 relating to the organization and relief plan in a disaster event, an ORSEC and all the material and human resources available to respond in a disaster event, and according to article 23 of this decree requires all the wilayas and municipalities to carry out this plan for the first time, in order to define the at-risk areas and its type and then the alert stages to inform citizens.

Successive governments have emphasised a great importance to this tool, as evidenced by the issuance of many legislative texts in this regard, the most important of which is "EXECUTIVE DECREE NO. 19-59 OF 26 JOUMADA EL OULA 1440 CORRESPONDING TO 2 FEBRUARY 2019 SETTING OUT THE PROCEDURES FOR DRAWING UP AND MANAGING EMERGENCY ORGANISATION PLANS", which clarifies in its fourth paragraph the scopes of intervention of this tool, at the national, provincial and municipal levels: The national, province, and municipal levels, and another for sensitive sites. It also contains release mechanisms, preparation procedures and intervention modules of this plan.

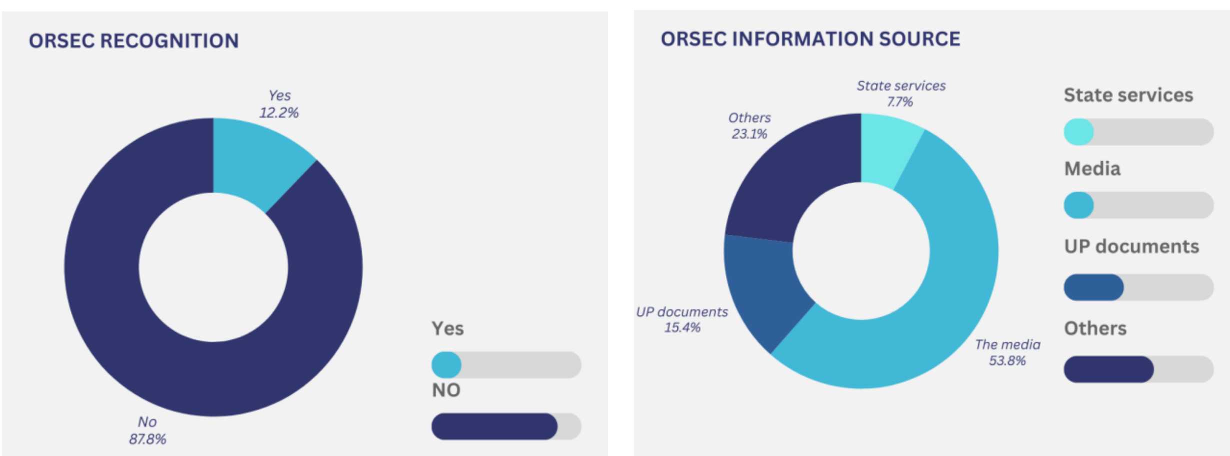
The most recent is (*Law no. 24-04* of 16 Chaâbane 1445 corresponding to 26 February 2024 laying down the rules for disaster risk prevention, intervention and reduction as part of sustainable development), which defines in its chapters the details of the implementation of this plan, which relates to the prevention of natural hazards, including the risk of flooding.

According to the results of the field investigation, we find that 87.8% do not even know about rescue plan ORSEC, while the remaining 12.2% know this plan. These results on the sources of knowledge of the scheme, reflect the inefficient current policy in the field of awareness on how to deal with risk, although Chapter 3, Article 10, explicitly recommends: "*The State shall ensure that citizens have equal and permanent access to all information relating to disaster risks*" and "*The State also provides this information to the various stakeholders*", or at least in dealing with the rescue plans set by the state itself, and therefore, we believe that the issue lies not only in risk management tools, but in their optimal application. (Figure 28) represents the sources of knowledge of emergency management plans ORSEC, which also shows the significant lack of awareness campaigns and citizen participation in decision-making. In this regard, as a step to remedy this situation, this law comes with recommendations on raising awareness among stakeholders and citizens alike in paragraph 11 of the same chapter, which recommends that "The State organises an annual disaster risk awareness and training programme for local authorities, stakeholders and civil society", As a significant evolution in dealing with the risk, it remains to be seen the implementation of this law.

Unusually, this law came with recommendations in its third chapter, on information and communication with the scientific research sector, a long-awaited step that would benefit both sectors. by providing training in risk awareness *(hazards, vulnerabilities, and means of prevention, intervention and recovery)* as part of a national scientific research and technological development programme on disaster risks at the relevant research institutions.

It is interesting to note that an entire chapter is devoted to penal procedures, and this is related to Chapter 8, which emphasises that any violator of the recommendations of Article 24 of this law will be subject to criminal penalties of up to 5 years imprisonment and up to 1000.000 DZD as a fine in a bold step toward hazard prevention, as Article 24 provides for the prevention of construction in areas prone to natural and technological hazards where the risk of flooding is mentioned as follows: (flood plains, streambeds, banks and downstream of dams below the flooding threshold).

Figure 28: Sources of ORSEC plan recognition.



Source: (The researcher 2024).

The Executive Decree 85/232: Relating to the prevention of risks and disasters in the short, medium, and long term, this decree stipulates in its second article the need to carry out the PPR Risk prevention Plan. However, the latter remains specific to natural and technological risks in a general sense, while the need for an independent flood risk management plan is increasing, since it is the greatest threat to the urban environment.

The Executive Decree 90/402: Related to the creation of a fund for natural disasters and major technological risks, which was modified by executive decree N ° 10/2000 dated April 18, 2001.

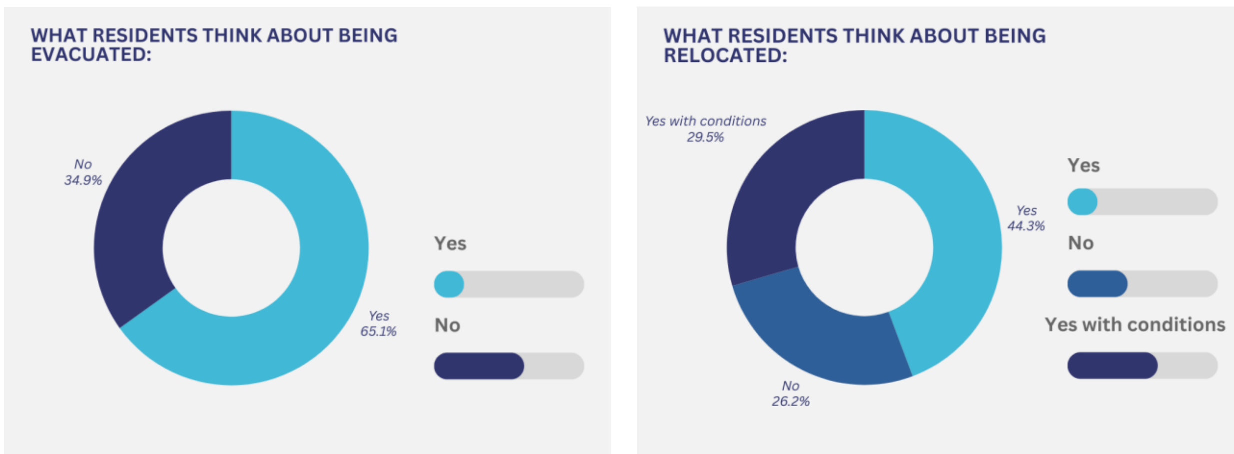
Despite the availability of legislative texts regarding disaster management and damages compensation, the question remains in the case of exceptional events that require a subsidy from the public treasury through an exceptional order from the country's supreme authorities.
The executive decree N ° 87/44: dated on 10/02/1987 relating to the risk of forest fires, in the national forest territory. One of the criticisms of this tool is its limited scope and lack of precision in defining the tools, and timing of the intervention while defining the tasks of all actors.

3-2-Legal texts appreciating flood risk prevention:

Environmental law: law N ° 10/03 of 7/19/2003 relating to environment protection within the framework of sustainable development, which speaks in its second part on the conditions of environmental protection, among these elements: the earth and the underground. in Art 60: The land must be intended for a use that is compatible with its nature, making it recoverable, and the development of the land is done for agriculture, industry or urban planning, in accordance with the requirements of the development and urban planning, taking into consideration the environment protection.
The law of water: Law N ° 83/17 of July 16, 1983 relates to water, modified and supplemented by Ordinance N ° 13/96 of January 1996, this law, in its 5th part, 1st chapter, the flood control, shows the prevention of construction which can modify the conditions of water flow. The authorities have put in place a flood estimation or management plan, regardless of event nature, caused either by heavy rainfall or by an overflow of a dam.
New towns Law: law 08/02 of May 08, 2002, relating to the conditions for the creation of new towns and its development, new towns must have a development plan that ensures its protection against natural hazards. The year 2011 saw the issuance of Executive decree no. 11-76 of 13 Rabie El Aouel 1432, corresponding to February 16, 2011 setting out the conditions and procedures for initiating, drawing up and adopting the development plan for the new town. In the first chapter, Article 3, it defines how to deal with and must determine major risks and easements in development plan for the new town.
Law 29/90: related to development and urban planning, this law aims at the general rules of the production of buildable land and environment protection, and natural environment in article N°1. The POS tool or land use plan, cited in Article 31, this article determines the natural and artificial easements, where exposed areas to natural and technological risk are identified, and the prevention of exploitation and construction on land before being approved by the various directorates in order to decide the land constructability.
Once the decision is taken at the national level, it is also emphasized that the implementation of the decision at the local level takes longer, because of the adaptation with local specificity, in Algeria in general, there is no explicit tool for the prevention and management of flood risks in general, except the existing urban planning tools, such as POS and PDAU, which do not take into account natural risks adequately, and lack sufficient engagement from specialists in the field of risk management. This can lead to new settlements in risk areas that might be avoided.

To provide further clarity, the results of the field investigation inicate that 65.1% refuse to evacuate even in the case of flood-related disasters, so how might they be motivated to change their residence (Figure 29). As for the question related to the possibility of changing the area of residence, within the context of protection against the risk of floods, the answers came 44.3% in favor of the idea, while 26.2% were against, and the remaining 29.5% of response was affirmative, with stipulations attached, most of which were about providing better places than the current ones, as a clear indication of the effectiveness of this solution of moving to less risky areas, these are generally placed in the new town, which, in turn, decongest the city of Annaba.

Figure 29: Residents opinin about leaving their areas.



Source: (The researcher 2024)

The law 29/90 is intended to control the anarchic urbanization, and not specifically aimed at flood risk management, this plan is regulated only prohibition of implantation in the areas considered as natural and artificial easements, and it has given the dimensions regulation of for this purpose, but it overlooks other exposed sites to flood risk of the plains type for example, so there the need is for a specialized plan such as the PPRI, insight into the phenomena is deemed advantageous for local actors, to adopt this plan by collected data during the previous decades.

Public authorities committed to take the necessary steps to allocate adequate resources for facilitate the understanding of phenomena, via the technical know-how for an effective management of flood risk at the local level. In the case of planning and urban planning tools, the question is how to integrate natural risk into these tools in order to achieve its main objective of protecting the living environment, and the status of risk territory governance in this context, defined by scale of intervention of each actor and field of responsibility by rights and duties in at risk territory. Development and urban planning tools, as well as flood-related risk management are essential for sustainable urban development, taking into account social, economic, and environmental issues, while minimizing risks of natural origin such as floods. The aim of city management process is to establish a better living environment, in the case of the city of Annaba, the current urban policy is based on urban rehabilitation and improvement as most appropriate, leading to the insight that the application of development tools in study area offers a restricted perspective in case of floods.

3-3-Action planned within the SNAT and SRAT framework:

The purpose of the National Plan of Territory Development (Schéma National d'Aménagement du Territoire [SNAT]) is to implement development policies that ensure the identification of all major risks, and promotes mitigation of these consequences. The Regional Plan of Territory Development (Schémas Régionaux d'Aménagement du Territoire [SRAT]) can also serve as a crucial instrument for risk management, but the major risk's part is often less detailed, because the document is not specialized in risk management at regional scale. In this case, the adoption of a PPRI at a large level can help to facilitate the application of SRAT guidelines, that make it more harmonious. However, there may be problems in risk management at wilaya of Annaba level due to the nonexistence of an actor who organizes regional risk management and ensures cohesion between the other actors. consequently, it is essential to develop a comprehensive global flood risk management policy.

3-4- Stakeholder identification and recognition:

The most interviewed citizens believe that the APC is the main actor in risk prevention and management, nonetheless, in case of crisis management, the intervention is frequently carried out by civil protection agencies. In addition, it must protect citizens primarily, and ensure risk prevention and information as well as the population evacuation as a crisis management measures until the return to normal, civil defence personnel must have an evacuation plan for people in the event of a disaster, in particular for sensitive equipment such as schools located in flood zones. The coordination between the civil protection and the weather services can help to estimate the time of disasters, for the information and the alert of the citizens, The coordination between civil protection and weather services can help to estimate the time of disasters to inform and alert citizens, allowing them to subscribe to a form containing information and means of communication to ensure a real-time alert, the citizen can also contact via a toll-free number.

3-4-1- Shifting from collective to individual management practices:

The active involvement of citizens in urban management is crucial for enhancing the effectiveness of city governance, and to achieve better outcomes, it is required to be supported by legal coverage, and this is done through the involvement of the associative movement in the risk management, due to its roles of living environment protection, as well as controlling the modifications on the spaces such as environmental associations, by their constant criticism of structural measures and the modification on the space that can have consequences on the natural ecosystem. The associations of the victims who are always against the public actors, because of the negative impressions left by previous events, where they most often put the responsibility on elected officials and its management policy. The information transmission is made directly by links between citizens and the leaders of the associations, then the latter transmit citizens opinions to those responsible, to find more equitable solutions to the problems posed in terms of risk management.

3-4-2- Guidelines for better defining operational objectives:

It is imperative to establish clear objectives and their spatial allocation to ensure the efficacy of decision-making and intervention, also to facilitate the equitable tasks sharing across the territory, so it is not necessary to aim for general objectives by individual measures, local actors must be involved in the identification of operational objectives for an integrated strategy, such as the return periods of floods which induces a predetermined level of protection, and the shared with the stakeholders. Then the strategy must take into account the risk probability of occurrence, as for example a centennial flood it has the probability of occurrence of 1 in 2 of life. From the point of view of an integrated strategy, the identification of operational objectives is made in relation to expectations, constraints, wishes. However, the problem often encountered is the misdiagnosis of constraints, which can make structured measures ineffective. This is where strategic planning comes in to solve these problems. The disadvantage of the plans is that they are based on structural measures and abandon non-structural measures.

Chapter conclusion:

The presented results in this chapter highlight the complexity and diversity of flood risks in Annaba. The mapping based on the AHP method made it possible to precisely identify the most vulnerable areas by integrating various criteria such as topography, land use, and the proximity of waterways. These results show that certain urban and peri-urban areas in Annaba are particularly exposed to floods, requiring priority interventions to strengthen the resilience of these territories. The social assessment revealed valuable insights on the perception and preparedness of residents in the face of flood risks. The data show a significant variability in the perception of risk according to geographical areas and socio-demographic groups. Residents of frequently flooded areas tend to be more aware of the risk and adopt preparedness measures, while those living in areas perceived as less vulnerable often show an underestimation of the risk, and a lack of adequate preparation. This disparity underlines the importance of targeted communication and awareness-raising adapted to local specificities. The comparative analysis of the technical and social results made it possible to identify important convergences and divergences. Some areas identified as high-risk by the AHP mapping correspond to the high-risk perceptions of residents, which validates the accuracy of our technical approach. However, other areas show discrepancies, where residents fail to recognize the risk, despite technical evidence. These differences highlight the challenges of managing perceptions and community mobilization. The implications for the integrated management of the flood risk in Annaba are multiple. First, it is crucial to strengthen the protective infrastructure in the areas identified as high risk. This includes the construction of levees, the improvement of drainage systems, and the establishment of early warning systems. Besides, it is imperative to develop awareness-raising and education programs to improve risk perception and encourage preparedness behaviours, notably in areas where residents demonstrate a tendency to undervalue flood risks.

General Conclusion

This thesis examines flood risk management strategies in Annaba, as a critical issue for the safety and well-being of local populations, as well as for the protection of infrastructure and urban environment. By implementing a holistic approach to flood risk policy assessment combining a multicriteria method for risk mapping, and decision making and a field survey for assessing the social aspect of risk, we were able to obtain a comprehensive and multidimensional vision of the challenges and opportunities related to flood management in this region.

The insights generated by this study, based on the multi-criteria analysis, provide clear guidelines for the development of a global strategy for integrated flood risk management. By focusing on infrastructure while integrating complementary measures, risk managers can improve flood resilience in a sustainable and effective way. Overall, our method was the one that obtained the most robust results, so, future research should explore complementary methods to refine assessments and strengthen the robustness of management plans.

These results underline the need for a participatory and inclusive approach in flood risk management. The involvement of local communities in the process of planning and implementing risk management measures is essential to ensure their effectiveness and sustainability. By involving residents in decision-making, listening to their concerns and integrating their local knowledge, where authorities can formulate more contextually relevant strategies that gain broader acceptance among the population.

In conclusion, this study demonstrates that flood risk management in Annaba requires an integrated approach, that combines rigorous technical analyses, with a thorough understanding of the social aspects of the risk. The results obtained serve as a solid basis for formulating recommendations and public policies aimed at improving the city's resilience towards floodings. And the policy implications and practical measures proposed to achieve these objectives, informed by the lessons extracted from the integrated risk analysis.

Proposals for Action:

This study suggests a development of policies that integrating land use planning, water management and disaster risk reduction, this end requires a holistic and interdisciplinary approach. To develop such policies, it is necessary to well identify the risk areas, since it is a key element of effective management, taking into account land use as a risk-generating factor, includes the climate change which increases uncertainty.

There is an expanding need for a new management paradigm with a risk zoning by integrating data on exceptional events, uncertainty, and preparation for extreme scenarios.

The valorisation of green spaces and buffer zones, the creation of parks and natural spaces to serve as natural barriers against disasters on the one hand and leisure activities for the well-being of citizens, therefore a double interest.

The implementation of strict regulations with the force of the law for construction in high-risk areas and offer incentives for environment preservation and natural ecosystems.

There is a growing imperative for investment in infrastructure for stormwater management and flood prevention, such as dykes and retention basins, and the establishment of a separate sanitation network for the exploitation of stormwater and reduce the risk of pollution.

Develop and maintain warning systems for natural disasters in collaboration with other disciplines such as electronics by installing sensors on the waterways at a certain threshold, for a real-time early warning, and invest in advanced meteorological and hydrological monitoring systems in general.

The improvement of the mechanisms for the development and the way in which emergency plans are triggered and carried out for local communities, including evacuation routes and shelters. And involve citizens in the process of flood risk management and planning for a richer risk culture.

Create intersectoral committees bringing together the different sectors and these decision-makers such as urban planners, water managers, environmental experts, local authorities, community representatives and civil society. And set up performance indices to evaluate the policy effectiveness, and on this basis, scheduling of periodic revisions of flood risk prevention plans to adjust strategies according to new data and challenges.

Search for public-private partnerships with the aim of a double interest for private companies, on the other side to ensure flood risk prevention, and the search for international financing and change of experiences. And develop insurance strategies that encourage proactive risk management behaviours.

The establishment of Sustainable Urban Drainage Systems (SUDS) such as Permeable roadways, green roofs, as a reinforcement of drainage infrastructure, this type of plans is designed to manage surface water runoff in urban areas, promoting sustainable water management practices. Integrating SUDS into urban planning can significantly mitigate flood risks, improve water quality, and improving the urban environment. And on the other hand, by Mitigating urban heat islands using this technique, the elements of vegetated SUDS can help by providing shade and cooling by evapotranspiration.

Implement flood-proof building designs by promoting the use of flood-resistant materials and elevated building designs in areas at risk of flooding. And apply this solution for existing structures to support more resilience to floods.

Study limitations:

Although this research has offered significant insight into flood risk management, several limitations need be taken into account. Firstly, the data used in this study comes mainly from statistical sources and climate models which, although reliable, may not capture all the variability and uncertainty associated with future events, due to the uncertainty in the treatment of floods, caused by the multitude of natural and anthropogenic factors, on the other hand, the difficulty of obtaining up-to-date data due to the multiplicity of natural and anthropogenic factors, especially in developing areas, making accurate modelling and prediction of such behaviour more complex.

Furthermore, the risk assessment methods adopted, while efficient, are largely based on minimizing assumptions that might not fully encompass the complexities of environmental systems affected by flooding. Finally, research has focused on specific case study situations, limiting the generalizability of findings to other geographical or socio-cultural contexts. To overcome these limitations, future research has the potential to incorporate more recent and varied data, use more robust methodological approaches and extend the analysis to other regions for a better overall understanding of flood risk.

Despite these limitations, research into flood risk management continues to progress and provide valuable knowledge for reducing the vulnerability of populations and property to this natural hazard.

Study contributions:

This study provides several contributions to knowledge, policies and practices, focusing on the specific context of flood risk in Annaba, as a coastal city in Algeria, in several fields such as:

Knowledge and contextual understanding: The study provides a detailed examination of the geographical and urban characteristics of the city of Annaba, that influences the risks of flooding. This adds to the broader understanding of flood risk management in the Mediterranean and North African urban contexts.

Risk assessment methodologies: It can introduce or refine flood risk assessment methodologies, based on a global approach to identify this type of flood-related risk, especially in areas of rapid urbanization with similar climates and topography.

Historical data on floods: By compiling and analysing the historical floods in Annaba, and determining the return periods, the study brings valuable data to the body of research on the frequency, intensity and impacts of floods on the region.

Impact Analysis: The study probably offers an overview of the socio-economic and environmental impacts of the floods in Annaba, improving the understanding and risk culture among citizens, by focusing on how floods affect the population, infrastructure and ecosystems.

Policy contributions through recommendations: Based on its conclusions, the study probably proposes concrete strategic recommendations to local, regional and national authorities to improve flood risk management strategies.

Regulatory framework: The study may suggest updates to existing regulatory frameworks governing urban practice, land use and environmental protection to mitigate flood risks.

Disaster preparedness and response: to improve disaster preparedness and response mechanisms, including organization and relief plans, could be an essential contribution to the management policy.

Climate adaptation strategies: The study probably addresses the need to integrate flood risk management into broader climate change adaptation strategies, with emphasize resilience in urban planning and development policies.

Contributions to Practice: The study probably describes specific tools and instruments for flood risk management, such as improved drainage systems, flood barriers, and green infrastructure solutions like (green spaces, wetlands, riparian buffers, and green roofs) which notably alleviates the consequences of urban flooding in comparison to grey infrastructure alone (dykes, canals, dams).

Community Engagement: The study highlights the importance of citizen involvement in flood risk management, by proposing strategies to involve local populations in preparedness and mitigation efforts, as a non-structural measures by community engagement to enhance resilience.

Reinforcement of building capacity: In order to training programmes and capacity building initiatives for local authorities, emergency services and community organisations could be a key practical contribution.

Integrated Approaches: Promote integrated approaches that combine scientific research, policy development and practical measures to deal comprehensively with flood risks.

Sustainable Development: Support sustainable urban development, by advocating for resilient infrastructure and adaptive strategies capable of resisting and recovering from floods. These contributions collectively aim to reduce flood risks, protect lives and property and promote sustainable and resilient urban development in the city of Annaba, as well as in other regions dealing with similar issues.

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Table list:

Map list:

Figure list :

Table of Contents:

List of Abbreviations:

ACSG: Association Canadienne des Sciences Géomatiques (Canadian Association of Geomatics Sciences).
AHP: Analytic hierarchy process.
ANRH: Agence Nationale des Ressources Hydrauliques (National Agency for Water Resources)
APC: L'Assemblée Populaire Communale (Municipal People's Assembly)
APW: L'assemblée Populaire de Wilaya (Provincial People's Assembly).
ARC: African Risk Capacity.
ASA: Algerian Space Agency
AU: African Union.
CatNat: Catastrophes Naturelles (Natural Disasters)
CBA / CAA: Cost-Benefit / Cost-Advantage Analysis.
CEA: Cost-Effectiveness Analysis.
CNERU: Centre National d'Etudes et de Recherches Appliquées en Urbanisme (National Centre for Urban Planning Research Studies)
CR: Consistency Ratio.
DEM: Digital Elevation Model.
EU: European Union.
GIS: Geographical Information Systems.
GPS: Global Positioning System.
GPU: Grand Projet Urbain (Major Urban Project).
HPI: Human Poverty Index.
IDF: Intensity, Duration and Frequency.
IDW: Inverse Distance Weight.
IPCC: Intergovernmental Panel on Climate Change.
LUCC: Land Use and Cover Changes.
NDVI: Normalized Difference Vegetation Index.
NESC: National Economic and Social Council.
NGO: Non-governmental Organizations.
NRHD: National Report on Human Development.
ONA: Office National d'Assainissement (National Office of Sanitation).

ORSEC: Plan d'organisation et de secours (Organization and rescue plan)
PCS: Plan Communal de Sauvegarde (Communal Safeguarding Plans)
PDAU: Plan Directeur d'Aménagement et d'Urbanisme (Master Plan of Development and Urban Planning)
PER: Plan d'Exposition au Risque (Risk exposure plan).
PNAE-DD: Plan National d'Actions pour l'Environnement et le Développement Durable (National Action Plan for the Environment and Sustainable Development).
POG: Plan d'Organisation Générale (General Organization Plan).
PPRI: Plan de Prévention du Risque Inondation (Flood Risk Prevention Plan)
PUD: plan d'urbanisme directeur (Master Urban Planning Plan)
SNAT: Schéma National d'Aménagement du Territoire (National Plan of Territory Development).
SRAT: Schémas Régionaux d'Aménagement du Territoire (Regional Plan of Territory Development).
SUDS: Sustainable Urban Drainage Systems.
UN: United Nations.
UNDP: United Nations Development Program.
UNESCO: United Nations Educational, Scientific and Cultural Organization.
USGS: United States Geological Survey.

Appendices:

Appendix A: Survey questionnaire:

جامعة باجي مختار - عنابة -
كلية علوم الأرض (قسم التهيئة)

استمارة استبيان:

ملاحظة: هذا الاستبيان موجه لغرض البحث العلمي فقط، وليس لأي غرض اخر.
(إذا كانت لديكم إضافة يمكنكم استخدام ظهر الورقة مع كتابة رقم الإجابة)

يرجى الإجابة على الاستبيان التالي بوضع علامة (X) في المكان المناسب او بملء الفراغات:

1)- أنت: ☐ رجل ☐ امرأة. العمر: ....

2)-انت تسكن في سكن: ☐ فردي (فيلا) ☐ جماعي (عمارة)

3)-أي صيغة؟ ☐ اجتماعي ☐ تساهمي ☐ ترقوي ☐ تطوري
☐ مستأجر ☐ اخر (...)

4)-هل لديك جميع التجهيزات والمرافق الأساسية في الحي الذي تسكن فيه؟
☐ نعم ☐ لا، ماذا ينقص في حييكم: ....

5)-في رأييك هل تعتبر منطقتكم معرضة للأخطار المتعلقة بالفيضانات؟

☐ نعم ☐ لا ☐ بعض المكونات فقط حساسة لأخطار الفيضانات.

6)في حالة وقوع ضحايا جراء الفيضانات، برأيك من هو المسؤول عن ذلك؟

....

7)- هل تعتبر خطر الفيضانات أمرا مقلقا بالنسبة لك؟ ☐ نعم ☐ لا

8)-هل تذكر انه كانت هناك حملات تحسيسية ضد خطر الفيضانات من طرف أي جهة من الجهات؟ ☐ نعم ☐ لا

-إذا كان نعم، من قام بذلك ومتى؟:...

9)-في السنوات الأخيرة هل لاحظتم تغيرات في سلوك الفيضانات: ☐ نعم ☐ لا

10)-ما هي برأييك الأسباب؟

- ☐نقص وتدهور حالة المنشآت الخاصة بالحماية ضد الفيضانات
- ☐أسباب تتعلق بالتغيرات المناخية
- ☐أسباب أخرى اذكرها: ....

11)-إذا كان هناك تغير في الفيضانات في نظرك هل أصبحت:

- ☐أسرع.
- ☐أكثر ارتفاعا.
- ☐تستغرق مدة أطول.
- ☐أكثر تكرارا.

12)-هل سمعت من قبل بمخطط التعرض للخطر (PER) او مخطط تنظيم النجدة (ORSEC)؟

☐ نعم ☐ لا

من طرف من:

- ☐وسائل الاعلام.
- ☐أدوات التهيئة والتعمير.
- ☐المصالح العمومية.
- ☐مصدر اخر وضحه (..)

13)-برأييك من المفترض ان يكون المسؤول عن ابلاغ وتحذير المواطنين في حالة احتمال حدوث خطر الفيضانات؟ ....

14)-كيف تتصرف في حال حدوث فيضانات في منطقتك؟ ....

....

15)-ما هي الوسائل المستعملة من طرف السلطات العمومية لإبلاغكم بخطر الفيضانات؟

☐المذياع ☐ التلفاز☐ متعامل ☐ الهاتف ☐ ملصقات ☐ مكبرات الصوت

16)-هل تعتقد ان نشرة الأحوال الجوية كافية كإنذار بوجود خطر فيضانات محتمل؟ ☐نعم ☐لا

17)-هل تلقيتم من قبل إنذارات من السلطات العمومية بقدوم فيضانات بمنطقتكم؟

18)-إذا كان نعم من أي مصدر؟ ....

19)-ما هو تقييمكم للإنذار؟ ☐مفيد ☐غير مفيد ☐متأخر.
20)-ما هي في رأييك حدود الخطر المقبول؟ ....
21)-هل لديك في منزلك اشخاص بحاجة الى رعاية خاصة مثل:
☐ أطفال صغار ☐اشخاص مسنين ☐ذوي الاحتياجات الخاصة
22)-هل سمعت من قبل بمفهوم التنمية المستدامة؟ ☐نعم ☐لا
23)-ما هو برأييك دور المواطن في تسيير خطر الفيضانات في إطار التنمية المستدامة؟
:...
24)- ما هو حسب رأيكم دور جمعيات حماية البيئة في تسيير خطر الفيضانات؟
:...............

....
25)- هل تظن ان هذا داخل في الوعي لدى المواطن؟ ☐ نعم ☐ لا
26)- هل تعرف ارقام النجدة مثل ارقام (الشرطة، الحماية المدنية...) ☐نعم ☐لا
27)- ما هي التدابير المتخذة من طرف السلطات في إطار حماية مدينة عنابة من خطر الفيضانات؟ ....

....
28)-هل شهدت حدث متعلق بالفيضانات في منطقتكم من قبل؟ ☐نعم ☐لا
متى كان ذلك؟ :...........................
29)-ما هي المواد المستعملة في بناء مسكنكم؟ ....

....
30)-هل مستوى الأرضية في الطابق الأرضي في منزلك هي أعلى من مستوى الطريق في الشارع؟ ☐نعم ☐لا
31)- هل البالوعات الداخلية للمنزل هي بنفس المستوى مع أرضية الطريق في الشارع؟
☐نعم ☐لا
32)-هل قمتم من قبل بتشخيص لدرجة التعرض للخطر لمنزلكم من طرف مختصين كمكتب دراسات معمارية...؟ ☐نعم ☐لا.
- إذا كان نعم، من طرف من كان ذلك؟ ....
33)- برأييك من هو المسؤول في حال حدوث كوارث متعلقة بالفيضانات؟
☐التقصير من طرف السلطات المحلية. ☐الظروف الطبيعية. ☐ نقص الحذر والحيطة عند المواطنين.
34)- ما هي الأسباب؟
☐ وجود منشآت حساسة لخطر الفيضانات مثل المدارس.
☐ وجود بنايات لا تتطابق مع المواصفات التقنية في حا حدوث فيضانات مثل السكن الهش.

35) قبل انتقالك للسكن في هذا الحي هل تم اعلامكم بأن هذه المنطقة معرضة لخطر الفيضانات؟ ☐نعم ☐لا. إذا كان نعم، من طرف من؟ ....

36) في رأييك، هل مسكنكم مطابق للمعايير التقنية في حال حدوث فيضانات؟
☐نعم. ☐لا.

37) هل تعرفون تدابير الحماية ضد الفيضانات؟ ☐نعم. ☐لا.
إذا كان نعم، ما هي: ....
هل هي مؤقتة ام دائمة؟ : ....

38) ما هو تقييمكم لإجراءات الوقاية من خطر الفيضانات المنجزة من طرف الجهات العمومية في المدينة؟
☐كافية. ☐غير كافية، ☐عديمة الجدوى. ☐بدون رأي.

39) هل لديك في مسكنكم تدابير للحماية من خطر الفيضانات؟ ☐نعم. ☐لا.
- إذا كان نعم، على أي فيضانات اعتمدتم في انجاز هذه التدابير الوقائية؟ ....
- ما هي الاعمال التي قمتم بها؟:
☐ الرفع من مستوى التجهيزات وشبكة التزويد بالكهرباء.
☐ الرفع من مستوى الطابق الأرضي فوق المستوى المعهود لارتفاع المياه.
☐ استخدام مضخة لتفريغ المياه من المسكن.
☐ تدعيم اساسات البناية لتفادي خطر الانزلاق الناجم عن الفيضانات.
☐ الرفع من مستوى الارضية بواسطة الردم (remblais).
- برأييك هل تكلفة انجاز هذه الاشغال مرتفعة نسبيا؟ ☐نعم. ☐لا.
- ما هو تقييمك لنجاعة هذه التدابير؟ ☐جيدة. ☐متوسطة. ☐سيئة.

40) هل تظن ان اجلاء السكان في حال حدوث فيضانات يعتبر الحل الأمثل؟
☐نعم. ☐لا. - إذا كان لا، ما هو البديل برأييك؟: ....

41) هل تقبلون بحل تغيير مكان الإقامة في حل وفرت لكم السلطات مكان اخر غير معرض لخطر الفيضانات؟ ☐نعم. ☐لا. ☐نعم بشروط.
- ما هي الشروط؟ : ....

42) هل تظن أن مسكنكم معرض لخطر الفيضانات؟ ☐نعم ☐لا.

43) ما هي العوامل التي تؤثر سلبا على عمل شبكة تصريف المياه؟:

....

44) هل لاحظتم من قبل اشغال تنظيف البالوعات وشبكة الصرف الصحي من طرف المصالح العمومية خاصة قبل موسم الامطار؟ ☐نعم. ☐لا.

45) ما هي رسالتك للمصالح المعنية؟ : ....

Appendix B: Raw data from the case study (table of land use areas)

TABLEAU DES SURFACES DE L'OCCUPATION AU SOL

Secteurs		1		2		3		4		5		6		7		Total	
		SUP	%	SUP	%	SUP	%	SUP	%	SUP	%	SUP	%	SUP	%	SUP	%
Secteur Urbanisé	TISSU URBAIN	2348.6	50.5%	585.7	17.9%	312.8	6.5%	427.3	15.5%	899.0	15.8%	188.6	11.2%	92.5	2.5%	4855.6	18.3%
	Grand Equip. (*)	/	/	/	/	/	/	/	/	/	/	563.2	33.4%	/	/	563.6	2.1%
	ACTIVITES	/	/	219.0	6.7%	7.2	0.1%	30.6	1.1%	1008.1	17.7%	151.6	9.0%	8.3	0.2%	1425.0	5.4%
	TOTAL 1	2348.6	50.5%	804.7	24.6%	320.0	6.6%	457.9	16.6%	1907.1	33.5%	903.4	53.6%	100.8	2.7%	6844.2	25.8%
POTENTIEL		604.58	13.%	424.8	9.3%	257.07	5.3%	484.9	16.7%	415.0	7.00%	219.2	11.5%	2.1	0.1%	2427.0	9.1%
Secteur Non Urbanisable	EUCALYPTUS.	200.3	4.3%	/	/	351.7	7.3%	163.5	5.9%	19.7	1.3%	/	/	/	/	735.4	2.8%
	PINS MARITIME	101.6	2.2%	/	/	/	/	77.4	2.8%	/	/	/	/	/	/	179.0	0.7%
	CHENE.LIEGE	82.7	1.8%	/	/	517.5	10.7%	/	/	/	/	/	/	/	/	600.3	2.3%
	MAQUIS ET BROU-SSAILLES	757.5	16.3%	/	/	1846.0	38.2%	622.5	22.6%	1023.2	18.0%	/	/	/	/	4249.2	16.2%
	OLIV.	/	/	/	/	291.6	6.0%	/	/	36.4	0.6%	/	/	/	/	328.0	1.2%
	OCCUP. VARIEE	417.02	8.9 %	/	/	/	/	/	/	/	/	/	/	/	/	417.02	1.5%
	TERRAIN Aagricole	/	/	1966.6	63.3%	1219.83	25.2%	874.28	32.5%	2252.3	39.8%	286.67	17%	3579.9	97%	11072.8	41.7%
	PLAGE	11.0	0.2%	/	/	/	/	/	/	/	/	56.2	3.3%	/	/	67.3	0.3%
	MARECAGE	23.2	0.5%	41.5	1.3%	27.7	/	/	/	/	/	106.5	6.3%	/	/	199.0	0.7%
	TERRAIN. Inondable	/	/	15.9	0.5%	/	/	8.5	0.3%	/	/	/	/	4.1	0.1%	28.5	0.1%
	LIT.majeur O. Bouhdid	5.0	0.1%	/	/	/	/	/	/	/	/	/	/	/	/	5.0	0.02%
	BASSIN D'epandage	/	/	/	/	/	/	/	/	/	/	138.6	8.2%	/	/	138.6	0.5%
	RETENUE SIDER	/	/	/	/	/	/	/	/	5.4	0.1%	/	/	/	/	5.4	0.02%
	BASSIN de rétention	1.8	0.04%	/	/	/	/	/	/	/	/	/	/	/	/	1.8	0.01%
	DECHARGE	/	/	/	/	/	/	46.5	1.7%	31.7	0.6%	/	/	5.0	0.1%	83.2	0.31%
	CARRIERE	6.9	0.1%	29.1	0.9%	/	/	24.2	0.9%	1.4	0.03%	/	/	/	/	61.7	0.2%
	FALAISE	90.1	1.9%	/	/	/	/	/	/	/	/	/	/	/	/	90.1	0.34%
	TOTAL 3	1697.1	36%	2035.1	62%	4254.3	88%	1817	66%	3370	59%	563.7	33%	3589.0	97.2%	18538.8	69.7%
TOT/SECTEURS		4650.3	100%	3264.6	100%	4831.4	100%	2759.8	100%	5692.1	100%	1686.7	100%	3691.9	100%	26582.9	100%

Appendix C: division of urban sectors:

Sous Secteurs	Quartiers	Population RGPH	Nombre de Population	Evolution En V. A	T.A.G.M Annuel en %
I	Beni M'hafeur	4374	4696	322	1,54
	Saint Thérèse	6667	6925	258	0,82
	Patrice Lumumba	11709	11002	-707	-1,33
	Cité FLN	3346	3104	-242	-1,60
	Centre ville	9550	9067	-483	-1,11
	Vieille ville	10310	10358	48	1,10
	Beau séjour	8273	8593	320	0,82
	An Nasr	3512	3648	136	0,82
	Port Saïd	2726	2616	-110	-0,88
	Seybouse	5799	7174	1375	4,68
	Zone Indus	926	891	-35	-0,82
	Avant port	862	895	33	0,82
	Total sect. I	68054	68969	915	0,29
II	Oued Edheb	10089	10567	478	1,00
	8 Mai 45	12587	14517	1930	3,11
	11 Décembre	6714	6407	-307	-1,00
	Didouche Mourad	8719	8863	144	0,35
	Sidi Brahim	11843	11302	-541	-1,00
	Tabacop	525	556	31	1,23
	Cardozo	223	1603	1380	52,83
	Total sect. II	50700	53815	3115	1,29
III	05 Juillet	4839	7219	2380	8,98
	Entrée ouest (Rym)	1426	6041	4615	36,41
	Safsaf I	20785	21869	1084	1,10
	Safsaf II	21598	24816	3218	3,03
	Belaïd Belgacem	10439	12017	1578	3,07
	Sidi Harb	4199	5303	1104	5,17
	Total sect. III	63286	77265	13979	4,38
IV	Zaafrania	4644	4824	180	0,82
	Elysa	3747	3536	-211	-1,24
	O/ Forcha	10605	12156	1551	2,98
	L'orangerie	9286	9089	-197	-0,46
	La colonne	15751	15074	-677	-0,94
	Total sect. IV	44033	44679	646	0,31
V	R/ Zahouane	1474	1804	330	4,44
	Sidi Aïssa	8183	8993	810	2,05
	O/ Kouba Gassiot	10494	11522	1028	2,03
	Zone éparse	1477	1131	-346	-5,57
	Total sect. V	21628	23450	1822	1,75
	Total communal	247701	268178	20477	1,72

Appendix D: Raw data (table of POS):

Tableau des POS

Désignation		Superficie Ha	Type d'intervention	Observation
01	POS Centre ville	225.82	Modernisation	Délimitation du nouveau centre
02	POS Vieille ville	17.62	Réhabilitation, aménagement	Révision
03	POS Port de plaisance	54.82	Aménagement	Mise en valeur du front de mer
04	POS Ménadia	213.40	Restructuration	Révision
05	POS Zaafrania I	61.80	Restructuration	Revision
06	POS Zaafrania II	220.11	Aménagement	
07	POS Oued Forcha	92.20	Restructuration	Révision
08	POS Sidi Harb	151.50	Restructuration	
09	POS Plaine Ouest	246.92	Restructuration	Révision
10	POS Errym	135.33	Restructuration	
11	POS 5 Juillet	122.75	Aménagement	
12	POS Sidi Achour	70.71	Aménagement	
13	POS TAMZANI	144.83	Aménagement	Rehausser l'image de l'entrée de la ville
14	POS 19 JUIN	67.40	Aménagement	Complexe sportif
15	POS TABACOOP	110.20	Aménagement	Révision
16	POS Champ de Mars	90.94	Aménagement	Révision
17	POS Didouche M	146.15	Restructuration	Révision
18	POS Oued Edheb	100.47	Restructuration	Révision
19	POS Sidi Aissa I	103.62	Restructuration	Révision
20	POS Sidi Aissa II	252.52	Aménagement	
21	POS Refes Zehouane I	54.81	Restructuration	Révision
22	POS Refes Zehouane II	123.93	Aménagement	
23	POS Ain Achir	126.71	Aménagement	Révision
24	POS Zone Touristique	662.60	Aménagement Valorisation	Mise en valeur du parc naturel

Appendix E: Raw data of housing stock:

SECTEURS	Parc Logts Exist au 1/01/2005(1)			Déficit Exist 2005	Logt Progr En C-M-L	Court Terme 2005-2010		Moyen Terme 2010-2015		Long Terme 2015-2025		Logement additionnels 2005-2025
	DUR	précaire	TOTAL			Besoin Global	Besoin Addit	Besoin Global	Besoin Addit	Besoin Global	Besoin Addit	
I	50115	1865	51980	5032	7744	61545	3686	66399	4854	76672	10273	18813
II	8735	1601	10336	2484	1458	16919	6726	24296	7377	37211	12915	27018
III	4878	377	5255	1040	042	8216	3296	11101	2885	13991	2890	9071
IV	4628	364	4992	1268	326	9953	4999	13713	3760	18436	4723	13482
V	13259	642	13901	1887	483	21105	7363	26597	5492	31446	4849	17704
VI	7797	1524	9321	1758	114	8571	660	9073	502	9562	489	1651
VII	1124	390	1514	524	076	2124	924	2597	473	3359	762	2159
interco_mm	**90536**	**6763**	**97299**	**13993**	**10243**	**128433**	**27654**	**153776**	**25343**	**190677**	**36901**	**89898**

Appendix F: Additional statistical analyses and demographic data:

Projection Démographique à Court, Moyen et long termes du 01/01/2005 au 01/01/2025 Selon les secteurs

Périodes Secteurs	Popu Exist Janvier 2005	Pop. Estimée 1/01/2010			Pop. Moyen Terme 2015			Pop . Long Terme 2025			Pop. Addit 2005-2025	
		Pop. Global	Tx. AGMA 2005-10	Pop. Addit 2005-10	Pop. Global	Tx. AGMA 2010-15	Pop. Addit 2010-2015	Pop. Global	Tx. AGMA 2010-15	Pop. Addit 2010-2015	Pop.	Tx. AMGA
I	269181	292751	1.69	23570	316803	1.59	24052	367592	1.50	50789	98411	1.57
II	63366	93425	8.07	30059	121947	5.47	28522	186055	4.31	64108	122689	5.53
III	35511	45191	4.94	96.80	55504	4.20	10313	69954	2.34	14450	34443	3.45
IV	40069	54739	6.44	14670	68561	4.60	13822	92179	3.00	23618	52110	4.25
V	89301	116078	5.38	26777	132986	2.76	16908	157229	1.69	24243	67982	2.87
VI	39099	43150	1.99	4051	45368	1.01	2218	47809	1.05	2441	8710	1.01
VII	11241	12791	2.62	1550	14079	1.94	1288	16789	1.77	2710	5548	2.03
Total Interco	**547768**	**658125**	**3.74**	**110357**	**755248**	**2.79**	**97123**	**937607**	**2.19**	**182359**	**389839**	**2.72**

Projection Démographique à Court, Moyen et long termes du 01/01/2005 au 01/01/2025 Selon les secteurs

Périodes Secteurs	Popu Exist Janvier 2005	Pop. Estimée 1/01/2010			Pop. Moyen Terme 2015			Pop . Long Terme 2025			Pop. Addit 2005-2025	
		Pop. Global	Tx. AGMA 2005-10	Pop. Addit 2005-10	Pop. Global	Tx. AGMA 2010-15	Pop. Addit 2010-2015	Pop. Global	Tx. AGMA 2010-15	Pop. Addit 2010-2015	Pop.	Tx. AMGA
I	269181	292751	1.69	23570	316803	1.59	24052	367592	1.50	50789	98411	1.57
II	63366	93425	8.07	30059	121947	5.47	28522	186055	4.31	64108	122689	5.53
III	35511	45191	4.94	96.80	55504	4.20	10313	69954	2.34	14450	34443	3.45
IV	40069	54739	6.44	14670	68561	4.60	13822	92179	3.00	23618	52110	4.25
V	89301	116078	5.38	26777	132986	2.76	16908	157229	1.69	24243	67982	2.87
VI	39099	43150	1.99	4051	45368	1.01	2218	47809	1.05	2441	8710	1.01
VII	11241	12791	2.62	1550	14079	1.94	1288	16789	1.77	2710	5548	2.03
Total Interco	**547768**	**658125**	**3.74**	**110357**	**755248**	**2.79**	**97123**	**937607**	**2.19**	**182359**	**389839**	**2.72**

Appendix G: Additional climate data:

- **Les vents :**

Tableau N°4 : pourcentage moyen mensuel des vents qui soufflent suivant une direction donnée enregistrée de 1913 à 1938 à la station du Cap de Garde d'après SELTZER.

Direction / mois	N	N.E	E	S.E	S	S.O	O	N.O
Septembre	20	15	11	1	4	1	10	38
Octobre	13	14	9	2	5	2	14	41
Novembre	8	7	8	3	8	4	21	41
Décembre	5	3	6	3	11	5	25	42
Janvier	9	5	5	2	8	5	21	45
Février	12	9	9	2	5	3	19	41
Mars	10	12	10	2	4	1	20	41
Avril	12	10	7	1	4	1	18	47
Mai	17	11	11	1	4	1	14	41
Juin	22	11	7	1	2	1	12	44
Juillet	26	12	7	0	1	0	9	45
Août	25	16	8	1	2	1	10	37
Moyenne annuelle	**15**	**10**	**8**	**2**	**5**	**2**	**16**	**42**

Tableau N°2 : Pluies mensuelles : Moyennes des hauteurs pluviométriques enregistrées de 1913 à 1938 aux stations de Cap de Garde et de Annaba (avant port) et de 1926 à 1938 à la station de Séraïdi.

Mois / Station	S	O	N	D	J	F	M	A	M	J	J	A	Année
Annaba	31	75	108	133	149	105	73	57	37	15	03	07	787
Cap de Garde	31	73	103	111	120	82	60	45	33	14	04	06	682
Séraïdi	36	87	126	158	154	115	90	71	47	20	05	10	919

Station aéroport les salines Annaba :

T 1 : Température moyenne minimale.

T 2 : Température moyenne maximale.

P : Hauteur pluviométrique moyenne mensuelle.

Tableau N°5 :

Mois	T1 °c	T2 °c	T2-T1 °c	T1+T22 °c	P (mm)	Humidité Relative (%)	Rosée Nbre jours	Brouil. Nbre jours	Brume Nbre jours	Ensoleillement nul Nbre jours
S	18,35	28,73	10,38	23,54	29,58	72,80	7,31	0,31	1,87	0,31
O	14,53	25,46	10,93	20,00	74,98	74,24	8	1,31	2,37	0,43
N	10,73	20,43	9,7	15,58	101,58	76,60	7,81	0,68	1,43	1,12
D	7,92	17,46	9,54	12,69	100,53	76,11	10,5	1,5	2,31	2,12
J	6,88	16,23	9,35	11,55	92	76,82	6,56	1	1,68	2,06
F	7,26	16,99	9,73	12,12	73,05	77,34	7,81	1,87	2,87	1,43
M	7,66	18,18	10,52	12,92	72,13	75,78	8,25	1,81	2,68	1
A	9,77	20,17	10,40	14,97	54,64	74,59	6,06	1,31	3,31	1
M	12,72	23,21	10,49	17,96	34,01	75,31	7	2,37	5,12	1
J	16,06	26,82	10,76	21,44	15,42	72,6	5,18	1,5	3,5	0,12
J	18,80	30,34	11,54	24,57	2,87	69,88	4,5	1,43	3,18	0
A	19,64	30,46	10,82	25,05	7,67	72,23	4,87	1,18	2,62	0,31
Moy	12,52	22,87	10,35	17,69	Cumul 657,94	74,52	Cumul 83,85	Cumul 16,27	Cumul 32,94	Cumul 10,09

- **Les températures :**

Tableau N°3 : Les températures moyennes mensuelles de l'air enregistrées de 1913 à 1938 d'après SELTZER.

Mois / station	S	O	N	D	J	F	M	A	M	J	J	A	Moy. Ann.
Annaba	23,53	20,00	16,25	12,80	11,40	11,90	13,65	15,45	18,40	22,04	24,06	25,40	17,95
Cap de Garde	24,7	20,5	16,7	13,1	14,8	12,2	15,7	18,7	20,7	22,3	25,4	26,3	19,3
Séraidi	20,2	15,5	10,6	6,8	5,8	6,8	9,3	11,5	18,5	18,7	21,5	22,4	13,8