وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
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A Thesis Submitted in Partial Fulfillment of the Requirements for the Academic Master's Degree in

Field : Geography and Regional Planning

Specialization: Urban Planning

Thesis Title:

The Legal and Organizational Framework for Flood Crisis Management in Djelfa: Effectiveness and Limitation

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Academic Year: 2025/2026

Acknowledgment

First and foremost, I praise Almighty God for granting me the strength and patience to complete this research dissertation.

I would like to express my deepest gratitude and utmost respect to my supervisor, **Professor Foufou Atif**, for being an exceptional mentor and for his unwavering moral, administrative, and academic support throughout this journey.

My sincere thanks and appreciation also go to my assistant supervisor, **Mr Daifallah Ahmed Wail**, who was a constant source of technical guidance and analytical support, meticulously steering this work toward completion.

I am highly indebted to the civil protection executives of the Wilaya of Djelfa (DPC) for providing the critical data, spatial registries, and institutional infrastructure that facilitated this study. I extend special recognition to:

Mr. Belkheiri Salim, Head of the B.C.R.S.

Commander Khalidi Mokhtari, Head of the Prevention Service DPC.

Finally, I deeply thank the distinguished Chairman and members of the Examination Committee at Ziane Achour University of Djelfa for their academic evaluation, as well as everyone who contributed directly or indirectly to the realization of this architectural and planning endeavor.

Dedication

To my small family… my sanctuary and ultimate source of strength…

To my beloved mother, Nesrine; the core of my existence and my eternal guide.

To you alone belongs the credit for everything I am today.

Without your endless sacrifices, profound love, and prayers, this work would have never seen the light, and I would not have stood where I am now.

To myself; with immense pride and appreciation for the resilience, growth, and milestones achieved throughout this demanding year.

To my first supportive, my dear father, Abbas Chouarani.

To my dear sisters, Naila and Meryem; my soul companions who stood by me through thick and thin, sharing every bitter and sweet moment of this journey.

To the memory of the one who departed this world but will never leave my heart; my late grandfather, Driai Ezzeddine… my second father, who would have been remarkably proud of my achievements today if he were here. May his soul rest in eternal peace.

To everyone who walked by my side, supported me genuinely, shared my sorrows, and celebrated my triumphs…

I dedicate this humble milestone.

ABSTRACT

This study evaluates the institutional framework for flood risk management in Djelfa Commune, examining the shift from the reactive model of Law 04-20 to the proactive, resilience-based approach of Law 24-04. Utilizing the Analytical Hierarchy Process (AHP), the research reveals a severe spatial conflict between urban planning tools (PDAU/POS) and hydrological realities, as high-density developments encroach upon statutory river easements. Field diagnostics expose structural bottlenecks in the drainage network, a regulatory void due to the lack of a Flood Risk Prevention Plan (PPRI), and institutional fragmentation that cripples the ORSEC Plan during flash floods. To enhance urban resilience, the study advocates for enforcing non-aedificandi zones, adopting Nature-Based Solutions (NbS), and integrating a shared Web-GIS decision-support system.

Keywords: Flash Floods, Law 24-04, ORSEC Plan, Spatial Conflict, Urban Resilience, Djelfa.

ملخص الدراسة

تُقيم هذه الدراسة الإطار المؤسساتي لتسيير مخاطر الفيضانات ببلدية الجلفة، راصدةً التحول من المقاربة الردعية للقانون 04-20 إلى الاستراتيجية الاستباقية القائمة على مرونة المدن في القانون 24-04. باستعمال نظام التحليل الهرمي، كشف البحث عن تعارض مكاني صارخ بين أدوات التعمير (PDAU/POS) والواقع الهيدرولوجي نتيجة التوسع السكاني والصناعي داخل الارتفاقات القانونية للأودية. كما أبرز التشخيص الميداني عوائق هيكلية في شبكات الصرف، وفراغاً تنظيمياً لغياب مخطط وقاية ملزم، وتشتتاً إدارياً يعرقل مخطط تنظيم النجدة أثناء الفيضانات الفجائية. ولتحقيق المرونة الحضرية، توصي الدراسة بالتطبيق الصارم لمناطق حظر البناء، واعتماد الحلول القائمة على الطبيعة ، وإدماج منصة رقمية موحدة للـ WebGIS لدعم القرار.

الكلمات المفتاحية :الفيضانات الفجائية، القانون 24-04، مخططORSEC ، الصراع المكاني، المرونة الحضرية، الجلفة.

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Abbreviation List

Urban Planning and Administrative Frameworks

- **APC:** Assemblée Populaire Communale (The municipal government / Municipal Popular Assembly).
- **DUC:** Directorate of Urban Planning and Construction
- **LU/LC:** Land Use / Land Cover.
- **PDAU:** Plan Directeur d'Aménagement et d'Urbanisme (Master Plan for Development and Urban Planning).
- **POS:** Plan d'Occupation des Sols (Land Use Plan / Site Development Plan).

Risk Management and Emergency Frameworks

- **AHP:** Analytical Hierarchy Process (A Multi-criteria decision-making model).
- **BBB:** Build Back Better.
- **BMS:** Bulletin Météorologique Spécial (Special Meteorological Bulletin).
- **CENAC:** Centre National de Coordination Opérationnelle (National Operational Coordination Center).
- **DPC:** Direction de la Protection Civile (Civil Protection Directorate).
- **DRR:** Disaster Risk Reduction.
- **EWS:** Early Warning System.
- **MRV:** Measurement, Reporting, and Verification system.
- **NbS:** Nature-Based Solutions.
- **ORSEC:** Organisation de la Réponse de Sécurité Civile (Algerian Emergency Relief / Management Plan framework).
- **PCS:** Plan Communal de Sauvegarde (Communal Safeguard Plan / local ORSEC).
- **PGP / PGR**: Plan de Gestion des Risques / Plan Général de Prévention (General Prevention Plans / Flood Risk Prevention Plans).
- **PMA:** Poste Médical Avancé (Advanced Medical Post used for triaging).
- **PPRI:** Plan de Prévention des Risques d'Inondation (Flood Risk Prevention Plan).
- **RPA:** Règlement Parasismique Algérien (Algerian Para-Seismic Regulations).
- **SFRE:** Sudden Fall Rainfall Event.

Institutions and Agencies

- **ANRH:** Agence Nationale des Ressources Hydrauliques (National Agency for Hydrological Resources).
- **ASJP:** Algerian Scientific Journal Platform.
- **DGPC:** Direction Générale de la Protection Civile (General Directorate of Civil Protection).
- **DRE:** Direction des Ressources en Eau (Department / Directorate of Water Resources).
- **EPIC:** Établissement Public à Caractère Industriel et Commercial (Public Industrial and Commercial Enterprise status).
- **NMRD:** National Delegation for Major Risks.
- **ONA:** Office National d'Assainissement (National Office for Sanitation).
- **ONM:** Office National de la Météorologie (National Meteorological Office).
- **ONS:** Office National des Statistiques (National Statistics Office).
- **UNDRR:** United Nations Office for Disaster Risk Reduction.

Technical, Geographical, and Safety Metrics

- **AEP:** Alimentation en Eau Potable (Drinking Water Supply network).
- **CAT-NAT:** Catastrophes Naturelles (Mandatory Algerian Catastrophe Insurance Scheme).
- **CW:** Chemin de Wilaya (Provincial Road).
- **DEM:** Digital Elevation Model.
- **DN:** Diamètre Nominal (Nominal diameter).
- **FPT:** Fourgon Pompe-Tonne (Standard Fire Truck).
- **CCI:** Camion Citerne pour Feux de Forêts / Grande Capacité (Heavy Tanker emergency truck).
- **GDP:** Gross Domestic Product.
- **GIS / Web-GIS:** Geographic Information System / Centralized Web-GIS Platform.
- **ML:** Machine Learning.
- **DL:** Deep Learning.
- **NGM / NGA**: Nivellement Général du Maroc / de l'Algérie (General Elevation Benchmark references above sea level).
- **RN:** Route Nationale (National Highway).
- **SCADA:** Supervisory Control and Data Acquisition system.
- **STEP:** Station d’Épuration (Wastewater Treatment Plant, specifically Kaf Haouas STEP)

GENERAL INTRODUCTION

Introduction

In the contemporary discourse on spatial planning and environmental governance, the paradigm of major risk management has shifted from a purely reactive, post-disaster intervention model toward a proactive, resilience-based approach centered on Disaster Risk Reduction (DRR).

Globally structuralized by international benchmarks like the Sendai Framework, this evolution underscores that disasters are not merely inevitable biophysical phenomena, but rather the catastrophic intersection of physical hazards and socially manufactured vulnerabilities. In Algeria, this conceptual transformation found its definitive legislative baseline in Law No. 04-20 of December 25, 2004, which established the overarching rules for prevention, intervention, and risk reduction within the framework of sustainable development. (Law No. 24-04, 2024)

While there is some theoretical obligation to abide by these agreements, applying them practically is a big challenge when dealing with local urban dynamics, especially in fragile environments. (Anis, 2023)

The Djelfa region is located in the high central steppic plateau of Algeria and represents an important socio/economic and transport hub. Djelfa's territory is characterised by a semi-arid climate, irregularly timed high intensity convective precipitation events, and a topographic closure that results in Djelfa being located inside a synclinal basin surrounded by steeply graded topographic ridges, causing the area to behave like a giant natural funnel. Hence, when short-lived violent rain events occur in the area, the surface runoff rapidly flows down the escarpments making ephemeral streams (oueds) become extremely destructive flash floods in just a few minutes. (Chabira, 2022)

The origin of the risk in Djelfa (the manufacturing of risk) is primarily human-made, whereas the origin of the natural hazard is due to hydro-climatic variability. The rapid overpopulation resulting from years of the very high birth rate combined with rapid migration from rural to urban areas has caused the urban expansion to be uncontrolled and the large percentage of the area to be sealed with impervious material. The extensive uncontrolled growth has outpaced the structural and functional ability of its infrastructure and has resulted in residential and industrial areas developed into the active floodplain and drainage corridors (Servitude des Oueds). Consequently, many of these highly vulnerable structures (black spots), such as Boutrifis, Berbih and Ain Chih, have resulted in areas of repeat devastation due to systemic flood risk and a very visible spatial conflict between the formal land-use plans and the dynamicity of the hydrological processes. (Zouhair MAYOUF)

1. Problem Statement

Even though Algeria has an extensive legislative framework for the reduction of numerous types of disasters—such as Law No. 04-20—the Wilaya of Djelfa remains very vulnerable to flash floods. The combination of ongoing significant material damage, extensive damage to public infrastructure, and the continued inability to prevent flooding from multiple annual sources point to a significant gap between the de jure legal framework (theory) and de facto organizational implementation. Consequently, this research will seek to answer the following primary research question:

"To what extent does the current legal and organizational framework for flood crisis management in Djelfa create a sustainable urban resilience and what are the operational limitations that prevent this from becoming a reality?"

Sub-Questions

1. What are the legislative and institutional mechanisms (such as the ORSEC Plan and dynamic Prevention Plans) adopted to manage flash flood risks within the Algerian administrative hierarchy?
2. How do the natural hydro-climatological characteristics and rapid, uncoordinated urban dynamics of the Djelfa Commune interact to amplify the structural mechanisms of flood risks?
3. What are the practical constraints, administrative gaps, and field-level operational failures that hinder the effective application of risk servitudes within the contemporary urban fabric of Djelfa city?

2. Research Hypotheses

To address the core problem and guide the empirical investigation, we propose three interconnected hypotheses:

- **H1 (Spatial Hypothesis):** The high flood risk index and the multiplication of "black spots" in Djelfa are directly linked to rapid urban expansion and land-use changes that systematically ignore the hydrographic network and encroach upon natural drainage easements.
- **H2 (Legislative Hypothesis):** The Algerian legislative system (specifically Law No. 04-20) is theoretically comprehensive but lacks precise, updated regulatory by-laws and enforcement mechanisms adapted to the local geomorphological and edaphic specificities of semi-arid regions, thereby limiting its statutory effectiveness.
- **H3 (Operational Hypothesis):** The critical limitations of flood crisis management in Djelfa stem from weak inter-sectoral coordination among

local authorities, coupled with a fundamental misalignment of spatial urban planning instruments (POS/PDAU) with local hydrological realities.

3. Research Methodology

This study applies an integrated mixed-method approach that merges three analytical dimensions in order to provide a comprehensive spatial assessment and verify the research hypotheses:

A descriptive-analytical method to establish a conceptual, physical and legal framework based on analysis of Algerian urban planning and primary risk law (Laws 04-20 and 90-29) in conjunction with meteorological/hydrological information obtained from the ONM and ANRH relative to the Djelfa region;

A technical spatial analysis using GIS and AutoCAD to digitize hydrographic networks and conduct multi-criteria overlay analyses of flood susceptibility maps with respect to the existing Official Urban Land That Use Plan (POS) to help identify structural vulnerabilities;

An empirical field investigation that entails visually assessing the condition of selected hazard-prone sites and engaging in semi-structured interviews with relevant stakeholders in the areas of Emergency Response (Civil Protection), Urban Planning (DUC), and Municipal Technical Services to gauge the extent of their operational capability and systemic obstacles.

4. Research Obstacles and Limitations

The data collected from institutional fieldwork revealed that Djelfa has a disjointed local data ecosystem, which makes it difficult for them to develop crisis response plans effectively. The impediments to the operational capacity of the Djelfa local data ecosystem were classified by operational category as follows:

Institutional Data Hoarding (DRE): Institutional culture exhibited an extreme bureaucracy which hoarded essential structural maps and underground drainage capacity for use and denied advanced hydraulic simulations of underground systems to develop further.

Administrative Inertia (ONA): Extreme administrative delays and repetitive administrative cycles within the Djelfa region led to significant loss of time spent engaged in operational research.

Technical Obsolescence: DRE provided administrative data included nothing but old and non-technical graduation theses with a large amount of descriptive errors, and no engineering specifications for conducting thorough risk assessments are available.

5. Structure of the Dissertation

The dissertation is organized into three chapters in order to pursue and test the research questions and hypotheses established in the study. The structure of the dissertation follows logically from one chapter to another.

Chapter One - The Physical and Urban Context of The Study Area: This chapter provides baseline information for the Djelfa Commune. It looks at the hydro-climatic and geomorphological characteristics of the area and how these geographic factors are exacerbated by rapid demographic increases, significantly soil sealing, and rapid urban extension to produce localized flooding hazards in the study area given the semi-arid climate and synclinal basin topography.

Chapter Two - The Legal and Institutional Framework for Major Risk Management: It provides a review of the Algerian national risk governance framework with a special emphasis on the role of Law No 04-20 in the management of disaster risk. This chapter will systematically review the de jure existing legislative framework as well as the hierarchically structured emergency response framework (ORSEC), outline the statutory roles of locally-administrative tiers in this legislative framework and identify key areas for review of changing risk governance practices and legal frameworks to reduce vulnerability to floods and develop enhanced resilience strategies in communities affected by floods.

Chapter Three - Operational Diagnosis, Limitations and Resilience Strategies:

The empirical component of the overall research is contained in the final chapter of the research. This chapter includes mapping the geographical elements using Geographic Information Systems (GIS), AutoCAD, and physical inspections of the areas with respect to the identified spatial disputes (POS/PDAU) and actual geographic flood hazard areas.

Furthermore, this section will include the limitations of both the technical limitations, administrative limitations, and social limitations of urban resilience — which include cross-sectoral fragmentation and information asymmetry. After providing these three limitations, the results of this chapter will provide recommendations regarding how to use strategic resources through nature-based solutions, legal solutions, and digital solutions to achieve urban resilience.

Chapter 01:

The Physical and Urban Context of the Study Area

Introduction of the chapter

This chapter provides a rigorous spatial diagnosis of Djelfa, a rapidly expanding city in the high central plains of Algeria, to analyze how its unique physical environment and human development intersect to create high risks of flash flooding. Located precariously between the Tell Atlas mountains and the Saharan highlands, the city's terrain naturally funnels water from intense, short-duration summer thunderstorms directly into its urban core. (Chabira, 2022)

To establish an environmental baseline for evaluating current flood crisis management and legal frameworks, this research explores Djelfa's topography, hydrography, and historical urban expansion. Ultimately, the study illustrates how rapid demographic growth and human activities specifically soil sealing and building over natural drainage corridors have transformed natural climate hazards into severe urban risks, significantly increasing the population's exposure to violent hydraulic events. (Kupicom, 2026)

1. Physical and Climatic Characteristics

Djelfa's hydraulic behavior is strongly determined by its physical environment. The area is situated at the border of two distinct environments; semi-arid steppe at the northern end and Saharan fringe at the southern. This gives it an irregularly dry climate with sudden, intense flooding. A good understanding of the topography and climate factors are critical to understanding Djelfa's susceptibility to flooding.

1.1. Topography and Basin Morphology

The relief of the Wilaya of Djelfa is structured by four distinct physiographic zones that dictate the movement of water across the territory. These zones transition from northern plains to central mountains, finally leveling out in the southern desert.

1. **The Northern High Plains:**

Typically this area is a monotone area with very little slope, and sub-horizontal area with hills that eventually lead to enclosed depressions. These depressions are often called chotts and dayas. Even though these areas are flat, the elevations range from 650 m to 900 m above sea level. Although most slopes here have little slope (typically less than 5%), the basin fills up from pooling of water will eventually form wetlands during times of high humidity. (Chabira, 2022)

2. **The Zahrez Depressions:**

Created as a result of the hydro-eolic process, these two depressions (Zahrez Chergui and Zahrez Gherbi) are essential components of the regional hydrology system. A geological elevation divides them and they are adjacent to the Atlas Saharien to the south. The elevations in the area vary from 1200 meters to 760 meters. (Chabira, 2022)

3. **The Atlas Saharien (Ouled Nail Mountains):**

The central mountain range in the wilaya has the highest points, which can go from 1000 to 1600 meters above sea level. This region also has many steep slopes; most slopes have a degree of inclination of more than 15°; some of these slopes have a degree of inclination greater than 25°. Three examples of peaks are Djebel Senalba (1598 m), Djebel Sahary (1273 m), and Djebel Bou Kahil (1404 m). (Chabira, 2022)

4. **The Saharan Platform:**

This southern zone is remarkably flat and sub-desertic; While it presents fewer constraints for general development, it offers no significant natural relief to assist in rapid drainage, leading to stagnation in specific topographic lows. (Chabira, 2022)

Djelfa is shaped like an enormous funnel due to its topography, which includes mountains that encircle it as a syncline (basin). The geology of Djelfa is primarily responsible for its susceptibility to flooding. High-intensity rainfall on steep mountains that surround Djelfa quickly turn into surface runoff, and as that runoff flows downhill towards Djelfa, it accumulates both speed and volume before entering the city’s low-lying urbanized basin.

Table 1 : Hypsometric Classification and Topographic Context of the Djelfa Region

Elevation Class (m)	Topographic Significance	Regional Context
131 - 423	Extreme Lowlands	Southern Saharan Border
424 - 679	Low Plateaus	Transitional Steppe
680 - 868	Medium Plains	Central High Plains
869 - 1115	High Plains / Urban Basin	Djelfa City Core
1116 - 1602	Mountainous Summits	Ouled Nail / Senalba Peaks

Source: Analysis based on Digital Elevation Models (DEM) of the study area.

The slope angles vary in the wilaya quite a bit; there is a very large difference in slope angle for certain area, for example there are over 80% of sloped areas in Ain Ouessara, the slopes between 0 degrees and 3 degrees are in theory the best for future urban developement. However there are also parts of central Djelfa where the mountains are present creating high kinetic potential, this is due to how a lot of water can be concentrated at one time on the steep hills; as a result, Floods will happen faster, which allows less time for emergency intervention to take place and gives Floods greater destructive force.

1.2. Semi-Arid Climate and Thermal Fluctuations

Djelfa has a semi-arid climate, which experiences very extreme abrupt seasonal alterations and very large temperature gaps throughout the year. The climate of Djelfa can be defined by bedragglingly cold winters and wickedly hot, dry summers with varying transitional periods between each season causing the region to have drastic weather patterns.

The amount of temperature variation or fluctuation is one of the most important components of how temperature is assessed throughout this region. High Plains and other semi-desert areas have a much colder winter as compared to any coastal region in Africa. The average minimum temperatures during the month of December reach an astounding 4.8°C; whereas, the average maximum temperatures in August can get as high as 27.4°C (and will typically be at least 30°C in most years). The amount of fluctuation will have a significant impact on the condition of the soil. The extreme heat during the summer heat and the dry conditions will lead to a desiccated surface creating a hard crust that has a very hard time accepting any moisture when it finally does rain. (Ministère de l'Environnement et des Energies Renouvelables, 2019)

Another significant characteristic of this region is its variability of humidity levels throughout the season. December will typically have the maximum relative humidity level of 85% - whereas July will typically have the minimum level of relative humidity of 32%. The combined effect of the low levels of humidity and the hot dry winds from the south (known as the Sirocco) will have a serious compounding impact on the higher rates of evaporation and lower levels of precipitation in the area. (Ministère de l'Environnement et des Energies Renouvelables, 2019)

1.3. Geomorphological, Geologic, and Climatological Foundations of Flooding in Djelfa

To assess the flood risk in the Djelfa municipality, one considers the geographical, geological, and climatological features of the area. It is located in the centre of Algeria's High Plateau between 900 and 1200 metres above the sea level (NGM), providing a connection point between Algeria's Tellian Atlas in the north and the Pre-Saharan desert in the south. (Civil protection, 2020)

In terms of climate, the bioclimatic index of Bagnouls and Gaussen is an example of seasonal climate in the region. Bioclimatically, there is a lack of moisture in a given month when the cumulative monthly precipitation P (in millimetres) is equal to or less than twice the average monthly temperature T (in degrees Celsius):

$$P \leq \text{le } 2T$$

Long-term meteorological data are analyzed using this index to define a dry period that occurs from June through to September (summer dry) and a wet period that runs from October through to May (winter wet). The average annual rainfall is between 250 mm and 300 mm, throughout the historical baseline of stagnation (275mm).

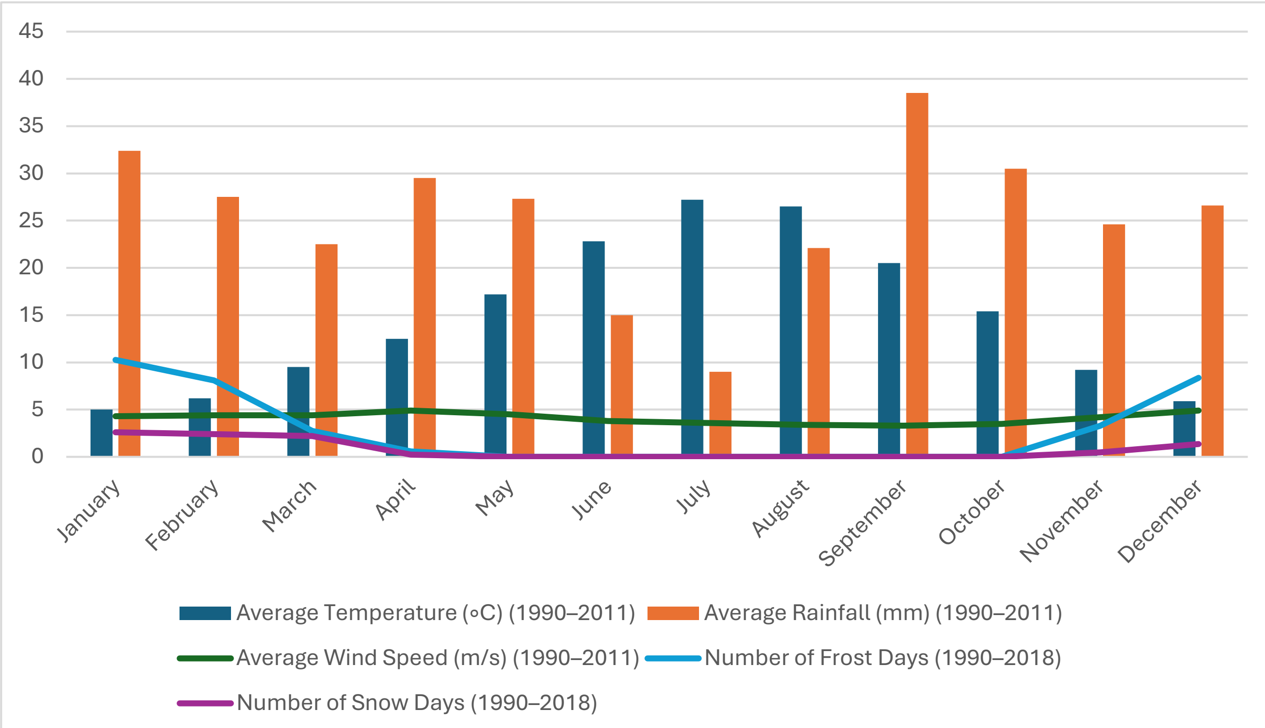
Rainfall in a semi-arid landscape such as this one will exhibit high interannual variability and will be very episodic in nature due to localized, rapidly developing convective storms. Convective storms are often intensified by the uplift of moisture from the western slope of the Ouled Naïl mountain range. (Civil protection, 2020)

Table 2 : Average Monthly Climatic and Hydro-Climatic Parameters for Djelfa City (1990–2018 Baseline)

Month	Average Temperature (∘C) (1990–2011)	Average Rainfall (mm) (1990–2011)	Average Wind Speed (m/s) (1990–2011)	Number of Frost Days (1990–2018)	Number of Snow Days (1990–2018)
January	5.0	32.4	4.3	10.26	2.60
February	6.2	27.5	4.4	8.09	2.40
March	9.5	22.5	4.4	2.74	2.20
April	12.5	29.5	4.9	0.57	0.24
May	17.2	27.3	4.5	0.00	0.00
June	22.8	15.0	3.8	0.00	0.00
July	27.2	9.0	3.6	0.00	0.00
August	26.5	22.1	3.4	0.00	0.00
September	20.5	38.5	3.3	0.00	0.00
October	15.4	30.5	3.5	0.00	0.00
November	9.2	24.6	4.2	3.30	0.47
December	5.9	26.6	4.9	8.35	1.37
Total/Avg	**14.85**	**305.5**	**4.0**	**33.31**	**9.28**

Source: The National Agency for Hydrological Resources (ANRH) and the National Meteorological Office have gathered climatic data.

Figure 1: Integrated Monthly Meteorological Chart of Combined Climatic Parameters for Djelfa City (1990–2018)



source: by the student based on ANRH and NMO climatic data

From a geological perspective, Djelfa is positioned in a symmetric synclinal formation aligned on the northwest to southeast direction. The northern flank (Djebel Senalba) has dip angles greater than 45°, whereas the southern flank has a dip angle of less than 30°.

The stratigraphy is predominantly filled with sedimentary units belonging to the Cretaceous Period. (Civil protection, 2025)

- Triassic: This formation outcrops at the north entrance of Djelfa city and is composed of evaporitic units containing halite, laminated gypsum, anhydrite and clay. The rock is characterized by poor water holding capacity and high salinity due to the presence of salts.

- Barremian and Albian: These two rock formations consist of relatively thick sandstone units with a high primary and secondary fracture permeabilities and yield large quantities of water by way of productive aquifers.
- Cenomanien and Senonian: The two stratigraphic units comprise of low permeability marls, clays and marl limestones.
- Turonian: This formation is characterized by massive dolomitic limestones, with numerous fractures in the rock, which have demonstrated to be productive from a hydro-geological perspective (with discharges of 12 l/s to 15 l/s).
- Quaternary: The Quaternary is characterized by variable thickness alluvial, colluvial and windy sandy deposits.

Soils in the region include shallow regosols on steeper slopes, alluvial–colluvial deposits with valley bottoms and sandy xeric soils all have low organic matter content and high percentage of sand with strong susceptibility to being eroded.

Dry conditions produce hard surface crusting of the soils which creates low initial Volume of Water Retained by Soil (H0 ≈ 14 mm). Large volume of water from intense precipitation creates very rapid surface runoff to cause flash flooding. (Civil protection, 2020)

2. Hydrographic Network and Drainage System

The Djelfa area has a dense network of intermittent watercourses called Oueds. These watercourses serve as the main route for water during floods and are a key factor in how the city's location affects its physical exposure to disasters.

2.1. Major Watersheds and Collectors

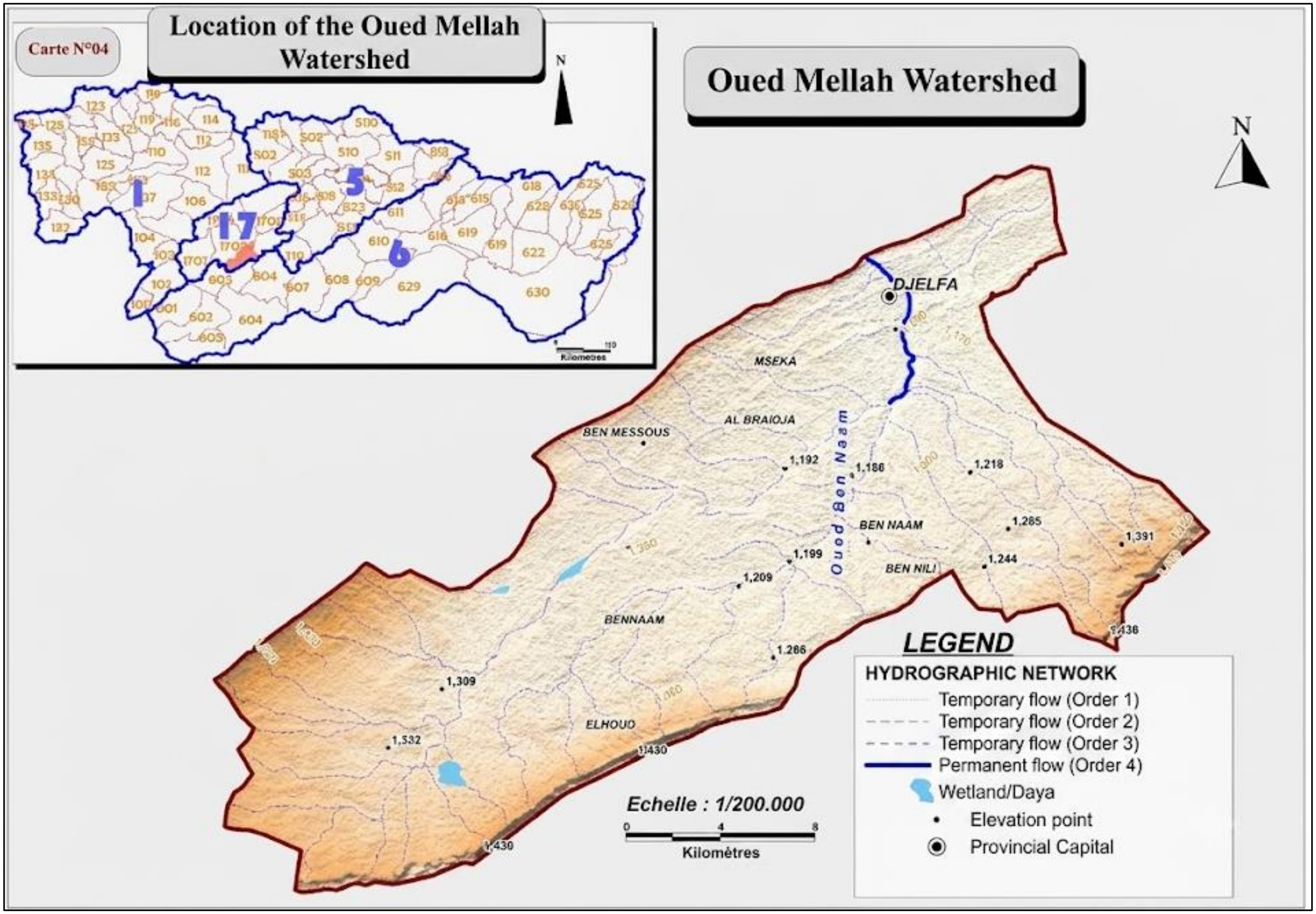
Hydrography of Djelfa (Wilaya di Djelfa) is primarily endorrheic because it drains into a series of internal basins rather than an oceanic basin except for the river inflow from Oued Touil and Oued Ouark which are located in the extreme north portion of the Wilaya.

As such, the city of Djelfa lies at a hydrographic junction with multiple tributaries contributing to its total river inflow :

- **The Northern Collectors:** Collect water from the southern slopes of the Atlas Saharien and drain toward the Zahrez depressions..
- **The Central Urban Network:** This system is organized around the **Oued Mellah**, which serves as the principal collector for the urbanized syncline..
- **The Southern Collectors:** Drain the southern face of the Ouled Nail mountains toward the Oued Djeddi and the Saharan platform..

The hydrological system has an dense and complicated network of tributaries because it is a mountainous environment. Local maps have shown that the city of Djelfa (at "ACL Djelfa") has been almost completely surrounded or crossed by both ephemeral and oueds. Major oueds, such as Oued El Hadid and Oued Metreklat, feed into the central oued system known as Oued Mellah. (Chabira, 2022)

Map1 : Location of the Oued Mellah Watershed



Source: Automated processing of DEM (ASTER2011) + modified by student

2.2. Natural Drainage Patterns and Oued Mellah

The Oued Mellah is the primary hydraulic actor within the city. It crosses the entire study area along the line of the "Cluse de l'Oued Mellah" (Oued Mellah Gap) which follows its path, as well as through the southern flank of the Djebel el Gada. The drainage pattern is classified as sub-dendritic; although it retains a tree-like appearance, it is limited by the geological structure (i.e., Djelfa Anticlinal).

A defining characteristic of this drainage network is its tributaries' orientation; a large proportion of secondary waterways exhibit a marked preference for an N-S orientation (flow from the steeply graded ridges into the E-W flowing main stem of the Oued Mellah) (I.e., runoff from mountains located both north and south of the Oued Mellah meets at or near 90 degree angles to the main channel, creating turbulence and increasing potential for overtopping of the banks of the Oued Mellah during periods of heavy rainfall).

In times of heavy rain, Oueds behave extremely violently and unexpectedly. They are dry for the majority of the year and can be commonly seen as "dry beds", however when a major storm occurs, they react within minutes to the storm's rainfall. The amount of solids (mud, rocks & debris) that are carried downstream by fast-moving Flash Floods increase the amount of density in the flow and, the force with which the flows are applied to the urban infrastructure being affected by the Floods.

2.3. Groundwater Potential and Drainage Constraints

From a hydrogeological perspective Djelfa has many groundwater resources (aquifers), including the Djelfa Synclinal (primary sources of drinking water and irrigation) as well as their potential impact on stream flow or flooding.

Table 2 : Major Hydrogeological Units, Groundwater Potential, and their Hydrological Roles in the Djelfa Region

Hydrogeological Unit	Maxima Potential (Hm3)	Role in Local Hydrology
Zahrez Basin	140	Terminal catchment for northern flows
Ain Ouessara Plain	55	High-potential agricultural aquifer
Djelfa Synclinal	40	Primary urban water supply
Oued Touil Valley	25	Western drainage corridor
Synclinal of Ain El Ibel	45	Southern regional support

Source: Monograph 2021 of the Wilaya of Djelfa

The Djelfa Synclinal contains a large aquifer that has a recharge rate of 24.10 x 10^3 m^3/year. The presence of a high groundwater table (i.e. the remontée de nappe) in some low lying urban areas can cause soils to be saturated from below, resulting in very little capacity for soil to absorb rainfall even with moderate precipitation (Chabira, 2022). This coupled with the endorheic characteristics of the regional drainage creates conditions whereby floodwaters remain in topographically depressed areas for prolonged periods of time, leading to the potential for damage to the structural foundations of buildings as well as the urban sanitary sewer system. (Zinai & Nesrat, 2018)

3. Urban Dynamics and Spatial Expansion

The flash flood hazard is caused by the geographical aspects of the area there and human actions have developed the region (Djelfa) so rapidly into a regional capital that there has been little consideration given to the area's topography and hydrology. (Guehguih Salhi & Ghanem, 2023)

3.1. Demographic Evolution and the Urban Surge

Since the 1960s, the population in Djelfa region has experienced an explosive growth. From 1966 to 2008 (Guehguih Salhi & Ghanem, 2023), this population experienced a four-fold increase, which is mainly due to high birth rates and large-scale migration from rural areas into urban centers in search of safety and services. (Kupicom, 2026) (Bendechou, Akakba, Kalla, & Hachi, 2024)

Table 3 : Demographic Evolution and Population Growth Rates in the Wilaya and Commune of Djelfa (1966–2020)

Census (RGPH)	Wilaya Population	Growth Rate (%)	Djelfa Commune Population
1966	241,849	-	25,600
1977	459,000	4.3	45,900
1987	494,494	2.2	84,200
1998	797,706	4.5	158,700
2008	1,090,578	3.2	265,833
2020 (Estimate)	1,710,393	-	579,971

Source: Compiled from National Statistics (ONS) and RGPH data.

As of the year 2020, the Commune of Djelfa had almost 580,000 residents. The spike in population has created significant challenges to urban planners; consequently, huge areas of the built environment have expanded quickly and often without any control. (Bendechou, Akakba, Kalla, & Hachi, 2024)

3.2. Spatial Expansion and the Impermeabilization of Soil

The hydrologic response of the Djelfa Basin has been greatly changed due to the rapid urbanization in Djelfa. Modern hydraulic studies have shown that the urban environment (roads, buildings and paved surfaces) causes hydrologic problems and greatly reduces the ability of soil to absorb (infiltrate) rainfall.

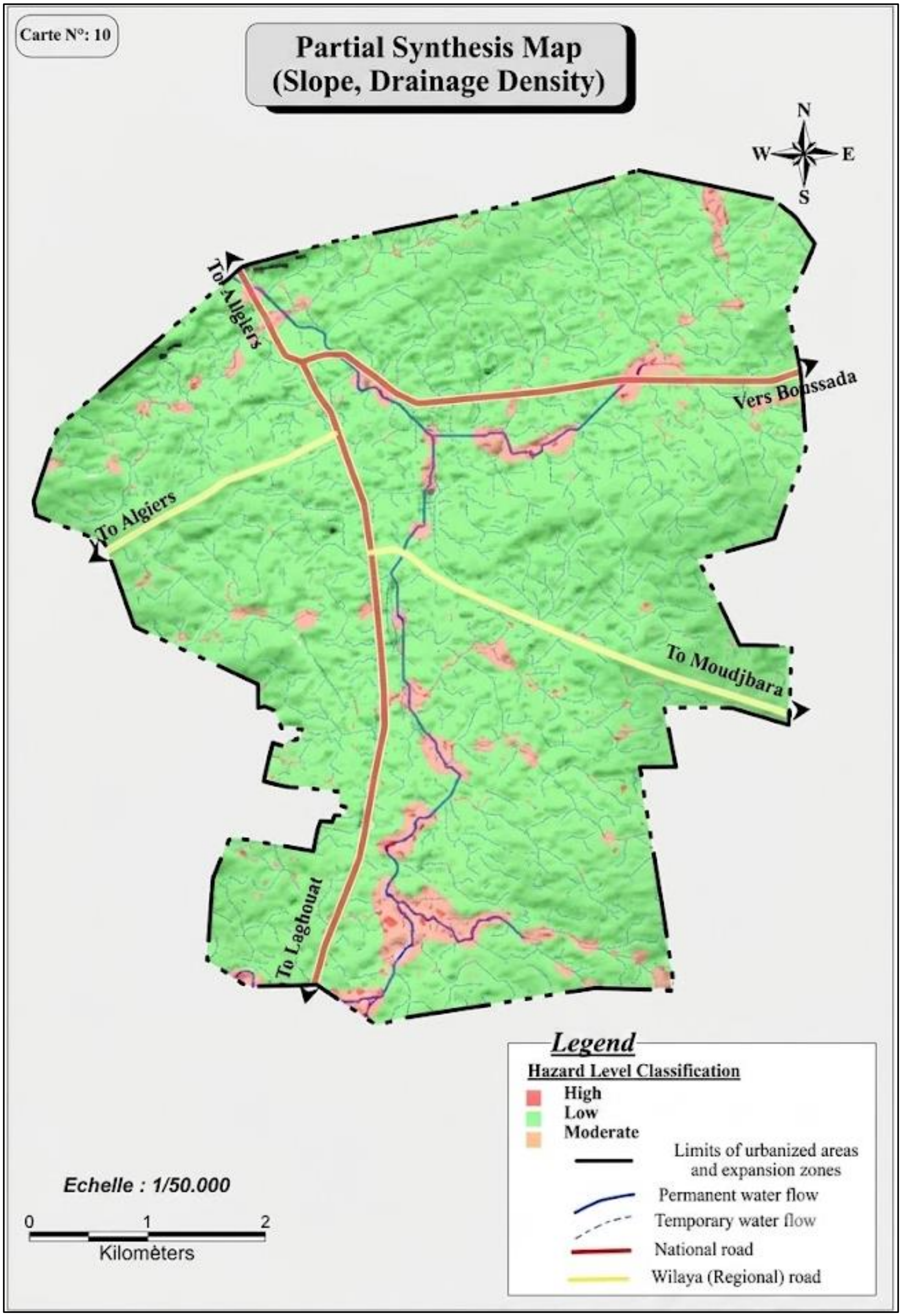
Hydrological modifications due to urbanization (LULC) in Djelfa are significant. From the 1990s until today, Djelfa has seen a change from the colonial grid of houses to a more dispersed and polycentric urban fabric (Kupicom, 2026). This development causes an excessive amount of sealing of the soil (impermeabilization). In a natural steppe environment, rainfall can enter the ground (infiltrate) and/or be slowed by the sparse vegetation. In our case, with all the LULC changes occurring in Djelfa, most of the rainfall is converted to runoff immediately after the rain subsides (Bendechou, Akakba, Kalla, & Hachi, 2024). In addition, the increase in runoff due to urbanization has increased the amount of water entering Oueds and decreased the amount of time needed for that water to collect and flow into the Oueds. Consequently, the floods have increased in instances of flooding and in their unpredictability. (Chabira, 2022)

3.3. Construction in Risk Zones and Natural Pathways

The spatial diagnosis' most noted component is that drainage ways (natural) and flood prone area's are consistently occupied. Due to lack of sufficient land (or safe land for that matter) and the rapid pace of expansion, many residential areas have been constructed directly on the banks of the Oued or located in the less stable lowlands of the urban syncline.

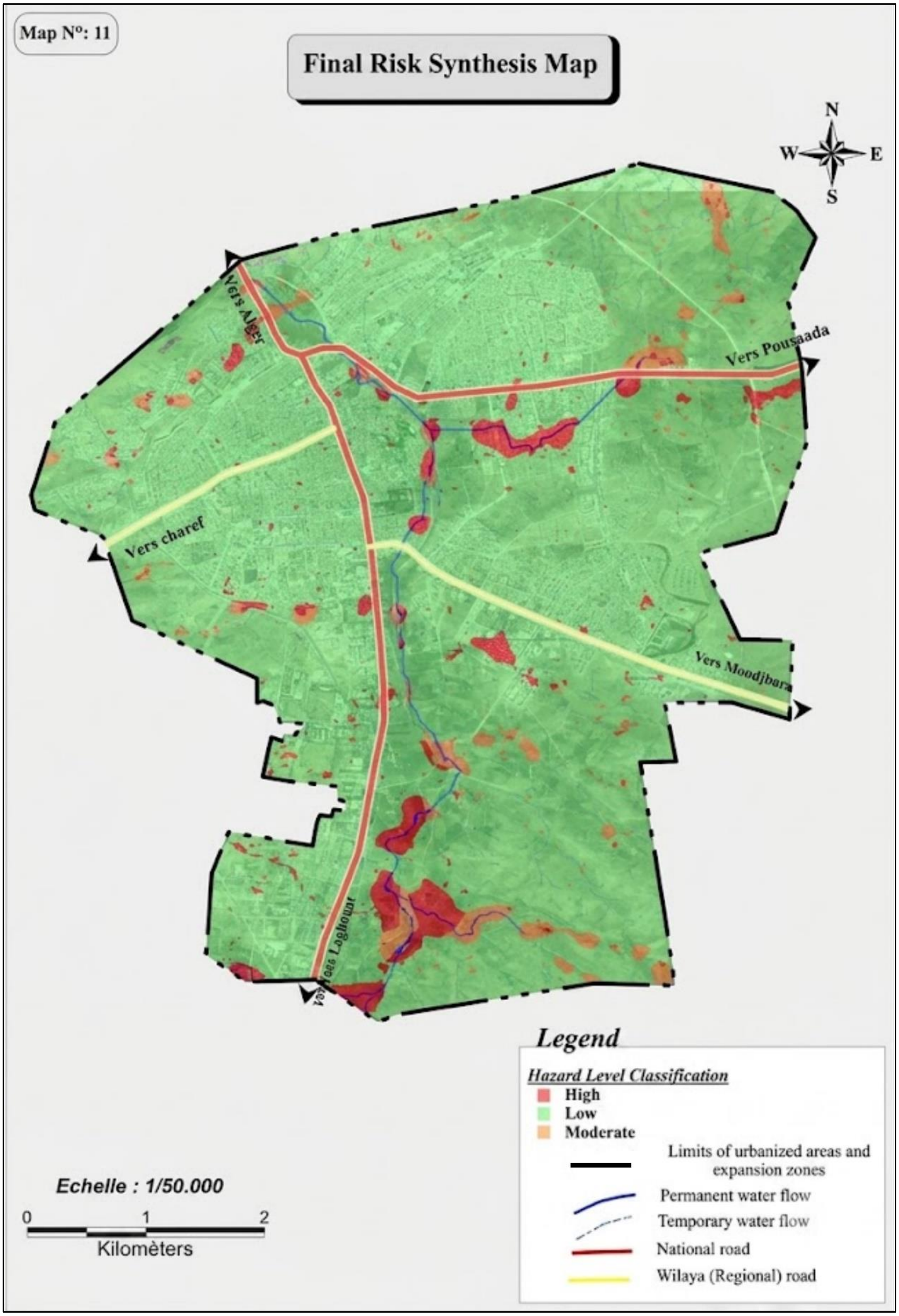
Analysis of the risk synthesis maps has revealed a direct relationship between the densest urbanized areas and "high" hazards. The secondary branches of the Oued Mellah (illustrated on image 03) have a large percentage of the land area that constitutes the most vulnerable areas to flooding.

Map2 : Prtial Synthesis Map (Slope, Drainage Density)



Source: Automatic processing of the DEM (ASTER2011) modified by the student

Map3 : Final Risk Synthesis Map



Source: Digital globe background 2006 modified by the student

The following types of human activity have resulted in changes in the natural topography:

- **Embankment and Encroachment:** Construction directly on the edges of Oueds reduces the cross-sectional area of the riverbed, forcing water into streets when it overflows..
- **Inadequate Drainage Systems:** The rapid growth of neighborhoods has outpaced the development of stormwater infrastructure. Many systems are undersized or poorly maintained, becoming clogged with solid waste and sand transported by the floods..
- **Anthropogenic Barriers:** New roads and walls often act as unintended dams, blocking natural flow paths and causing water to pool in residential basements..

3.4. Neighborhood-Level Vulnerability: The black spots

The crossroads between the physical hazard and urban sprawl has caused many black spots across Djelfa city. The Protection Civile and satellite studies have identified these black spots as having the highest likelihood of experiencing repeated disasters. (Chabira, 2022)

1. **Northern Districts (Boutrifis, Belbidh, Bahrara):**

These regions are heavily impacted in the northern region of the city. Boutrifis is located directly in the path of runoff from the northern mountain range. Many house and lives were lost during the flooding of 2015 in these communities.

2. **The Eastern Gateway (Gare Routière):**

Due to being situated at the bottom of several drainage lines, the area surrounding the central bus station is prone to flooding, and this often causes major disruption to the city's main transport route to the rest of the country.

3. **Western Neighborhoods (Ain Chih):**

Intense runoff in residential districts located near the Hamdoun school extends beyond the available capacity of both local AEP (water supply) and the local sewerage systems serving the area.

4. **Southern Expansion Zones (Berbih and Boulevard 6):**

The continued expansion of the urban area to the south means that as you develop further upstream, you approach the remnants of the basin. Therefore, neighbourhoods such as Berbih will be located in areas where mountain torrents will have a lot of kinetic energy associated with them before they enter the main Oued Mellah.

Table 4 : Identification, Danger Classification, and Vulnerability Drivers of Flood-Prone Neighborhoods in Djelfa

Neighborhood	Danger Class	Primary Vulnerability Driver
Boutrifis	Very High	Steep mountain runoff path / Historical density
Berbih	High	Recent expansion in upstream/risk zone
Gare Routière	High	Topographic depression / Infrastructure hub
Ain Chih	Medium	Insufficient drainage / Soil sealing
Belbidh	Medium	Proximity to Oued Mellah secondary branches

Source: Derived from Protection Civile data and SAR Sentinel-1 flood mapping.

The 2015 flood is a prime illustration of the vulnerability described. A severe rain event in Morett had occurred on September 8, 2015 resulting in two deaths and causing damage to over 25 neighborhoods and causing extensive damage to the City's hydraulic systems. This event confirmed that our current urban fabric is fundamentally at odds with the natural hydrographic patterns of our region. (Chabira, 2022)

3.5. The Manufacturing of Risk: Hazard vs. Stake

Following the conceptual framework utilized in modern urban risk assessment, the situation in Djelfa is a perfect demonstration of the formula (Chabira, 2022):

Risk = Hazard times Vulnerability.

- **The Hazard (Aléa):** This is the natural phenomenon the probability of violent rain and topographical funneling. It is largely non-controllable.
- **The Stake (Enjeu):** This is the human element the half-million residents, the businesses, the schools, and the infrastructure placed in the basin.
- **The Vulnerability (vulnérabilité):** This is the characteristic of the community that makes it susceptible; In Djelfa, vulnerability is high due to poor site selection for housing, massive soil impermeabilization, and a historical lack of structural protection works..

The devastating impact of a natural climate event (rainfall), that human activities have altered, now has an ongoing impact on the urban environment. By constructing in areas that are subject to risk, and converting permeable land to impermeable surfaces (such as concrete), cities create their own risks or "manufactured" risks. A spatial assessment confirms if there is no significant change in managing urban contexts, cities will increasingly suffer additional financial losses from increasing frequency and intensity of extreme weather events caused by climate change.

Conclusion of the chapter

This chapter demonstrates a clear causal correlation between Djelfa's physical environment and its trajectory of urbanization, showing how natural systems and unchecked urban dynamics intersect to create flash flood crises. The research highlights how the topography of the Ouled Naïls mountain range and the High Plains creates a natural catchment that funnels surface water into a sub-dendritic hydrographic system (primarily the Oued Mellah and its tributaries), directing intense flash floods straight toward the urbanized syncline.

Furthermore, this research indicates that while the natural geography creates the hazard, the crisis itself is driven by 40 years of explosive population growth (from 25,000 to over 500,000 residents). This study illustrates how rapid expansion forced development onto the banks of the Oued and into natural drainage features, leading to widespread soil sealing that accelerates the volume and speed of runoff. Consequently, specific neighborhoods like Boutrifis and Berbih have emerged as systemic black spots of vulnerability. Ultimately, this study argues that the Djelfa flood crisis is not merely a climate issue, but a critical breakdown of urban planning and land management systems. By documenting this transition from a natural hazard to urban vulnerability, this research sets the stage to evaluate current legal and organizational frameworks, identify structural limitations, and propose solutions for a safer urban future.

Chapter 02:

The Theoretical, Legal, and Organizational Framework

Introduction of the chapter

Chapter 02 of the study will provide an in-depth theoretical, legal, and institutional analysis of flood risk reduction and flood management mechanisms in Algeria as established in the physical and spatial diagnosis of the study area discussed in Chapter 01.

1. Conceptual Approach to Risk Management

When transitioning from a reactive approach to emergency management to a proactive, risk-based way of governing, we have fundamentally changed how we understand disaster risk reduction (DRR). Traditionally, disasters were seen as geophysical events that are unavoidable often referred to as Acts of God (or simply, natural disasters) but today, through the lens provided by the Sendai Framework for Disaster Risk Reduction 2015-2030, and other contemporary academic writings, we now see disasters as the result of a combination, or a result of the interaction between, the socially constructed vulnerability of society, and geophysical hazards.

In Algeria, this conceptual evolution has been articulated in Law 24-04 of February 26th, 2024 which provides the overall legal framework for the prevention, response/intervention and mitigation of the risk of disaster within the context of sustainable development; this law aligns with National Laws of Algeria and also aligns very closely with international standards set forth by the United Nations Office for Disaster Risk Reduction (UNDRR).

To develop a rigorous conceptual framework for managing risk, it is critical that the definitions of each of the main components of risk management are clearly defined; one must understand the mathematical interdependence of the components of risk management; and finally, one must have an overarching or systemic view of the crisis management cycle - especially the transformational concept of building back better. (Unated Nations, 2022)

1.1. Definitional Frameworks: Hazard, Vulnerability, Exposure, and Resilience

The fundamental terminology for Disaster Risk Reduction (DRR) is based around four main components that are interconnected: hazards, vulnerability, exposure and resilience. These terms are not merely used as descriptions of conditions but as variables to be defined and measured for purposes of assessing and reducing risks. The 2017 ISO and UNDRR definitions are a framework to support a common basis for the definition of these terms around the globe, and thereby to permit interoperability among both the various international scientific communities and the national institutions involved in managing regulations. The definitions specified in Article 2 of Algerian Law 24-04 therefore provide an important formal linkage from AL 24-04 to the definition of hazards within Algeria. (UNDRR, Hazard Exposure: Definition and Terminology, 2017)

1.1.1. The Ontology of Hazard

The physical aspect of risk is known as a "hazard" (aléa) as explained by the United Nations Office for Disaster Risk Reduction (UNDRR). According to their terminology, a hazard is defined as "any potentially harmful event, incident, or activity that may result in loss of life or injury; damage to property; disruption of society or commerce; or environmental degradation". Hazards stem from both natural causes (geological, hydrometeorological, biological) as well as anthropogenic (technological, environmental degradation). (UNDRR, Hazard Exposure: Definition and Terminology, 2017)

Algerian Law No. 24-04 also captures this wide range of hazards and requires that they be defined as any "process, event, or human activity that can cause loss of life, injury, or other negative effects on health; damage to physical property; disruption of society or commerce; or degradation of the environment" (Art. 2). This definition legitimizes the multi-dimensional nature of threats that face the Algerian territory. Through its identification of 18 different classes of "major hazards" that comprise Algeria's national hazard profile, Algerian Law No. 24-04 captures this dimensionality by identifying the complete set of hazards in Algeria – from earthquakes and landslides to viral epidemics and technological malfunctions. (Law No. 24-04, 2024)

Table 5 : Comparative Matrix of Hazard Dimensions and Definitions Between the Global UNDRR/Sendai Framework (2017) and Algerian Law No. 24-04

Hazard Dimension	UNDRR/Sendai Framework (2017)	Algerian Law 24-04 (Article 2)	Implications for DRR
Primary Definition	Potentially damaging event or human activity.	Process, phenomenon, or human activity causing harmful impacts.	Shifts focus from the event to its potential consequences.
Origin	Natural (geological, etc.) or human-induced.	Comprehensive; includes natural and anthropogenic sources.	Requires intersectoral coordination between environmental and industrial agencies.
Scope of Impact	Life, property, environment, and social/economic functions.	Health, assets, social/economic stability, and environment.	Mandates a holistic assessment beyond mere physical damage.
Temporal Nature	Includes latent conditions and future threats.	Part of the development cycle; necessitates continuous monitoring.	Justifies investment in long-term prevention over short-term response.

Source : Created by the student

According to seismologists, the threat from earthquakes is now the greatest hazard to life and property in Algeria's history. The majority of earthquake activity in Algeria can be attributed to the shallow- to intermediate-depth tectonic environments found in northern Algeria; therefore , it is common for these earthquakes to originate at depths of less than fifteen kilometers. (Ministry of Interior, Local Authorities and National Planning, 2024)

The data and information available from historical observations indicate that some of the highest-magnitude earthquakes ever recorded in the region include: Algiers (1365 and 1716), Orléansville (1954 and 1980), and Boumerdès (2003). Due to the longstanding seismic hazard in Algeria, the 2024 Algeria Para-Seismic Regulation (RPA) now governs such activity through defining (7) seismic zones (with increasing intensity level) throughout Algeria where per-seismic zone. (Ministry of Interior, Local Authorities and National Planning, 2024)

1.1.2. The Susceptibility of Systems: Vulnerability

An individual's, community’s, asset’s, or system's potential for being negatively affected from the impacts of a hazard is referred to as vulnerability. According to the UNDRR, “Vulnerability is the condition determined by physical, social, economic and environmental factors and/or processes that make an individual, community, asset or system susceptible to the impacts of hazards. Unlike hazards which are usually external phenomena, vulnerability is an indelible feature of the Human-Environment System”. (UNDRR, Disaster Vulnerability: Definition and Terminology, 2017)

Under Algerian Law 24-04, the identification and mapping of vulnerabilities shall occur at the wilaya and commune levels. This legislation underscores that vulnerability is dynamic and shaped by factors of development. For instance, a building's level of exposure, the complexity of supporting infrastructure, or the number of actors responsible for the delivery of public services will all be components in determining whether a building is vulnerable to the possibility of flooding. (Law No. 24-04, 2024)

Foundational academic literature considers vulnerability as existing throughout a development continuum in the Pressure and Release model by Wisner et al (2004). These authors reference "root causes" (limited access to decision making; economic systems) and “dynamic pressure" (rapidly growing cities; lack of skill level) to indicate pressure created by socio-economic forces on social institutions and physical infrastructures that leads to the creation of unsafe conditions (i.e., lack of protective structures; site locations) as a result of the coalescing nature of socio-economic pressure and physical hazards. (Roxana L. Ciurean, 2013)

1.1.3. Spatial Dimension: Exposure

It is defined as "the structure of both assets (such as buildings) and landform types (such as rivers, roads, etc.), with the assets located on the landscape that create threats and are also located on that landscape providing some level of physical threat".

Where to Find Changes in the Conditions of Population, Urban and a Low Population Density But a Very High Density on a Landform: "The Level and Types of Exposure Will Vary by Type of Land Usage, but Each Has to Meet Some Level of Service"

This means the users of youth who have been impacted in both rural areas (urban variety) and urban areas.

The diagram below represents how the population will be distributed in different types of urban areas to show the total number of people living or visiting the areas. In addition, data is shown to show percentages of population in urban and rural areas, as well as categories of housing type (i.e., single family; multiple units attached). (UNDRR, Hazard Exposure: Definition and Terminology, 2017)

1.1.4. The Capacity to Adapt: Resilience

The UNDRR defines "resilience" as the ability of a system, community or society that is exposed to hazards to resist, absorb, accommodate, adapt and evolve, and recover from the impact of the hazard as quickly and effectively as possible. Resilience includes "capacity" - i.e., the capabilities and resources that exist within a community and the community's ability to use them to manage and reduce risk. In Algeria, the law places resilience as one of the three priorities stated in Article 4. The law requires that the Government invest funding to finance operations that will enhance resilience capacity (responsive resilient structural elements), as well as, enhance social resilience (i.e., public education and communication strategies). Resilience is defined as the ability to support the community in absorbing and recovering from the shock from a hazard; therefore, it will be key to the proactive approach that is focused on prevention. (UNDRR, Disaster Resilience: Definition and Terminology, 2017)

1.2. Mathematical Modeling of Risk: Determinants and Interdependencies

An important element of a DRR Master's thesis is the detailed examination of the mathematics that link together risk and its determining factors. Most of the academic community circles use a formula that defines the level of risk as being equal to hazard multiplied with exposed persons and level of vulnerability.

1.2.1. The Core Equation of Disaster Risk

Throughout the literature defining risk, many authors refer to a "pseudo-equation" for this purpose. Specifically, the equation used to define risk is typically defined as; (Roxana L. Ciurean, 2013)

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability}$$

With a more complete and widely accepted informal definition now being used by both the UNDRR and other contemporary research; (Salvaña, 2025)

$$Risk \; = \; \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

According to this formulation;

- Hazard (H): Is the probability of a physical event of a certain strength occurring in a specified location.
- Exposure (E): Is a measure of how many elements (people, buildings and infrastructure) are present in the area impacted by the hazard.
- Vulnerability (V): Is an estimate of how much damage (or fractional loss of value) will occur to the assets affected by the hazard, and generally ranges from 0 (no damage) to 1 (total loss).

Some researchers go so far as to also include Capacity (C) in the denominator of the risk equation (Salvaña, 2025) :

$$Risk = \frac{\text{Hazard} \times \text{Exposure} \times \text{Vulnerability}}{Capacity}$$

In this version of the risk equation, the impact of risk can be reduced by decreasing either the numerator (i.e. decreasing hazards, decreasing exposure, and decreasing vulnerability) or, by increasing the denominator (i.e. increasing capacity (strength) and/or resilience).

1.2.2. Rigorous and Integrated Risk Assessment

For engineering and planning purposes, risk is often defined in a mathematically rigorous sense as a "Pointwise Risk" (r) or an "Integrated Risk" (R) over a specific area (A). (Salvaña, 2025)

Pointwise Risk (r):

$$r(T,P,B,Q,x,y) = h(T,P,B,x,y)\,.\,e(P,B,x,y)\,.\,v(P,B,Q,x,y)$$

Integrated Risk (R):

$$\mathrm{R(A,T,P,B,Q)} = \int_A h\,.\,e\,.\,v\;dxdy$$

In these models:

- T represents environmental elements (topography, soil).
- P and B represent distributions of population and buildings.
- Q represents the resilience of individual exposed elements.

This integral approach allows for the probabilistic interpretation of risk as the "expected loss of value" over a defined period. In Algeria, this mathematical perspective is vital for the implementation of the "CATNAT" insurance scheme, where the state aims to increase subscription rates to 25% to offset the 34 billion DA spent annually on post-disaster interventions. (Salvaña, 2025)

1.2.3. The Coupling Coordination and Multi-Risk Approaches

Modern risk modeling has moved beyond "single-hazard" assessments toward "multi-hazard" and "multi-risk" frameworks. This shift accounts for the interaction between different hazards (e.g., an earthquake triggering a landslide) and the "principle of concomitance" established in Article 5 of Algerian Law 24-04. This principle requires that the identification and evaluation of risks take into account the interactions and potential aggravation of risks when multiple events occur simultaneously. (Law No. 24-04, 2024)

Table 6 : Quantitative Risk Components, Mathematical Formulations, and the Expected Effects of Targeted Planning and Structural Interventions.

Risk Component	Quantitative Metric	Role in the Mathematical Formula	Effect of Intervention
Hazard (H)	Probability Density (P)	Multiplier ($0 \leq H \leq 1$)	Reduction via structural prevention (e.g., dams).
Exposure (E)	Asset Value / Pop. Count	Multiplier ($E > 0$)	Reduction via land-use planning and relocation.
Vulnerability (V)	Fragility Function (f)	Multiplier ($0 \leq V \leq 1$)	Reduction via building codes and retrofitting.
Capacity (C)	Resilience Index (Q)	Mitigating variable	Increase via training, alert systems, and insurance.

Source : Created by the student

These variables demonstrate that risk is not linear; e.g., for extreme hazard scenarios, disaster risk from an extreme hazard might occur due to the exposure rather than the vulnerability and thus even a strong structure could fail when subjected to forces of nature.

1.3. The Crisis Management Cycle: A Systemic Perspective

Operationalizing the risk management process involves implementing a continuous cycle of four main phases Prevention, Preparation, Response, and Recovery. The Sendai Framework, along with Law 24-04, describes these four phases as being part of a continuous cycle that follows all four stages of the disaster timeline and incorporates risk reduction into all four phases. (Paul Y Kim, 2015)

1.3.1. Prevention and Mitigation

Both structural and non-structural measures are used to prevent the development of new risks and reduce existing risks through a set of various risk prevention strategies.

The strategic basis of the national disaster risk reduction (DRR) policy is that prevention is the principle way of reducing risk within the framework of Law 24-04. Article 7 sets out a number of specific objectives for the overall prevention strategy, including: reducing the number of deaths, reducing the number of persons affected.

There are a number of different ways in which Algeria has implemented prevention measures. They include:

- Security of infrastructure: Infrastructure development will include "securisation préventive" realisation of industry, dams, and flood defences

- Legislative and land use (general prevention plans) frameworks (principles of precaution and prudence) that establish guidelines for use even in situations where there is no definitive scientific certainty.

The most important lesson to be learned from Algeria's prevention strategy is the "1-to-4 rule": that for every 1 DA spent on prevention, the Government will save 4 DA in the future through preventative action. This economic rationale is the foundation for the Algerian Government's commitment to the establishment of a "General Prevention Plan," which is specific to each of the 18 major risks that have been identified. (Ministry of Interior, Local Authorities and National Planning, 2024)

1.3.2. Preparedness

Preparedness encompasses the enhancement of competencies and knowledge to proficiently respond to disasters and foresee them. The national alert system as per Law 24-04 article 18 is defined and organized as three levels—national, local, and specific site in order to accelerate the transmission of information.

The major benchmarks of preparedness in Algeria are the following:

- Early Warning and Alert System Development: Development of multi-hazard early warning systems (EWS) is vital for the population to be informed in a timely manner during catastrophic events.
- Simulation and Planning: Conducting periodic national and local exercise simulations for the “Plan d’Organisation de Secours” (ORSEC) will aid in the assessment of how well this plan works in the event of an actual disaster.
- Public Awareness: Increasing the level of public education on creating a “prevention culture,” in addition to providing transparency regarding the data collected on risk..

1.3.3. Response

During or shortly after a disaster, the response phase is when emergency measures are carried out to protect life and provide for people’s basic needs. The state of Algeria provides for “equal and permanent access” to services that intervene during this period through the Ministry of Interior and DNRM (National Delegation for Major Risk). The response is directed by the ORSEC plan, which identifies the duty of various sectors at the national and local level.

1.3.4. Recovery and Rehabilitation

Rehabilitation includes rebuilding and advancing the community's infrastructure and available resources after a catastrophic event. According to Priority 4 of the Sendai Framework, recovery is regarded as an essential opportunity to incorporate disaster risk reduction strategies within subsequent development opportunities whenever recovering after an event occurs. Thus, it is the phase at which the "Build Back Better" philosophy will begin to be implemented.

1.4. Build Back Better (BBB): The Mandate of Article 81

BBB refers to a new way of doing recovery that looks at the reconstruction of things so that they will be less likely to suffer the same disaster again. The legal basis for this approach in Algeria is in Law 24-04, Article 81 (part of the chapter on Relèvement).

1.4.1. Legal and Strategic Foundations of Article 81

The post-disaster recovery process is governed by the principle of "better reconstruction / rehabilitation" as set out in Article 81 from a named disaster event(s); this is designed to avoid creating new risk conditions based on simply rebuilding to where (pre-disaster) standards may have been a contributor to the underlying problem(s) initially.

Article 81 contains several significant operational requirements, identified as follows;

1. The integration of risk within the design of new infrastructure/buildings inclusive of recent updated paraseismic/geological standards (e.g., RPA 2024).
2. Prioritising using "sufficient methods/technologies" for reinforcing major public infrastructure and heritage buildings contained within a strategic planning framework.
3. Institutional oversight will be established via the creation of an intersectoral committee at the ministry of interior to provide to "better reconstruction/rehabilitation" methodologies or techniques based on technical studies created via an Inter-Government Initiative.
4. The resiliency of the housing stock and infrastructure is to be improved, ensuring future shocks do not result in identical losses.

Table 7 : Implementation Mechanisms and Long-Term Strategic Objectives of the "Build Back Better" (BBB) Principle Under Article 81 of Law No. 24-04

Component of BBB	Implementation Mechanism in Law 24-04	Long-Term Objective
Structural Improvement	Integration of new technical standards (Art. 5) and "Plan de confortement".	Reduction of structural vulnerability of the built environment.
Environmental Protection	Waste management plans for "catastrophe waste" (Art. 2).	Prevention of secondary health and ecological risks.
Social Recovery	Psychological support and continuity of essential services (Art. 81).	Strengthening of social cohesion and human capital.
Governance Reform	Sectoral responsibilities for execution and evaluation.	Enhanced intersectoral synergy and accountability.

Source : Created by the student

The BBB principle is also connected with the "Principle of Integration of New Techniques" (Article 5), which calls for the oversight and integration of technical developments in order to enhance the security of protection missions. This means that rebuilding efforts will be both restorative and progressive for Algeria.

1.5. Institutional Governance and the National Strategy (2025-2050)

An effective risk management strategy cannot exist without a strong governance framework. Algeria has established the National Delegation for Major Risks (DNRM) to fulfill this need, providing a "strategic and conceptual forum" for risk management. (Ministry of Interior, Local Authorities and National Planning, 2024)

1.5.1 The Role of the DNRM and Intersectoral Coordination

The Department of Natural Resources and Mines (DNRM) coordinates and assesses the various preventative measures that fall under the national disaster risk management system. In accordance with the Sendai Framework, an interdisciplinary approach that includes many hazards and many sectors is used. The DNRM uses the following main elements in its governance model (Ministry of Interior, Local Authorities and National Planning, 2024) :

- Intersectoral Committees: A committee comprised of 34 individuals from 14 ministries, 14 public agencies, as well as representatives from the scientific community, civil society, and international experts.
- Scientific Integration: The delegation will ensure that data and results from scientific research and modelling conducted at post-secondary institutions will be included when forming policies.
- The Strategy 2025 - 2050 - A long term vision to change how we deal with catastrophes because our response was mostly reactive. By making the shift to a more proactive approach by utilizing risk management we align with the Sustainable Development Goals and the Paris Agreement.

1.5.2. Strategic Objectives and Performance Measurement

The Algerian national strategy establishes measurable objectives (included in an MRV system) to monitor the implementation of Disaster Risk Reduction (DRR) initiatives. The established objectives include:

1. Reduce the total number of individuals killed in disasters and the number of people affected by disasters.
2. Reduce direct economic loss from disasters as a percentage of GDP (Currently - %0.7 of GDP).
3. Increase resilience for critical infrastructure such as healthcare and education.
4. Allocate 25% of the total annual budget for an intervention to the prevention budget (1-to-4; investment).

1.6. Nuanced Insights: The Systemic and Cascading Nature of Risk

An advanced Master's level thesis has to take into account that risk is becoming more and more systemic and liable to have cascading effects. A single hazard event can lead to multiple secondary failure events in multiple interdependent systems known as systemic risk. (UNDRR, TECHNICAL GUIDANCE ON COMPREHENSIVE RISK ASSESSMENT AND PLANNING IN THE CONTEXT OF CLIMATE CHANGE, 2022)

1.6.1. Cascading Impacts and Multi-Hazard Interactions

The "Principle of Concomitance" in Article 5 of Law 24-04 is a direct legislative response to the systemic nature of risk. For example, a seismic event in northern Algeria could give rise to:

1. Industrial accidents as damage occurs to petrochemical plants or storage facilities,
2. Infrastructure failures as water, energy and communications networks are disrupted, and
3. Health crises as diseases may emerge due to contaminated water and/or displaced populations.

To effectively manage these cascade effects requires "systems of systems" thinking, whereby the interconnections between urban sectors (transportation, energy and health) are identified and reinforced as collective sources of strength. The DNRM's role in coordinating 14 different ministries is critical in preventing "unforeseen consequences," where one sector's failure leads to other sectors' increased vulnerabilities. (UNDRR, 2022)

1.6.2. The Role of Climate Change as a Risk Driver

The increase in the number and severity of extreme weather events has prompted the need for a shift in thinking regarding how to prepare for and respond to hydrometeorological disasters, such as floods and droughts. This desire for a change in mindset will drive national strategy to include both current risks and future climate scenarios for effective adaptive planning. The changing climate is a major influencing factor compounding the frequency and severity of these phenomena. However, this process will require a paradigm shift towards prevention and preparedness based on new ways of assessing risks. (UNDRR, 2022)

2. The Legislative Framework for Major Risks

Over time, the legal framework in Algeria has continued to transform in order to address the enormous human and financial loss associated with natural disasters, and to develop a sophisticated level of institutional learning. Historically, Algeria's strategy toward managing major natural disaster events was of an initial response and reactive crisis management style. These types of tactics, like those used during the Bab El Oued floods in 2001 and Boumerdes earthquake in 2003, led to the development of Law 04-20 on December 25, 2004. This legislation established the first comprehensive legal basis for disaster prevention due to sustainable development. The Sendai Framework for Disaster Risk Reduction (DRR) has since evolved to a global consensus and the limitations to Law 04-20, mainly its gap in implementation and its main priority of post-event management, have become much more obvious as a result. On February 26, 2024, the recently passed Law 24-04 represents a commitment to implementing a proactive and resilience-based approach to mitigate the impact of a disaster event through incorporating urban planning, violent crime deterrent and intersectoral agreements on the outcome for the country. (Khaled, 2021)

2.1. The Historical Imperative and the Limitations of Law 04-20

To understand the legislative environment of Algeria, it is essential to know the “trauma based” mechanism that created Law 04-20. Before 2004, a mix of old laws and multiple ministerial decrees (for example the 1985 Decrees for Civil Defence) existed but did not provide enough structure to support the ever-increasing number of modern urban risks. The 2001 Bab El Oued floods (which killed 800+) and the 2003 Boumerdes earthquake illustrated just how poorly urban planning had integrated risk analysis into decision-making. (Khaled, 2021)

Thus, Law 04-20 was created to be a framework law for civil defence in that it created an overall concept of civil defence and identified 10 Major Risk Areas, including seismic, flood and forest fire risk, and created a requirement to develop General Prevention Plans (PGR) for each risk area. Academic critics from Algeria's Scientific Journal (ASJP) charge that the law is still "passive" and "too general." One main reason for this criticism is that there have been no application decrees issued by decree to provide details on how to put the law into effect. Of the thirty (30) compulsory regulatory texts that must be developed to make Law 04-20 operational, only six have been issued (over 20 years). Thus, we see the phenomenon of a legal void where sound, theoretical principles (e.g. the integration of risk into urban planning) lack the necessary administrative tools ("teeth") to stop the construction in high-risk areas.

Additionally, Institutional siloing was a major challenge for Law 04-20. Even though it called on all state institutions to be responsible, all of the real management occurred within the Ministry of the Interior while at the same time, the Ministry of Environment or the scientific community were often marginalized. This centralization of authority also inhibited the establishment of a local and site-specific risk culture. The focus was on the "Crisis Management" cycle of detection, intervention, and compensation rather than on the "Reduction" cycle of understanding, preventing, and rebuilding better than before. (Khaled, 2021)

2.2. The Paradigm Shift: Law 24-04 and Disaster Risk Reduction (DRR)

The update of Law 24-04 provides a new structural and doctrinal framework for the state of Algeria, which is aligned with the Sendai Framework's goals to reduce disaster deaths and economic losses. This change from "managing disasters" to "reducing risk" is more than just an issue of terms; it represents a complete transformation in how the state assesses vulnerability to disasters.

2.2.1. Expansion of the Risk Taxonomy

The most obvious change is that the number of major risks recognized has grown from ten to eighteen. This broader classification recognises that risks are multifaceted and interconnected, especially when assessed within the context of globalisation and climate instability.

Table 8 : Analytical Comparison and Expansion of the Major Risk Taxonomy Between the Repealed Law No. 04-20 and the New Law No. 24-04 Framework

Risk Category	Law 04-20 (Repealed)	Law 24-04 (New Framework)	Implication for DRR
Natural Risks	Seismic, Floods, Forest Fires, Climate Risks	Seismic, Floods, Forest Fires, Drought, Desertification, Coastal Erosion, Acridian (Locust) Risks	Addresses long-term environmental degradation and food security vulnerabilities.
Technological	Industrial, Energy, Radiological, Nuclear	Industrial, Energy, Radiological, Nuclear, Cyber Risks, Strategic Network Failures	Protects the digital and physical infrastructure of the modern state.

Health/Biological	General Health Risks	Human Health, Animal Health, Plant Health, Biotechnological Risks	Shifts to a "One Health" approach, managing zoonotic and agricultural threats.
Social/Urban	Large Human Groupings (Implied)	Large Human Groupings, Space/Aeronautical Risks	Manages risks associated with high-density urban events and modern transport.

Source : By the student

Cyber risks and coastal erosion are particularly pertinent at this moment in time. The coastline of Algeria (1,200km) is an asset of national importance but also at risk of significant damage due to erosion caused by rising sea levels, an issue that has previously received little to no attention from past legislation (“silent”). In order to establish coastal management as one of Algeria’s top priorities, Law 24-04 establishes the obligation to create specific protections for coastal areas.

2.2.2. Foundational Principles of the New Law

Law 24-04 redefines multiple elements of the legal framework for managing and regulating the environment with numerous concepts that did not exist or were poorly defined under the prior system, among others:

1. **The Principle of Precaution and Prudence:** Outlines that, in order to take an appropriate course of action in terms of risk mitigation, a determination cannot depend solely on an absolute level of scientific proof.

2. The Principle of Concomitance: States that the evaluation of risk must include an examination of how different types of hazards might interact with one another (for example; if a forest fire occurs and then a landslide occurs as a result of the fire destabilizing the soil).

3. The Principle of Resilience: Identifies building resilience into human settlements through their ability to withstand and recover from shocks as a national priority.

These principles direct the state to shift to a model for managing environmental risk based upon "continuously adjusting" its methodologies based upon use of the latest available scientifically and/or technologically based data. (Law No. 24-04, 2024)

2.3. Urban Planning Integration: Law 90-29 and the Non-aedificandi Revolution

The link between Law 24-04 and Urban Planning Law 90-29 is a critical point within the context of the legal framework in Algeria. Urban Expansion historically has been done in defiance of risk maps thus resulting in the creation of "precarious neighbourhoods" on both the wadi beds and slopes of unstable earth. Urban Planning law 90-29 created two primary tools for planning land-use, the Plan Directeur d'Aménagement et d'Urbanisme (PDAU) and the Plan d'Occupation des Sols (POS), which are used to develop and oversee all city or town planning in Algeria; however, local authorities have not used these tools as expected because either insufficient or no risk based data is available. (Law No. 90-29 , 1990)

2.3.1. Article 24 and the Enforcement of Risk-Based Servitudes

Law 24-04, Article 24 provides a transition between risk data and urban constraints that are legally enforceable. Moreover, it includes the authority to establish, enforce, and use Non-aedificandi (no-build) zones. These are areas where the degree of risk makes the establishment of any kind of human habitation inherently dangerous.

Table 9 : Legal Instruments, Enforceable Constraints, and Spatial Natures of Non-Aedificandi (No-Build) Zones Under Article 24 of Law No. 24-04

Zone Category (Art. 24)	Description and Constraint	Legal Instrument
Wadi Beds and Banks	Natural drainage paths and immediate floodplains.	Absolute *Non-aedificandi* servitude.
Dam Downstream Areas	Perimeters exposed to submersion in case of dam failure or controlled releases.	Strict zoning based on hydraulic thresholds.
Strategic Pipelines	Right-of-way for hydrocarbons, high-voltage lines, and water mains.	Buffer zones to prevent secondary disasters during maintenance or failure.
Geological Faults	Areas with high seismic or landslide potential.	Building prohibition or specialized engineering mandates.

Source : By the student

Law 04-20 allowed for some ambiguity in relation to the application of these three zones (i.e. the actual space identified as Part of each zone). In contrast, Law 24-04 provides for the integration of these servitudes directly into the POS/PDAU documents. This means that the Legal Style Building Survey and Legal Style Building Survey (required by Law 90-29) cannot be legally issued once the project site falls within an Article 24 location. Additionally, the law stipulates that all pre-existing structures located within these three zones will be subject to mandatory mitigation measures, or, if the mitigation measure cannot reduce the risk of an accident, will be subject to expropriation for public use.

The contours of the "Non-aedificandi" land bordering the sea have remained consistent between Laws 04-20 and 90-29. More specifically, Law 24-04, in conjunction with Law 90-29 (Article 24), creates a 100 metre vertical plane of no construction beyond the high water mark, which extends directly and completely along the coastline for so long as the risk for coastal erosion exists in accordance with newly appointed procedures.

2.4. Institutional Governance: The National Delegation for Risks (DNRM)

A principal reason for the failures of Law 04-20 was that there was little coordination and that the institutions created by Law 04-20 could be categorized as primarily "theoretical" in nature. Law 24-04 resolves these two issues by centralizing the organization responsible for strategic oversight of the elements of Law 24-04 within the newly created "National Delegation for Risk" (DNRM). (Ministry of Interior, Local Authorities and National Planning, 2024)

2.4.1. A New Model of Intersectoral Coordination

The Disaster Risk Reduction Mechanism (DNRM) serves as both a strategic and conceptual space dedicated to anticipating risks. The DNRM's goal is to break down existing silos that have traditionally impeded effective risk management; it operates via an Intersectoral Committee of 34 members composed of:

- 14 Ministry Representatives: Supporting alignment of sectors such as Housing, Agriculture, Water Resources, and Health;

- 14 Public Institutions: Inclusively incorporating technical bodies e.g., the Civil Protection and National Meteorological Office;
- Expert Panel: Including four qualified Algerian experts (two residing in country and two residing outside of the country), experts will advise on best practices and the scientific validity of the strategy;
- Civil Society: Two representatives representing the "associative movement" to assure their involvement, addressing one of the primary critiques towards the previous legislation. (Ministry of Interior, Local Authorities and National Planning, 2024)

The DNRM includes an annual report regarding the state of risks in Algeria as a mechanism to provide transparency and accountability. The DNRM is responsible for facilitating Priority Strengthening Plans (Plan de confortement priorisé) to be implemented for the priority retrofitting of all strategic public building (e.g., hospitals, schools) and heritage sites against seismic and structural threats. This shift from a general-planning model towards a prioritized-action model characterizes the procedural shift towards Disaster Risk Reduction.

2.5. Critical Evaluation of Penal Provisions: Articles 85 and 87

Before now there was a noticeable downside to the way the past has been handling floods when it came to illegal construction and building: a lack of prevention! This was mainly do to because of Law 04-20 as it did not have a strong enough punishments for people who could build in wadis and put live's in danger while following their illegal construction projects. The Main improvements over Law 24-04 are the penal rules provided in Article's 85 and 87.

2.5.1. Analysis of Criminal Accountability

With this change to the law, organizations will now be subject to much harsher penalties than in the past. This shift indicates that states are beginning to regard illegal construction in high-hazard areas as more than simply a violation of zoning regulations but as a potential danger to public safety.

Table 10 : Criminal Accountability, Targeted Infractions, and Penalty Structures for Urban Violations in Prohibited Zones Under Articles 85, 87, and 88 of Law No. 24-04

Provision	Targeted Infraction	Penalty Structure
Article 85	Construction in prohibited *Non-aedificandi* zones (floodplains, dam downstream, etc.).	Imprisonment (ranging from 2 to 5 years) and fines reaching up to 1,000,000 DA.
Article 87	Habilitation of Constatating Agents	Empowers judicial police and specialized sectoral agents to record infractions and halt illegal works immediately.
Article 88	Site Restoration	Empowers courts to order the demolition of illegal structures and the restoration of the site to its natural state at the offender's expense.

Source: By the student

Innovative in its extenuating circumstances, Article 87 expands the definition of "police power" from merely law enforcement to include other areas of the economy. For instance, officers who work in the fields of hydraulics, forestry, or urban planning are now empowered to act as judicial police for crimes brought about by specific risks, which means that the technical expert—best able to determine whether or not a wadi bed is an unsafe place to build—has the authority to initiate criminal action.

Nevertheless, achieving results through these legal provisions faces several political and socio-economic challenges. Both the legal status of buildings built without the required permits (regularization laws such as Law 08-15) and the prior history of amnesties means that there must be special protections put in place in order for the penal regime of Law 24-04 to be applied consistently. In addition, the law contains aggravating circumstances for public officials who enable illegal construction by issuing fraudulent building permits, and penalties for "failing in duty" range from 5-10 years of imprisonment.

2.6. Bridging the Gap: Flood Risk Prevention Plans (PGR)

Historically, the major challenge in flood protection in Algeria is the existing "oued culture," where many people see the dry riverbeds during periods of extended drought as usable land. As a result, the PGRs (Plan de Gestion des Risques) established under Law 04-20 have been ineffective, as the plans are typically just claims to be a static document that doesn't take into account the continued hydro-geographic changes or the growth of the urban area. (Khaled, 2021)

2.6.1. The Evolution of the PGR under Law 24-04

Law 24-04 mandates a more dynamic and integrated version of the PGR. These plans must now include:

1. **National Inundability Maps**: Precise mapping of all wadis and the areas downstream of dams, accounting for "exceptional" flood events.
2. **Vulnerability Atlases**: Cartographic data identifying communes and neighborhoods with high social and structural vulnerability.

3. **Early Warning Systems**: A three-tiered alert structure (national, local, and site-specific) to ensure that "Non-aedificandi" zones can be evacuated if prevention fails. (Law No. 24-04, 2024)

The DNRM plays a central role in "bridging the gap" by ensuring that the PGR is not just a hydraulic document but a land-use mandate. By integrating these plans with the "Specific Waste Management Plans for Disasters," the state also prepares for the logistical nightmare that follows a flood—such as the removal of millions of tons of mud and debris which, in 2001, paralyzed Bab El Oued for weeks.

2.7. The Economic Dimension: Insurance and Risk Transfer

A comprehensive risk reduction strategy must incorporate the concept of residual risk, i.e., the damage done by disaster when all the preventive measures are taken. Algeria has developed a method for diminishing residual risk through the creation of a CAT-NAT insurance program. This program is required under the provisions of Ordinance 03-12. (Anis, 2023)

Table 11 : Performance and Future Outlook of the Mandatory Catastrophe Insurance Scheme (CAT-NAT) in Algeria Under Ordinance No. 03-12 and Law No. 24-04

Insurance Element	Context and Performance	Future Outlook under Law 24-04
Mandatory Coverage	Covers earthquakes, floods, mudslides, and violent winds.	Expanding to cover new risks like drought-induced losses.
Subscription Rates	Historically low among households and the private sector.	Target of 25% subscription by 2025 through institutional incentives.
State Liability	The state historically bore 100% of the cost for uninsured victims.	Shift toward a "1 DA invested in prevention saves 4 DA in intervention" model.

Source : By the student

There has been research conducted academically into the ASJP and Cat Bonds (or Catastrophe Bonds) potential to shift risk into global financial markets thus marketising risk and allowing the Algerian Government to mitigate their risk of insolvency in the aftermath of catastrophic events whilst providing access to reconstruction funds without eroding the national budget. This is supported by Law 24-04, which creates an available source of high-quality risk information needed for international re-insurers and investors.

2.8. Critical Analysis of Legal Limitations and Future Outlook

Although much progress has been made under Law 24-04, some of the legal limits from ASJP literature continue to be an issue. One key concern is whether people will accept a social reduction in danger; A Non-aedicandi zone usually means families that live in unsafe homes will have to move out of those areas due to this law. Without a strong support of social housing, the government creates a conflict in rights between the right to be safe and the right to have housing.

In addition, the passive nature of the previously implemented strategies was often due to the absence of local-level technical capacity (commune level); This will be addressed through law 24-04, which requires the provision of disaster risk education and training for municipal officials, but a true institutional capacity effort will take years to complete.

The addition of strategic network failures as a large-scale risk creates a new area of law; As Algeria is in the process of digitizing its economy, fiber optics and power grids have become a critical area of security since they are vulnerable to natural disasters and cyber attacks. The law now requires that operators of both governmental and private sectors provide instrumentation and preventative security measures on these networks. This will impose a large compliance burden on state and private operators.

2.9. Synthesis and Strategic Recommendations

The emergence of Law 24-04 marks an important shift in the legal system of Algeria, moving from reactive measures of Law 04-20 to proactive measures of Law 24-04. With the establishment of a comprehensive framework for resilience through the codification of 18 risks, expanding the powers of the DNRM, and adding criminal penalties for illegal urban development, the State of Algeria has entered a new era. However, now the success of this law will ultimately rest upon its implementation. As such, there are a number of strategic imperatives that must be accomplished in order to achieve success with the new legislation:

Regulatory Speed: The State must avoid the problems caused by a lack of implementing decrees that were part of Law 04-20. There needs to be prompt promulgation of all implementing decrees, especially those related to coastal erosion and cyber-related risks, under the new law.

Judicial Consistency: The Courts of Algeria must consistently apply Articles 85 and 87 of the new law, regardless of any political or social influences to either legalize or "regularize" illegal buildings.

Scientific Integration: The DNRM must continue to work with the scientific community to ensure that "Non-aedificandi" zones are defined and created based upon the use of dynamic data rather than static and outdated maps or boundaries.

Participatory Culture: Article 10 of Law 24-04 guarantees a "right to information" - and this right must be transformed into a culture of community-based disaster management, where residents are no longer treated as "victims" but rather as partners in building an overall resilience.

3. Institutional Scaffolding and Operational Dynamics of the Algerian ORSEC Framework for Flood Intervention

The structure of disaster management within Algeria includes a highly complex structure of laws and functioning agencies for the purpose of addressing the growing frequency of major hydrological events. The primary mechanism of this structure is the renewed and formally articulated ORSEC plan (Organisation de la Réponse de Sécurité Civile), which has been instituted through Law No. 24-04 of 26 February 2024. This legislative change is a movement away from an 'emergency response' to an integrated risk management approach that includes prevention, response and recovery as part of sustainable development. Algeria is both vulnerable to Mediterranean-based flash floods to the north, and to Saharan-model-based "oued" flooding to the south, therefore a number of administrative structures have been developed to allow for organised responses through a hierarchical structure that enhances response by allowing for no more than five levels of administrative units between the top governmental office and the bottom tier of local government (i.e., municipalities). In this report, the case for the intervention mechanism of the ORSEC plan and the associated levels are provided through a systematic breakdown of ORSEC's hierarchy, the authorisation of local authoritiest' executive powers, the logistics of emergency resources, and agency roles and responsibilities with respect to local coordination. (ROUMANE, 2018)

3.1. Hierarchical Architecture and Structural Tiers of the ORSEC Plan

The foundation of the Algerian's flood response structural integrity is determined by the ORSEC plan's hierarchical decentralization. As detailed in the regulatory framework in Articles 65 and 66, the ORSEC plan is not a single organization, but a multi-tiered preparedness system that varies according to both the scale of the disaster as well as its geographic extent. Thus, each of these tiers of response operations helps to provide effective resource management to avoid over-using local capacity while providing a clearly defined line of authority and command linking the national strategy center to the frontline operations. (Boulekdam Chaouki, 2026)

3.1.1. The National Tier: Strategic Command and Inter-Regional Synergy

The National ORSEC Plan under Article 65 applies when an event exceeds the ability of one administrative region to respond to it; or when an event threatens the strategic infrastructure of the country. The National level is under the supreme authority of the Prime Minister who is supported by the Ministry of Interior, Ministry of Local Governments, and National Planning. The role of the National Level is to provide the coordination of assistance from around the country to the disaster area and create a framework for deploying elite specialized response units (e.g. Unités Nationales d'Instruction et d'Intervention (UNII), Civil Protection).

The National Level follows the "Principle of Solidarity," whereby resources from all non-affected Wilayas are sent to the disaster area under the authority of the National Command Post. The National Level is responsible for managing all interactions with international aid organizations and activating the National Fund for Major Risks and Catastrophes to ensure that the financial impact of recovery is distributed at the national level and does not deplete the budgets of affected regions. (ouah, 2025)

3.1.2. The Wilaya Tier: The Operational Nexus of Risk Management

Article 66 states that the Wilaya (Province) is the main level of intervention. The Wilaya ORSEC Plan is the primary operational document, which is specific to the province's hydrological and topographical features. There are 48 Wilayas that make up the country's administrative structure, and is at this level that the 14 specialized modules will have all of their physical presence and maintenance activities. (Boulekdam Chaouki, 2026)

The Wilaya level has a unique role in the "Permanent Secretariat" function, which is usually situated in the Civil Protection Intervention Service (SIDPC). This "Secretariat" performs the function of continuous risk monitoring and resource inventory updates. During the flood, the Wilaya Post of Command (PC) will be the primary decision-making centre, linking meteorological data provided by the National Meteorological Office (ONM) and hydrological reports prepared by Water Resources Department to determine when and where to deploy rescue modules.

3.1.3. The Communal Tier: Proximity Management and First-Response Logistics

The Commune (which is the basic unit of the state) is the last and also the lowest level within the overall structure of ORSEC because it is where immediate action takes place. The Plan Communal de Sauvegarde (PCS) is simply the ORSEC plan at the local level, which aims to give attention to management within the immediate area. Although the Commune does not have the technical equipment similar to that of the Wilaya (larger jurisdiction), it has an extremely important role in ensuring that alerts are sent out rapidly and locals can evacuate (where necessary) when neighborhoods have been classified as `hot zones'.

The following table shows how these levels relate to each other and also helps to provide a brief outline of the delegation of authority and the main objectives at each level in the response hierarchy. (ROUMANE, 2018)

Table 12 : Hierarchical Architecture, Lead Operational Authorities, and Primary Objectives of the Algerian ORSEC Framework.

Hierarchical Level	Lead Authority	Operational Scope	Primary Objective
National	Prime Minister	Inter-regional / National	Strategic oversight, inter-Wilaya resource leveling, international liaison.
Wilaya	Wali (Governor)	Provincial / Regional	Command of 14 modules, logistical orchestration, requisition of private assets.
Communal	Mayor (APC President)	Local / Municipal	Immediate public alert, local shelter reception, proximity rescue liaison.

Source : By the student

3.2. Executive Mandates in the Urgency Phase: Roles of the Wali and the Mayor

In Algeria, when a natural disaster occurs due to a flood, one of the first priorities is to stabilize the natural environment and protect human beings from further harm. The urgency phase is described as the time when the Wali and/or Mayor must activate the modules of the ORSEC plan (Article 367) and direct the emergency response (Article 368). During this phase there will be a change from normal administrative governance to extraordinary governance with the use of larger amounts of executive authority.

3.2.1. The Wali: Strategic Commander and Requisition Authority

Once ORSEC is officially activated, the Wali (governor) of each province takes over command of disaster response at the provincial level. In the Urgency phase, the Wali has both administrative and operational responsibilities and will lead the large mobilization of all 14 modules. (Guehguih Salhi & Ghanem, 2023)

1. Command of the Operational PC: The Wali establishes and directs the Post of Command at the Wilaya level of intervention. This PC will function as the "brain" of the operation and is where the heads of each of the 14 modules will report on their progress and needs. The Wali has primary responsibility at the PC to resolve inter-agency conflicts and ensure resources are allocated where the need is greatest (i.e., structural breaches in levee system, population stranded due to flooding).

2. Initiation of the Communication Protocol: During the Urgency phase, the Wali has sole authority for all official information regarding the disaster. The Wali's ability to do so is critical to maintaining social order and preventing misinformation that could create panic and/or lead to mass evacuations in spontaneous and disorganized directions. The Wali will also determine the "periodicity" (ie, frequency) for issuing media updates and will work with local radio and television stations to disseminate survival instructions to the population.

3. The Requisitioning Authority of the Wali: The ability of the Wali to requisition human and material resources from the private sector may be among the most powerful tools available. For example, in the event of a natural disaster, such as a large flood, the Wali may use their power to requisition private earth-moving equipment to restore access to blocked outfalls, or to requisition private transportation fleets to evacuate the public.

3.2.2. The Mayor: Frontline Activation and Local Intelligence

The Mayor of a municipality, or the President/Head of the Assemblée Populaire Communale (APC), acts as the "eyes and ears" of the Wali close-up with respect to the existence of dangers within their municipal area, and as such, the Mayor's role is determined by proximity to and continued existence of the population living within their municipality on a daily basis. (Zouhair MAYOUF)

1. Triggering the Plan Communal de Sauvegarde (PCS): The Mayor is responsible for activating the PCS for their municipality once a threat of flooding has been identified. This means that the Mayor must deploy municipal agents to warn residents who live in flood-prone areas, to open designated emergency shelters, such as schools or gymnasiums, and to otherwise prepare for the possible evacuation of the municipality's residents.

2. Activation of Modules at the Local Level: The 14 Modules of the flood response plan have been organized at the Wilaya level; however, the Mayor is responsible for overseeing the execution of the modules at their respective municipality. For example, with respect to Module 13 (Solidarity and Social Action), the Mayor will also be responsible for organizing an evacuation plan for the most vulnerable populations, elderly, children, and persons with disabilities, in order to evacuate these populations first and provide for their immediate food and medical needs.

3. Feedback Loop: The Mayor provides the Wali with essential technical information such as the malfunction of certain drainage culverts and overflows of locally utilized irrigation canals. This "on-site intelligence" allows the Wali to redirect heavy equipment from the Water Resources module and the Public Works module to the sites of failure.

3.3. The 14 Specialized Modules: A Functional Taxonomy of Intervention

The ORSEC framework in Algeria is executed via the "14 modules" referenced above; this is accomplished by utilizing the skills and resources for each specific module. These are the functional elements of the intervention, allowing for planned access to and usage of capabilities in response to an emergency, as opposed to adding an unplanned surge of personnel in response to an emergency. (ouah, 2025)

3.3.1. Core Response and Security Modules

Module 1 of the Ministerial Program provides search and rescue services for any physical search and rescue effort. In a flood, this would entail deploying the aquatic rescue teams and specialized divers.

Module 2 of the Ministerial Program is supported by the Gendarmerie and National Police to secure evacuated areas and ensure that rescue vehicles are given priority access through the use of "corridors of intervention."

Module 3 of the Ministerial Program provides an organized, coherent medical support system in response to a flood through the use of the Ministry of Health's medical services. This includes triaging injured persons at the PMA, managing patient volume at hospitals, and promoting the control of waterborne diseases that may occur from the flooding event. (ouah, 2025)

3.3.2. Technical and Logistical Infrastructure Modules

Module 4 – Expertise and Consulting will provide the Wali with technical evaluations to ensure that all infrastructure within their area of operation has been evaluated for safety as a result of high-stakes flooding.

Module 5 - Information will serve as the Wali's administrative branch for the Wali's Communication Strategy and Public Relations. (ouah, 2025)

Module 6 - Transport will deploy the necessary transportation assets for the following purposes: to evacuate victims of flooding and to provide logistical support to all agencies involved in responding to the incident.

Module 7 – Liaison & Telecommunications will ensure that there will be consistent, reliable interscale communications between the National level (Federal), the Wilaya level (State), and the Communal level (Local). This will ensure that the Wali has access to communication resources even if terrestrial (land-based) networks are unavailable.

Module 8 - Energy will manage the Public Safety of electrical and natural gas systems; as well as take measures to prevent fires and electrocutions in flooded areas by implementing a strategic planned shutdown of all non-essential electric and gas distribution systems in the flood zones.

Module 9 - Hydraulic, led by the Water Resources Department, is the critical module to manage the flow of water within the flooded areas; manage the structural integrity of dams situated in those areas; and restore the provision of potable water to the persons who inhabit the areas impacted by flooding.

Module 10 – Travaux Publics will oversee the physical restoration of the territory by engaging in activities such as the removal of debris from roadways and the repair of bridges to ensure that affected communities do not remain isolated from one another. (ouah, 2025)

3.3.3. Social Welfare and Economic Continuity Modules

Module 11 - Logistical supply – managing the buying of food and other essential items.

Module 12 - Housing - organizing the move from emergency shelters to semi-permanent temporary housing for displaced families.

Module 13 - Solidarity/Social Action - coordinating through the Algerian Red Crescent the distribution of financial and material assistance, as well as psychological support.

Module 14 - Finance - providing liquidity for the emergency response by ensuring sufficient funds are available immediately for logistics and requisition payments. (ouah, 2025)

3.4. The Strategic Reserves System for Emergency Logistics

In Articles 77, 78, and 79 of Law No. 24-04 provide a structured mandate for Strategic Reserves, a logistics system that separates the disaster response from the exposed nature of immediate supply chains. This represents a shift toward institutional autonomy for disaster management, allowing the state to have on hand the supplies it needs to support the population for extended periods of time, without the use of ad-hoc purchasing methods.

3.4.1. Article 77: The National Delegation and Essential Stockpiles

The National Major Risks Delegation (NMRD) established by Article 77 is a high-level body formed under the Prime Minister, that will develop the overall risk reduction strategy and the management of strategic stockpiles.

The NMRD has authority over the 'Reserve of Life-Sustaining Material' including non-perishable food, water purification tablets, tents, blankets, and heating material. In accordance with the law, these reserves are to be stored in "centralé stratégique nodale" (strategic nodal centers) to provide immediate assistance to each region in case transport routes are disrupted regardless of location. (Boulekdam Chaouki, 2026)

3.4.2. Article 78: Pharmaceutical and Sanitization Reserves

Article Seventy-Eight refers to the "Strategic Reserve of Health." This Strategic Health Reserve is managed by the National Agency for Prevention and Management of Major Risks. Throughout flooding events, there are one type of strategic reserve that is very important to having adequate supplies to prevent a secondary disaster of epidemic disease outbreaks due to flooding.

Included in the Strategic Health Reserve are vaccines for waterborne diseases, surgical supplies needed for emergency surgery, and mobile sanitation kits capable of being efficiently delivered/used for temporary facilities. The law states that rotation of the medications that are in the Strategic Health Reserve must be accomplished with rigorous protocols to ensure that all of the medication has not expired.

3.4.3. Article 79: Technical and Scientific Monitoring Reserves

Through Article 79, the National Agency for Earth Sciences embeds scientific evidence relating to risk management into a logistics framework. The term 'reserve' in this sense describes a strategic stock of monitoring devices (e.g., hydrological sensors; mobile weather stations; drones) that the commander of the disaster area (Wali) will use to get immediate, real-time, predictive information on the movement of water and weaknesses in the structure before he intervenes. This technological reserve enables interventions to be supported by scientific evidence, rather than just based upon immediate visual observations. (Pommelet, 2012)

Table 13 : Institutional Governance, Key Asset Categorization, and Intervention Phases of the Strategic Reserves System Under Articles 77, 78, and 79 of Law No. 24-04

Reserve Type	Governance	Key Assets	Intervention Phase
Logistical (Art 77)	National Delegation	Food, Tents, Potable Water, Blankets	Immediate Survival (0-72 hrs)
Medical (Art 78)	National Agency (Health)	Vaccines, Emergency Meds, Sanitation Kits	Stabilization (72 hrs - 2 weeks)
Technical (Art 79)	Agency for Earth Sciences	Hydrological Sensors, Drones, Comms Kits	Monitoring/Coordination (Active Phase)

Source : By the student

3.5. Institutional Synergy: Civil Protection and Water Resources in Local Coordination

The success of the Algerian flood relief program will depend primarily on how well DGPC and DRE work together. Together, they represent the operational and technical parts of the response.

3.5.1. The Civil Protection: The Operational Spine of the ORSEC Plan

The Civil Protection is the agency in charge of Module 1, and it has the overall authority to manage the operational Post of Command (PC); its structure is highly mobile, and its personnel are specifically trained in "aquatic intervention."

It manages the physical rescue of citizens from urban flooding using inflatable boats and specialized dive units to navigate through urban flood waters.

Provides the first link in the medical emergency chain through the SAMU (Emergency Medical Assistance Service) by conducting triage and stabilizing victims prior to entering the hospital system.

The Civil Protection's radio networks (Module 7) serve as the primary communication backbone when traditional cellular systems have been damaged by water in substations. (ouah, 2025)

3.5.2. The Department of Water Resources: Technical Management and Prevention

While the Civil Protection Agency saves lives, the Department of Water Resources (DRE) takes charge of managing the hazard itself. The DRE serves as the lead agency for Module 9 (Hydraulic), as they possess the technical skills needed to mitigate the physical effects of flooding.

- Hydrological Control: DRE engineers monitor the level of dams and lakes or streams. In a flood situation, they manage the “controlled release” of water from reservoirs in order to prevent dam failure and reduce impacts downriver.
- Pumping and Drainage: The DRE is responsible for deploying heavy-duty pumping equipment to reduce water levels in critical infrastructure, such as flooded hospitals or transformer stations.
- Post-Disaster Assessing: After the urgent phase has completed, the DRE completes technical audits of drainage and sewage systems to ascertain deficiencies and recommend structural redesigns to eliminate future failures.

Coordination at the local level between the two agencies is established via the "Permanent Coordination of the ORSEC Wilaya Plan" (Plan), which is made up of representatives from both DGPC and DRE. Through this plan, both the agencies work together to pre-compute flood scenarios and calibrate the responses of their modules accordingly. (Boulekdam Chaouki, 2026)

3.6. Modernization and Future Outlook: AI Integration and Sustainable Development

The transformation from Law No. 24-04 has helped Algeria "technologize" its organizational structure, as can be seen by the introduction of an AI-based, decision-support tool (EMHelp) to help in maximizing the effectiveness of executing ORSEC plans.

3.6.1. AI and Decision Support: The EMHelp Paradigm

The typical response to a flood has traditionally been "slow in making decisions" and "not coordinated between agencies." The EMHelp uses both machine learning (ML) and deep learning (DL) algorithms to analyze very large amounts of real time data (e.g. rain gauges, social media) to generate intervention scenarios, based on this analysis, that will provide the Wali with a "validated best case scenario". In this way, the EMHelp system will help to reduce the amount of cognitive load experienced by decision-makers during the time-urgent and chaotic phase of response and also use mathematics to deploy the modules (14) accurately. (Boulekdam Chaouki, 2026)

3.6.2. The Challenge of Urbanization and Infrastructure Resilience

Studies conducted in cities such as Tebessa and Sigus indicate that the institutional framework must face the challenges of a legacy of "rapid and uncoordinated urbanization." Flooding in those two cities was caused largely by the "urban drainage infrastructure" (Ik), but was also affected by anthropogenic activities that change the natural flow of water. To facilitate flood intervention, Law No. 24-04 provides for the inclusion of "General Prevention Plans" (PGP) in all processes involved in urban planning, ensuring that new constructions do not compromise the capacity of the state to provide flood intervention services. (Boulekdam Chaouki, 2026)

4. Historical Archive of Floods: Technical Inventory of Black Spots and Vulnerability Analysis in Djelfa

4.2. Comprehensive Black Spots and Flood Hazard Inventory

Djelfa's Protection Civile has identified the main flood "black spots" by mapping areas combining natural streams and urban areas/transportation networks. They warn the public about potential flooding at these sites, which could happen regularly. (Civil protection, 2025)

Table 15 : Spatial Registry, Threatening River Reaches, and Coordinate Boundaries of Documented Flood Black Spots in Djelfa Commune

Code	Commune	Locality (Lieu-dit)	Threatening River (Oued menaçant)	Start Coordinates (X, Y)	End Coordinates (X, Y)	Type of Area	Length (km)
17-1701-01	Djelfa	Ouled Abaidallah / Zaina	Oued Mellah	521682.00, 3827479.00	517184.00, 3843309.00	Urban	22.56
17-1701-02	Djelfa	Q. Zeriaa / Ain Chih / Aissa El Kaid	Oued El-Hedid	519660.75, 3836079.69	522404.00, 3838559.00	Urban	4.30

Source : the start and end nodes of the studied river reaches, as documented in the spatial registries of the Wilaya.

4.3. Spatial Classification of Flood Hazards and Morpho-Edaphic Risk Dynamics

The flood locations and severity in relation to the morphology/ geomorphology, physical structures, and soil characteristics of the basin are interrelated. The Djelfa area can be divided into three major geomorphological units that influence regional hydrology:

4.3.1. Steep Mountainous Catchments and Escarpments

The total area of the uplands is 21,318.12 Hectares which is 39.32% of the municipal area. These uplands have considerable vertical relief, which includes Djebel Senalba with a height of 1489m NGA. The uplands are typically steep with slope grades regularly found between 12.5%-25%. Uplands consist mainly of shallow reflagosols (0-5cm), and bare bedrock (0-5cm) which results in a very low water infiltration rate. Therefore, large amounts of precipitation during convective storms create a large amount of high-velocity runoff in a short period.

The presence of fast-moving streams typically leads to significant banks being eroded away at a rapid rate. This has resulted in the transport of large amounts of sediment downstream. (Civil protection, 2025)

4.3.2. Highland Steppic Plateaus and Glacis

These lands contain 52.48% of the city area (28,453 hectares) and are made up of rolling plains ranging from 0% to 8% steepness. The geology consists of limestone and gypsum crusts overlaid with much less consolidated (alluvial) soils that are very sensitive to erosion. As water flows off the mountains with high velocities, it transports a significant amount of sediment.

When this water enters areas with lower slopes, its velocity decreases, allowing the sediment it had been carrying to deposit or aggrade; by the time the sediment is deposited, it has filled up natural riverbeds or decreased the ability of those riverbeds to contain water and resulted in extensive lateral flooding on many agricultural lands. (Civil protection, 2020)

4.3.4. Urbanized Valley Depressions and Synclinal Basins

Djelfa city's urban centre is situated in a depression in a syncline, which is a low-lying valley formed as the confluence of a number of major seasonal torrents - the Oued Mellah (river), Oued El Hadid, Oued Messeka, and Oued Ben-Naam.

Beneath the urban centre are the thick impermeable Mio-Plio-Quaternary clays, which act as a barrier to downward flow of the water, thereby blocking the water from percolating down and creating a perched water table that saturates the shallow soils. As a result of the saturation of the ground, water from any further rain cannot percolate into the ground and runs off at high rates, creating large amounts of standing water. (Civil protection, 2025)

The Protection Civile has a three tier classification for these urban standing water hazard zones depending on their water depth and structural exposure and their flow velocity :

- **High Hazard:** An active river channel (e.g. Oued Mellah and Oued El Hadid) may be located in or adjacent to the path that carries the waters of the river. Typically found in areas with an unstable or slow-moving flow where water is more than 1.0m deep during extreme events, these locations usually contain a high number of illicit housing developed on or near the riverbanks.

- **Medium Hazard:** There are several urban low-lying sectors, large commercial and traffic corridors in the area. Most of these commercial and transport channels have been paved to prevent infiltration of the surface water, and have experienced numerous locations where storm sewers have been unable to drain properly due to large amounts of rain water being deposited.
- **Low Hazard:** Low-lying agricultural farmland, high river terrace farmland, and industrial areas all suffer from low velocity or stagnant water accumulation for limited periods of time, with no appreciable risk of physical property damage or injury to persons occurring.

4.4. Historical Flood Archive and Specific Hydraulic Behavior of Oued Mellah and Oued El Hadid

Algeria's history shows that floods on rivers are very dangerous and can do a lot of damage, e.g. in Algiers, where the Bab-El-Oued disaster killed 710 people in November 2001, and also at Ghardaïa, where a flood killed 34 people in October 2008 and caused 250 million DA worth of damage.

Flooding is a common hazard throughout the Djelfa wilaya and causes a lot of destruction; between 2015 and 2019, this area faced numerous catastrophic flooding events that led to loss of life, displaceme (Civil protection, 2025) :

Table 16 : Historical Flood Archive in Djelfa City: Chronology, Socioeconomic Impacts, and Severe Infrastructure Degradation

Location	Flood Event Date	Affected Area	Key Infrastructure Damage & Socio-Economic Impacts
Djelfa	04/08/2015 27/08/2015 18/09/2015 18/08/2018	Ouled Abaidallah, Zaina, Q. Zeriaa, Ain Chih, Aissa El Kaid	Extreme damage to hydraulic networks, including water supply (AEP) pipelines, main sewer lines, and riverbank retaining walls.

4.4.1. Specific Hydraulic Behavior of Oued Mellah and Oued El Hadid

In Djelfa city, the two primary drivers of flood risk are Oued Mellah and Oued El Hadid. Each watercourse exhibits distinct hydrological and hydraulic behaviors:

4.4.1.1. Oued Mellah (Priority 1 Inundation Reach)

Oued Mellah is the biggest drainage way throughout the municipality with an overall research reach of 22.56 km (urban and suburban core). Under regular dry conditions, there is very little water flow into the river due to the fact that it mostly receives untreated urban wastewater. (Civil protection, 2025)

The continuous introduction of large quantities of wastewater, as well as illegal dumping of other materials, results in the creation of very large quantities of plastic waste, household debris, and very thick organic silt lining the bed of Oued Mellah. When there are heavy rains, this waste creates insurmountable barriers to the flow of water. (Civil protection, 2025)

As a result, when the volume of water flowing into the river increases due to heavy blackouts, this causes the water to overflow the banks of Oued Mellah and subsequently create flooding in neighbourhoods like Ouled Abaidallah and Zina.

4.4.1.2. Oued El Hadid (Priority 2 Inundation Reach)

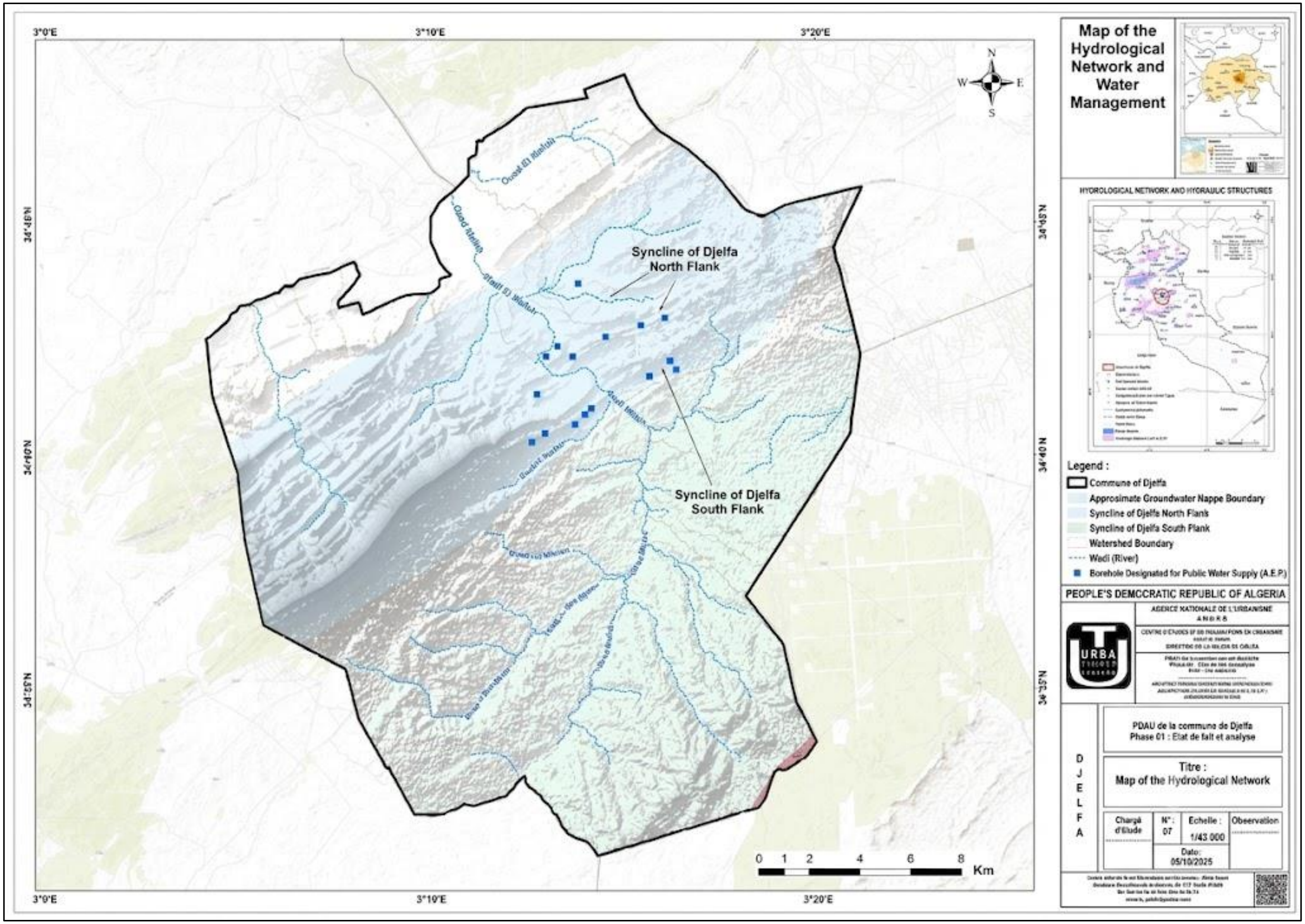
Chezy's open channel equation allows for calculation of flow for a 4.3 km reach and 4.098 km2 watershed of this seasonal mountain torrent, which has a very steep average slope (approximately 3.51%) resulting in a short wastewater accumulation time (Tc = 3.72 hours). Therefore, when heavy rain falls in the mountains, water drains quickly to the city limits resulting in an immediate high peak of runoff from the mountains into the city :

$$Q = C.S.\sqrt{Rh.I}$$

Floodplains would absorb the high energy from the flooding at normal conditions; however, the rapid and uncontrolled growth of urban areas is causing unplanned informal housing development (due to the lack of zoning regulations) on the active or flowing floodway and banks of multiple neighborhoods, i.e. Quartier Zeriaa, Ain Chih and Aissa El Kaid over the banks and flowing channel of the oued.

As a result of the construction of these buildings, the flow of water is being limited, causing an increase in flow velocity and also resulting in damaging flooding to adjacent residences. (Civil protection, 2020)

Map4 : Hydrological Network and Water Management Map



Source: Urban Planning and Developpement Center Urba-Tiaret

4.5. Downstream Cascade Effects and Multi-Sectoral Vulnerability Analysis

The spatial analysis of black spots highlights how flood events propagate through Djelfa's built environment, local economy, and social systems. These risks can be grouped into four primary areas of vulnerability:

4.5.1. Water Supply, Sanitation, and Public Health Hazards

Catastrophic flooding caused by water main bursts puts communities at risk of contaminated drinking water and untreated sewage being combined when floodwater inundates ruptured drinking water supply piping resulting in a highly infectious disease outbreak through water-borne pathogens like cholera and typhoid in urban populations. The time required to make repairs to underground piping systems generally delays service indefinitely. (Civil protection, 2020)

4.5.2. Transport Network Disruption and Isolation

Djelfa is an important place for transporting goods in the nation, located primarily around National Highway 1 (RN 1), which runs from Algiers to the Sahara. Djelfa also has several regional highways connecting with RN 1, including RN 46, CW 189 and CW 164.

Severe flooding can result in rivers, such as Oued Touil, Oued Mellah and Oued Besbas overflowing onto these routes, thereby delaying the ability to transport commercial cargo, interrupting the connection between remote towns and preventing emergency and aid vehicles from accessing affected areas. (Civil protection, 2025)

4.5.3. Destruction of Vulnerable Informal Housing

One large part of Djelfa's increasing population has been taken up with informal, self-constructed dwellings built on steep slopes along riverbanks e.g. Bloc 40, Chaoua, Bensaid and Bernada.

Most of these dwellings will not have had an engineering design and use the weakest building materials and shallow foundations; as such, they will not resist the lateral pressures and erosion from high-velocity floodwaters; therefore, making them all highly vulnerable to collapse suddenly. (Civil protection, 2025)

4.5.4. Soil Salinization and Agricultural Losses

Saline water from the Triassic rock layers can enter agricultural land through flooding and add an excessive amount of dissolved salt to soil. As this saline water evaporates during the hot and dry months, the dissolved salts remain in the soil surface layer.

This soil salinity process over time reduces crop yields, damages crops and vegetation, and causes desertification. Additionally, Salt-laden water also has a chemical reaction with concrete foundations which accelerates the deterioration of municipal infrastructure. (Civil protection, 2020)

4.6. Hydraulic Engineering Recommendations and Structural Mitigation Framework

Hydraulic engineers working on the ongoing flood risk in the city of Djelfa, Algeria, have built integrated systems to control flooding from the Oued El Hadid drainage basin. These systems will contain the design flood of the 10-year return period (Q10% = 6.54 m3/s) for normal operation, and be designed with a safety measure to ensure that they will not fail during the occurrence of a flood with a 100-year return period (Q100% = 13.79 m3/s). (Civil protection, 2020)

The Oued El Hadid protection system includes several key engineering components:

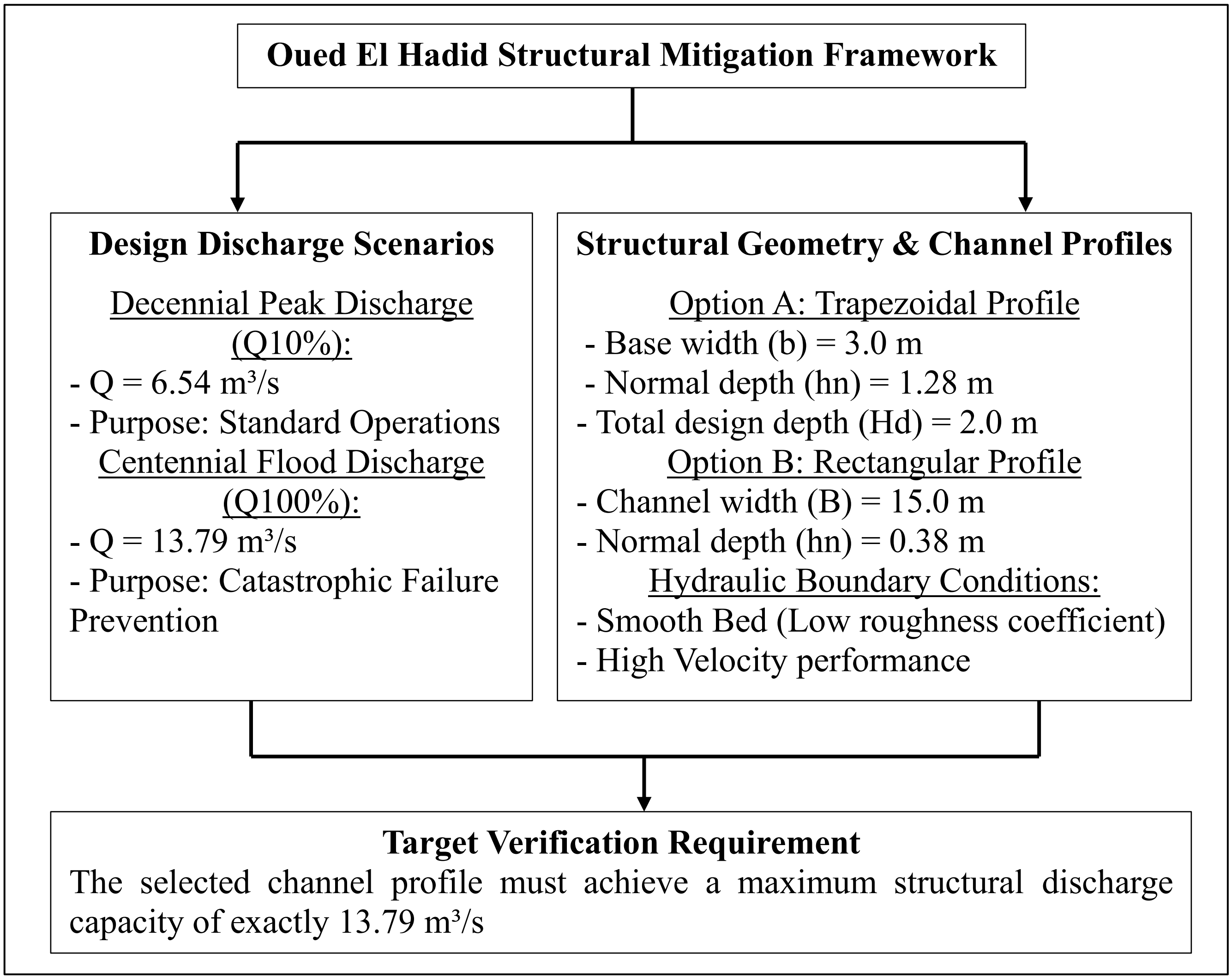


Figure 2: Methodological Operational Flowchart of the Multi-Tier Early Warning System (EWS) and Emergency Command Protocols Following a Special

4.6.1. Upstream Earthen Detention Dike

A floodwater-dispersal earthen dike (digue en terre) has been built in the upper part of the watershed to store floodwater temporarily and reduce the rate of runoff flowing to the City. By doing so, it will reduce peak downstream flows and help to avoid flooding in the Urban Drainage System.

4.6.2. Trapezoidal Concrete-Revested Gabion Channel

The trapezoidal channel 380 m long serves the function of a transition from a natural oued to an urban channel system. The channel is lined with gabion baskets that have a thickness measured of 30cm and a concrete top, with the channel having a base width (b) of 3.0m and a total height (Hd = 2.50m). (Civil protection, 2020)

Given a 100-year flood flow of 13.79m3/s, the normal depth (hn) is calculated at 1.28 m while having a flow velocity equal to 1.69 m/sec. Therefore, there is still an available freeboard (revanche) of 72cm remaining before any overtopping can occur (Civil protection, 2020) :

$$H_d = h_n + r = 1.28 \text{ m} + 0.72 \text{ m} = 2.00 \text{ m}$$

4.6.3. Masonry Retaining Walls and Recalibrated Channel

Then River flows into an 810 m long rectangular channel (stone masonry wall channels) and it has 15 m wide bottom with 0.004 slope from horizontal. During a 100 year flood, the water will be at h = 0.38 m deep (sub-critical) and flowing 1.68 m/sec; since it is below the erosive threshold for masonry (don't erode), the channel walls will not be damaged. (Civil protection, 2025)

4.6.4. Reinforced Concrete Protection Canal

The river is channeled through 1300 meters of reinforced concrete along the areas of highest density in an urban environment.

The smooth concrete bottom significantly decreases the hydraulic resistance of the channel (Manning n = 0.013 to 0.015), allowing fast-moving floodwater from high-velocity flows to reach the city centre.

4.6.5. Covered Box Culvert and Gallery

At Berrebih, the water is carried via a reinforced concrete box culvert and underground gallery (galerie en béton armé) to cross urban roads. By using a closed system, street debris cannot enter or clog the channel.

4.6.6. Culvert Bypass System at the RN 1 Bridge

Engineers put in place a multiple pipe culvert at the location where the channel bridges over National Highway 1 (RN 1). The culvert system consists of five (5) parallel steel reinforced concrete pipes with a 1500 mm pipe diameter.

This provides a total flow area (S_{total}) of:

$$S_{total} = 5 \times \left(\frac{0.75^2}{4}\right) \times 8.83 \text{ m}^2$$

The pipe flow during a once-in-a-hundred-year flood (13.79m3/s) has a full-pipe velocity of 1.56 m/s to ensure the highway bridge does not become impeded by water accumulation; therefore, the bridge remains a primary means of transportation. (Civil protection, 2020)

Table 17 : Hydraulic Engineering Design Scenarios, Structural Channel Profiles, and Peak Discharges for Oued El Hadid Mitigation Works

Location	Completed Structural Works	Completion Year	Total Cost (DA)
Djelfa	Reinforced concrete canal on Oued El Hadid (1300 ML) and channel recalibration.	2020	254,782,927.00
Djelfa	Reinforced concrete gallery at Berrebih.	2014	195,390,000.00
Djelfa	Rainwater collector network (2060 ML in DN 1200).	2020	38,114,510.00

4.7. Organizational and Legal Framework for Crisis Management and Risk Mitigation

Managing flood risk in Djelfa requires coordination between structural engineering and disaster response systems. The legal and organizational framework is structured around several key areas:

4.7.1. Emergency Response Fleet and Logistical Capacity

The Protection Civile maintains a specialized vehicle fleet and equipment inventory across the wilaya's units to manage flood emergencies (Civil protection, 2020) :

Table 18 : Inventory of Completed Structural Mitigation Works, Completion Timelines, and Capital Allocation Costs for Flood Protection in Djelfa

Equipment Type	Total Wilaya Inventory	Key Operational Units	Active Service Status
Sanitary Ambulance	38	Djelfa (4), Ain Oussera (3), Hassi Bahbah (2), Birine (2), Messaad (2).	35 Operational 3 Pending Repair.
Medicalized Ambulance	1	Djelfa Principal Unit (1).	1 Operational.
Mechanical Ladder	2	Djelfa (1), Ain Oussera (1).	2 Operational.

Standard Fire Truck (FPT)	15	Djelfa (2), Hassi Bahbah (2), Ain El Ibel (1), Messaad (1).	15 Operational.
Heavy Tanker (CCI)	15	Djelfa (2), Sidi Ladjel (2), Ain Oussera (1), Birine (1).	14Operational 1 Pending Repair.
Dewatering Pump (Moto-Pompe)	13	Distributed across all primary stations.	Portative, capacity < 60 m^3/h.
Trailer Dewatering Pump	2	High-capacity central units.	Towable, capacity ≈ 120 m^3/h.
Floating Pump	9	Distributed across key river stations.	Capacity < 15 m^3/h.
Mobile Lighting Generator	1	Central logistics park.	High-power towable unit (10 kVA).
Portable Generator	20	Distributed across all municipal stations.	Capacity < 6 kVA.

4.7.2. Early Warning Systems and Communication Logistics

The initial step in emergency response is coordinating that response through an early warning system that is linked to the National Meteorological Office (ONM) and the National Agency for Hydraulic Resources (ANRH).

There are two levels of meteorological alerts issued:

- Alerte A2 (Advisory/Calm): Issued when regional forecasts (3 to 5 days ahead) predict heavy rain and municipal services should prepare.
- Alerte A1 (Immediate Threat): The A1 alert is sent by the National Operational Coordination Center (CENAC) to the Wilaya's command post 24 to 48 hours before a storm is expected and is followed immediately with a Special Meteorological Bulletin (BMS).

When an A1 alert is received, the Wilaya will begin to implement the emergency response plan. This is the point when the Wilaya moves from a passive watch to active field operations:

- **Field Monitoring:** Emergency response teams develop an overview of the water level conditions around critical bridges and river systems through strategic deployment of personnel throughout those areas. Local emergency response centers utilize sirens and radio to alert the public living in flood prone areas.
- **Command and Control Center:** The Command and Control Center provides coordination between the Police, Gendarmerie, Health Services, and Public Works Departments to facilitate emergency response, using heavy equipment to remove debris and keep main roads open.

4.7.3. Operational Recommendations for Risk Mitigation

Operational measures to improve flood crisis management for the municipality should be prioritized based on our recommendations:

1. Sediment control upstream: The municipality should employ structural solutions such as check dams and sediment basins to limit the amount of sand, gravel, and organic debris from entering urban areas by trapping them before reaching the urban areas, effectively reducing siltation in concrete channels downstream.
2. Regular channel dredging: The municipality should develop a schedule of regularly scheduled dredging and debris removal for all open oueds, particularly Oued Mellah and Oued El Hadid, prior to the autumn storm

season to prevent refuse and silt from building up and maintain the design flow capacity of the channel.

3. Buffer zones and relocation plans: Strict non-building buffer zones should be established along active oueds. Over time, residents in high-risk informal settlements should be moved into planned housing areas outside of active floodplains.
4. Targeted infrastructure maintenance: Routine maintenance of storm water sewers and culverts along streets should be a priority to prevent localized flooding. Upgrading culvert grates and adding capacity to drainage inlets will also help prevent localized flooding during rainstorms.
5. Joint command exercises: The Protection Civile and the municipality should conduct regular joint emergency drills in order to test the communication systems and verify that all equipment is ready and to coordinate actions during a severe flood event. (Civil protection, 2020)

Conclusion of the chapter

This section synthesizes Algeria's paradigm shift from a reactive disaster response (Law No. 04-20) to a proactive, risk-reduction model (Law No. 24-04). It highlights that sustainable urban resilience requires integrating dynamic flood risk modeling into land-use planning tools (PDAU/POS) and strictly enforcing no-build zones (*non-aedificandi*) along active rivers.

To bridge the gap between legislative intent and actual enforcement, the study emphasizes overcoming institutional silos, preventing informal urban encroachment, and building local technical capacity. This can be achieved through:

- **Legal Accountability:** Rapidly issuing regulatory orders and strictly enforcing penal measures under Articles 85 and 87.
- **Institutional Synergy:** Fostering data-sharing and co-operation between the Directorate of Water Resources (DRE) and Civil Protection.
- **Technological Modernization:** Continuously updating vulnerability maps with real-time data and deploying predictive AI algorithms (e.g., EMHelp) alongside strategic logistical reserves to minimize crisis decision-making time.

Ultimately, this theoretical and legislative framework sets the stage for the next chapter, which evaluates the operational efficiency and structural limitations of these measures within the urban context of Djelfa.

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Chapter 03 :

The assessment of Effectiveness and Limitations

Introduction of the chapter

This section bridges the theoretical regulatory frameworks discussed previously with the empirical reality of flood hazard exposure in the Djelfa region. It transitions from macro-level policy analysis to ground-level operational utility through a dual approach:

- **Spatial and Policy Misalignment:** Utilizing an Analytical Hierarchy Process (AHP) multi-criteria analysis, the study compares formal urban planning tools (PDAU/POS) against the geomorphological vulnerability of the synclinal basin to expose gaps between urban expansion policies and physical flood risks.

- **Institutional Critique:** Beyond structural analysis, it evaluates the agencies responsible for crisis management—specifically the Directorate of Water Resources (DRE) and the National Office for Sanitation (ONA)—examining how transparency deficits and "defensive bureaucracy" hinder proactive risk reduction.

Ultimately, by synthesizing cartographic data with institutional analysis, this section establishes the evaluative baseline necessary for the urban resilience strategies proposed in the study's conclusion

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1. Confronting Planning Tools with Risk Reality

The overall spatial structure of the city of Djelfa represents a classic example of a conflict between the formal subdivision of urban land, with formal urban zoning tools such as the PDAU and its related POS produced by URBA TIARET, and dynamic hydrological processes. The evaluation of the existing spatial misalignment will require direct comparisons between the underlying hydrological determinants of flood risk and the existing urban planning instruments in place.

The geomorphology of the Djelfa Commune is defined primarily by a topographic closed synclinal basin. The closed synclinal basin is formed by the encircling, folded, steeply dipping, Cretaceous sedimentary rock ridges of the Ouled Naïl mountain range with Djebel Senalba in the northwest corner of the basin rising to an elevation of 1,489 m above sea level. The synclinal valley ultimately acts as a giant natural funnel directing surface runoff from the area surrounding the closed synclinal basin into the more topographically low urban core area, located between 869 and 1,115m above sea level and at the centre of the closed synclinal basin.

The multi-criteria decision-making model to define this susceptibility scientifically was constructed using the Analytical Hierarchy Process (AHP) of evaluating Nine (9) environmental and physical condition factors with their respective weights based on pairwise comparison matrices that were validated using consistent ratio () testing that was below the acceptable threshold of 0.10. The AHP model ranks the six physical weight factors as follows:

- Topographic slope (20.8%) is the factor that influences the speed and potential for kinetic energy generated by gravity as surface runoff from steep mountain escarpments (mountain cliffs) flows down to urban sites.

- Distance to streams/oueds (17.2%) identifies the boundaries of active floodplains and proximity to the lateral overtopping of wadis (open channels).
- Altitude/Digital Elevation Models (DEMs) (15.7%) designates geographic locations of low-lying terminal accumulation zones in synclinal valleys.
- Drainage density (11.7%) is the concentration of storm runoff channels from an extensive number of secondary and tertiary tributaries that channel surface flows into the primary drainage channels.
- Curvature (11.7%) provides a method to locate concave terrain shapes that naturally collect surface runoff.
- Land use/land cover (LULC (9.5%) describe how much impermeable cover will be associated with surface runoff as a result of building footprint and roadway pavement.

The integration of the criteria mathematically produces an index that identifies locations for high-risk development in terms of flood vulnerability. As we overlay the high weighted physical parameters with the spatial allocations in the third version of the PDAU, it becomes apparent that there is a major conflict between the need for rapid urban growth and hydrologic safety.

At URBA TIARET, the planners' total disregard of both topographical slopes and proximity to streams when assigning future urban sectors has created a situation where demographic pressures, such as the fact that the population of the commune increased from 25,600 in 1966 to an estimated 579,971 in 2020, are resulting in the zoning of high-density areas directly over active floodplains and steep runoff channels.

Specifically, POS 24 and POS 25 are located directly in high to very high flood susceptibility areas; POS 24 encompasses 33 ha (80.6 acres) of land planned for long-term development, while POS 25 contains 55 ha (136.6 acres) of land allocated for dense multifamily housing. In addition, the zoning has resulted in serious legal and spatial violations of the Servitude des Oueds (natural creeks, streams and rivers), which are defined by national land use regulations as protected, non-buildable zones for the provision of land for seasonal flooding due to vegetative cover and drainage. However, the third revision of the PDAU has authorized the horizontal expansion of both residential and industrial development sectors across these areas of the Servitude des Oueds.

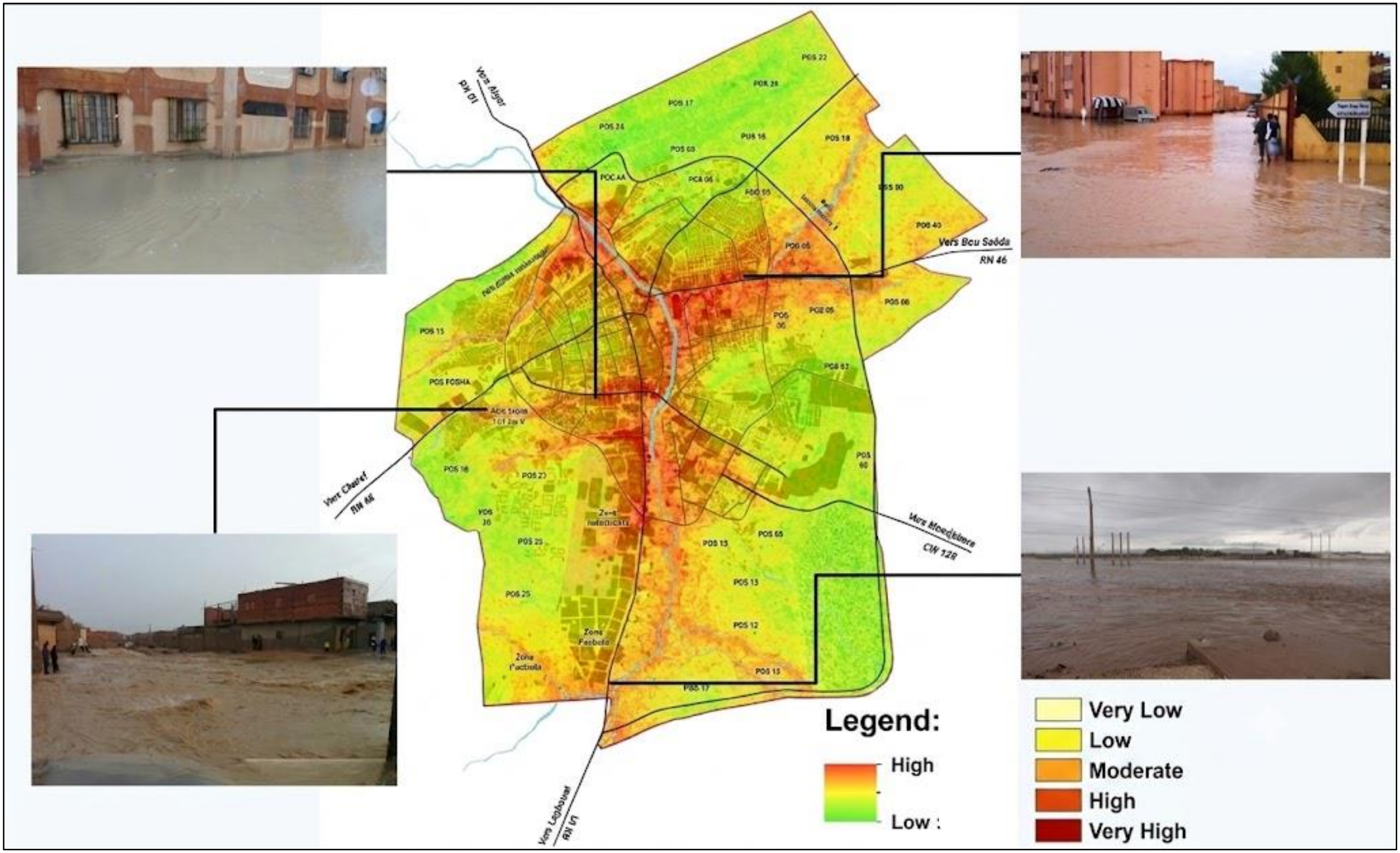
The large Industrial Zone, known as the Industrial Zone and flanking Activity Zones, located on highly impermeable Quaternary alluvial deposits between the Oued Messeka and the Oued Ben-Naam, make it difficult for water to permeate into the ground in the southern part of the syncline. In addition to replacing permeable floodplains with paved surfaces and massive industrial sites, these zoning regulations have greatly decreased the amount of infiltration. The runoff coefficient, or the amount of runoff caused by rainfall, during a storm will be artificially increased by the zoning. As a result, rainwater will become surface water immediately after it rains, thus flooding the nearby neighborhoods.

Table 19 : Spatial Conflicts Between URBA TIARET Planning Sectors and AHP Susceptibility Criteria

Urban Planning Sector / POS	Area (Ha)	Primary Planned Land Use	Dominant AHP Susceptibility Class	Major Hydrological Transgressions & Physical Risks
POS 24 (North-West)	33 Ha	Long-term residential expansion.	High to Very High (Slope > 15%, low altitude).	Built directly across mountain runoff corridors descending from the Senalba ridges; ignores natural drainage lines.
POS 25 (North-East)	55 Ha	Dense collective housing (e.g., 468-unit project).	High (Proximity to Oued Mellah tributaries).	Encroaches upon the Servitude des Oueds; replaces permeable alluvial buffers with concrete foundations.
Industrial Zone (South)	Over 150 Ha	Heavy manufacturing, storage, and processing.	Very High (Low altitude, high drainage density).	Built on Quaternary clays and alluvium at the confluence of Oued Ben-Naam and Oued Messeka.
Activity Zones (South)	Variable	Commercial warehousing and light logistics.	High (Concave curvature, flat slopes).	Promotes severe water ponding and runoff accumulation due to extensive soil impermeabilization.

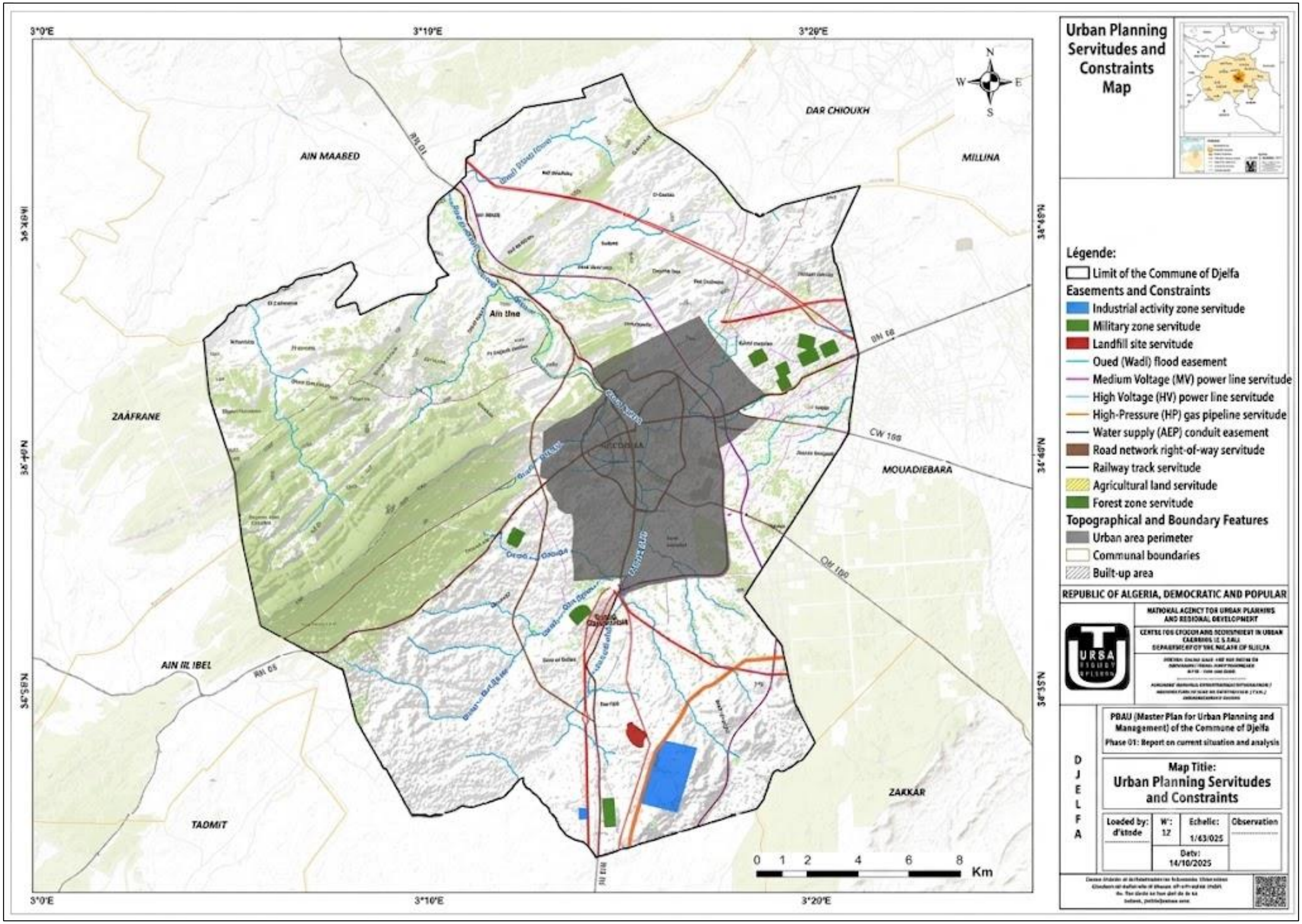
Source: By the student

Map5 : Flood Susceptibility Map of Djelfa Commune



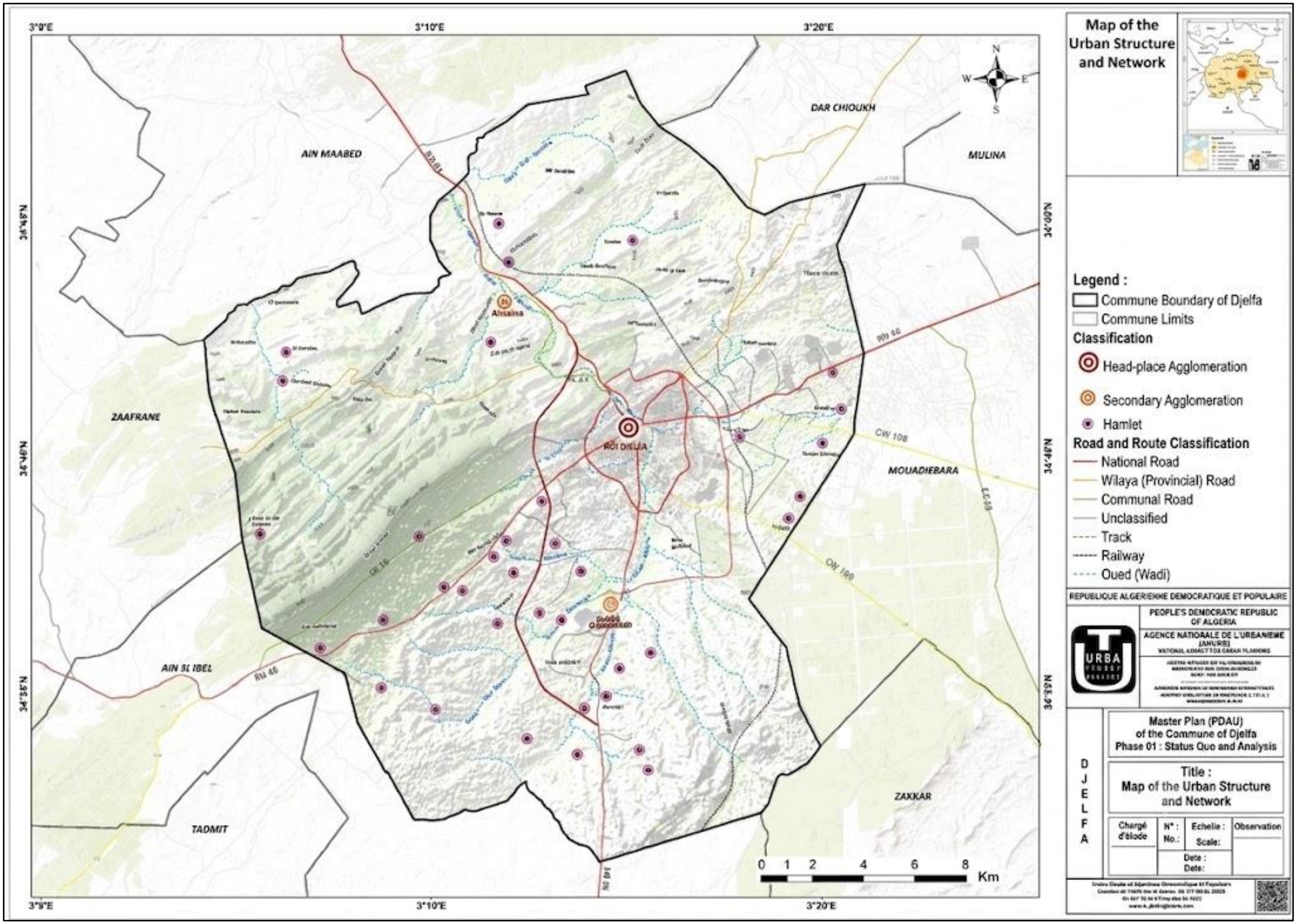
Source: Urban Planning and Developpement Center Urba-Tiaret modified by The Student

Map6 : Urban Planning Servitudes and Constraints Map



Source: Urban Planning and Developpement Center Urba-Tiaret

Map7 : Urban Stucture and Network Map



Source: Urban Planning and Developpement Center Urba-Tiaret PDAU 2

2. Evaluation of Infrastructural Preparedness

The inadequacies of Djelfa’s underground hydraulic infrastructure significantly compound the spatial risk created by poor planning. The municipal combined wastewater and stormwater drainage system operated by the local offices of the National Office Sanitation (ONA) is bedeviled by a massive mismatching of capacity.

The most significant structural bottleneck is at the junctions where secondary collectors connect to the municipal main interceptor trunk lines. The major regional interceptors that run parallel to Oued Mellah have been sized to receive flow with diameters ranging from 1,000 mm to 1,500 mm, while the secondary and neighborhood-level collectors in the densest urban areas, including POS 15, 16, 22, and newer developments in POS 24 and 25 are limited by the inadequate diameter of 300 mm to 500 mm.

The spatial risks caused by poor planning could be greatly exacerbated by Djelfa's inadequate underground hydraulic infrastructure. The combined municipal wastewater and precipitation drainage system, which is managed by O.N.A.'s local office(s), has a large gap between its total capacity and the actual amount flowing through it.

The major structural bottleneck affects the flowing water between neighborhood secondary collectors to the municipal interceptor trunk lines. There are three major regional interceptors that parallel the Oued Mellah, and they are designed with diameters between 1000 to 1500mm. The secondary and neighborhood collectors located in densely populated urban areas (POS 15, POS 16, POS 22) and the new areas around POSs 24 & 25 are all limited to very small diameters (between 300 and 500mm).

Under the assumptions described in the previous section, as part of the modeling of additional developments in the Djelfa area along with the water quality appraisals of the wastewater collected using the main interceptor system, it was found there would be significant issues with the storm water and combine sewers located in the neighborhoods to the north of the main interceptor system. This is due to the smaller pipe diameters for both the combined sewer pipes and the storm water pipes used to collect and convey wastewater and storm water.

And if environmental hydrology or the weather pattern for Djelfa is typical, then the average intensity of the rainfall events will exceed the capability of the pipes to convey the runoff in less than a three day period.

The diameter of the combined sewer pipe connecting the neighborhood to the 1,500 mm (60 in) interceptor would be 300 mm (12 in). Overall, the maximum values would flow through the interceptor resulting in at least 5% of the flow capacity from rain events that could occur during the year and would generate 100% of the flow capacity generated by the combination of the wastewater and storm runoff delivered through the sewer systems in the neighborhood.

Table 20 : Hydraulic Dimensions and Discharge Capacities of Djelfa's Drainage Network

Collector Class	Diameter Range (D)	Manning Roughness (n)	Theoretical Peak Capacity (Qmax at S=0.01)	Observed Storm Performance & Deficits
Secondary Neighborhood Collectors	300–500mm	0.013–0.015	0.08–0.31 m^3/s	Chronic surcharge; immediate backpressure overflows within 15 minutes of convective storm onset.
Intermediate Interceptor Links	800 mm	0.013	1.12m^3/s	Silted with fine sand; actual capacity reduced by up to 30% due to lack of desilting.
Main Wadi-Parallel Interceptors	1000 – 1500mm	0.013	2.01 – 5.98 m^3/s	Structurally adequate but hydraulically choked by backwater effects during peak wadi overtopping.

These drainage black spots are not separate spatial anomalies; they coincide directly with Djelfa's main national and regional transportation corridors. Djelfa is Algeria's most important land transportation node because it is where RN 01 (the main trans-Saharan highway connecting Algiers with the southerly oil basins and the Saharan border) intersects RN 46 (the highway connecting the western steppe to Boussaâda and the eastern plains).

The spatial registry of these intersections shows a significant operational vulnerability. The channels of Oued Melah, Oued el Hdid and Oued Bennaamcross RN 01 and RN 46 at these points. When severe rain events (e.g. storms) create rapid peak flows, the banks of these channels are easily overtopped. The resulting flooding floods these major highways with 0.5 to 1.0 meters of water, flowing at high velocities, and with debris, heavy mud and other junk.

This localized physical blockade paralyzes the entire city's transportation network. Crucially, this paralysis directly cripples the emergency response mechanisms of the Algerian Emergency Relief Plan (ORSEC). The ORSEC plan relies on 14 specialized, sector-specific modules to execute crisis interventions.

The transportation systems in the city have been effectively cut off from one another by a locally-based blockade created by physical obstructions of all types. This will in turn reduce the capacity for emergency responders to respond to emergency situations caused by either internal issues (such as a natural disaster) or outside issues (such as war). Emergency responders rely on the use of the ORSEC Plan, which consists of 14 modules divided into sectors, for carrying out crisis response interventions.

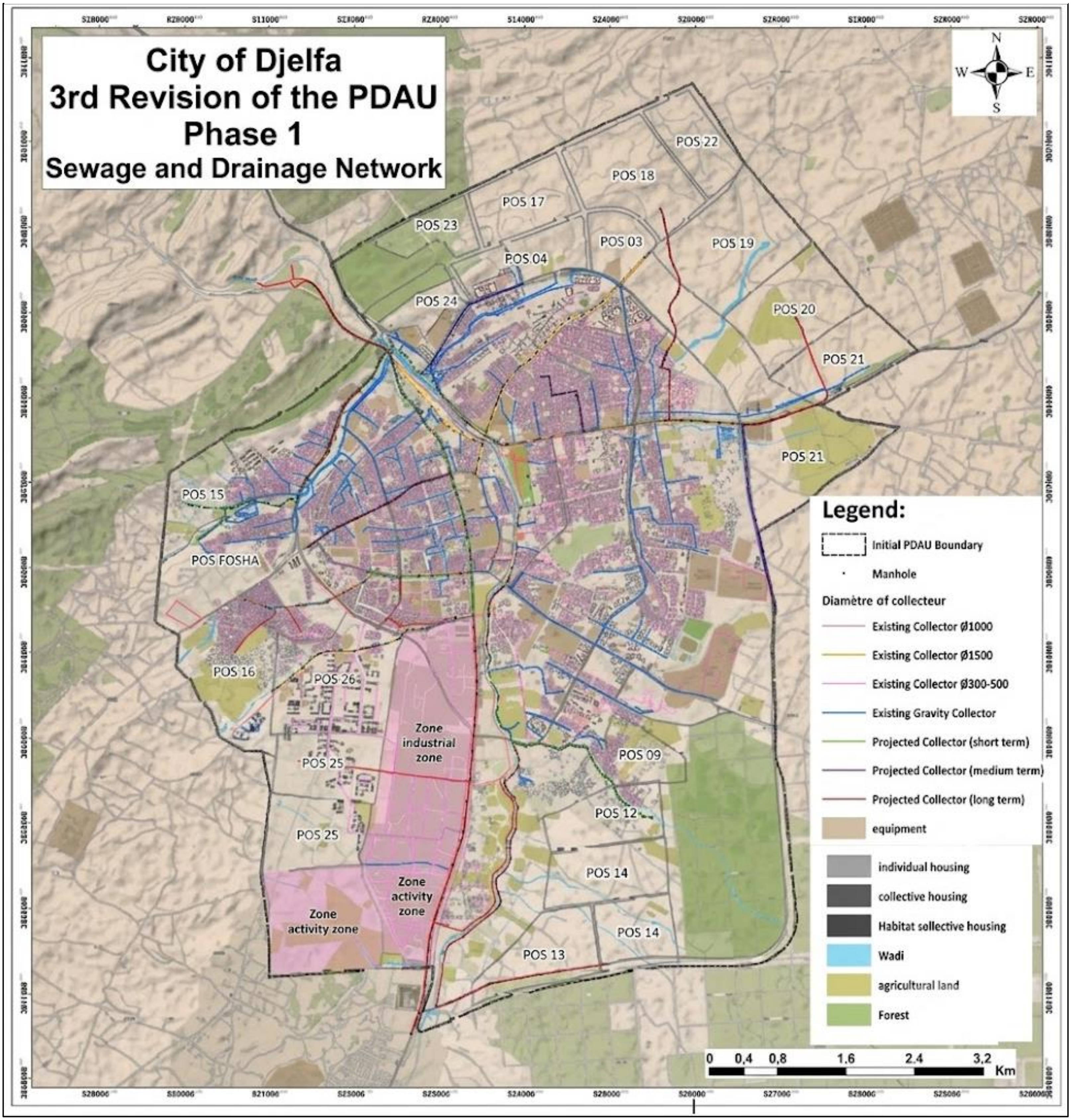
As is outlined in the official ORSEC Plan for Djelfa City, several key transportation connections (indicated on the map below with red circles) are particularly vulnerable to flooding from the two waterways that run through the city: Oued Mellah and Oued Sidi Slimane. As either waterway floods, these locations would be inundated and thus make it impenetrable, preventing emergency responders from making any attempt to access any major health care facility (e.g., H) or polyclinic (e.g., H) located along the shore of the two rivers.

In addition to being affected by floods, municipalities that have designated parallel parking spaces (P+) as either logistical staging areas or emergency response areas will also become isolated, as will the headquarters of the Protection Civile (i.e., central station in Jugha). This flooding will create a spatial barrier that eliminates the ability of the ORSEC Plan to function in a timely and effective manner.

RN 01 and RN 46 being submerged means that the Civil Protection Agency's aquatic rescue teams (Module 1) and medical dispatch units (Module 3) are unable to reach the severely affected neighborhoods (Boutrifis and Ain Chih) due to physical barriers.

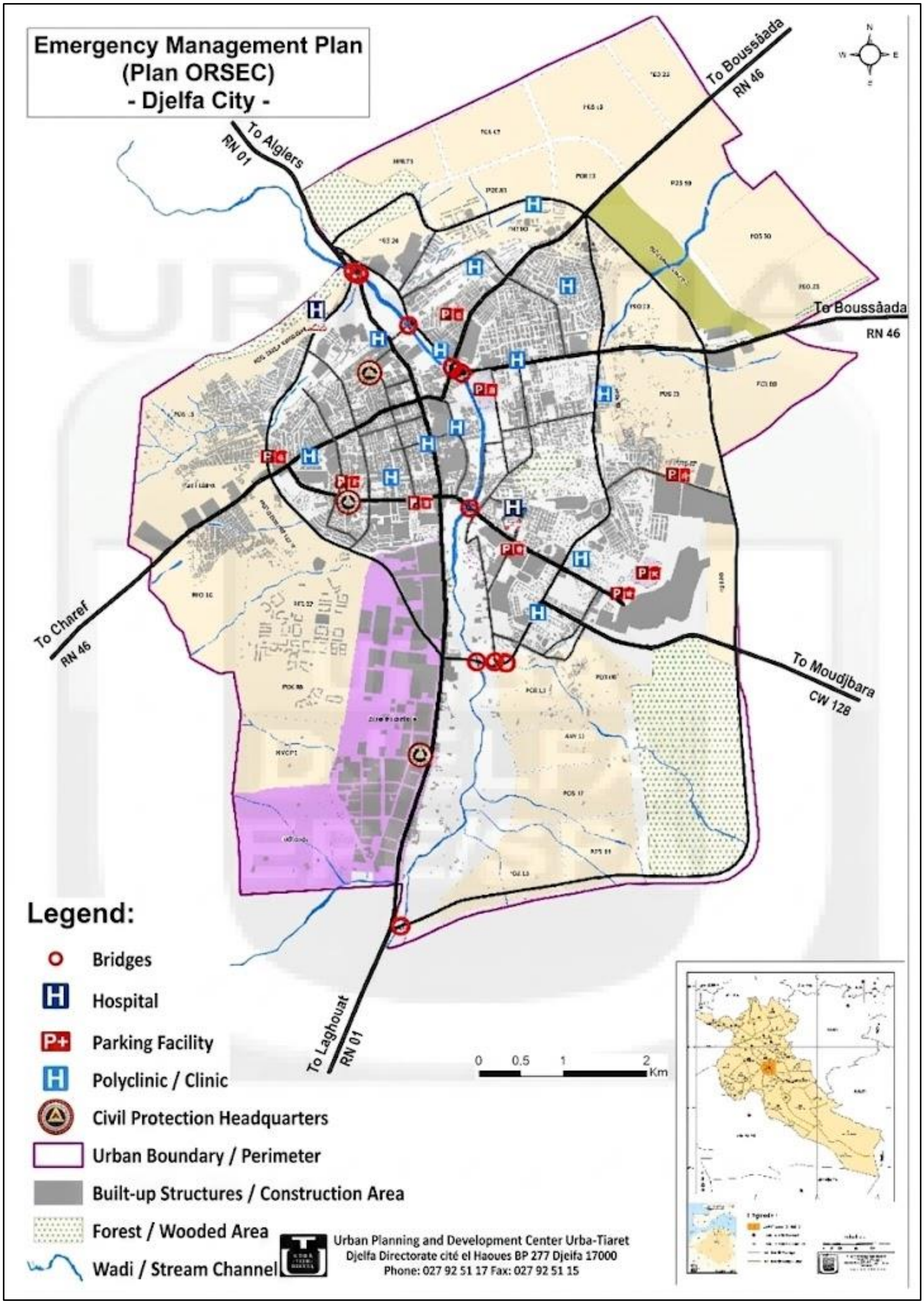
Therefore, local flash floods are transformed to be a humanitarian crisis (due to inability of rescue personnel to carry out timely evacuation), and there are vulnerable people in flooded or structurally unsafe informal housing.

Map 8 : Sewage and Draining Network



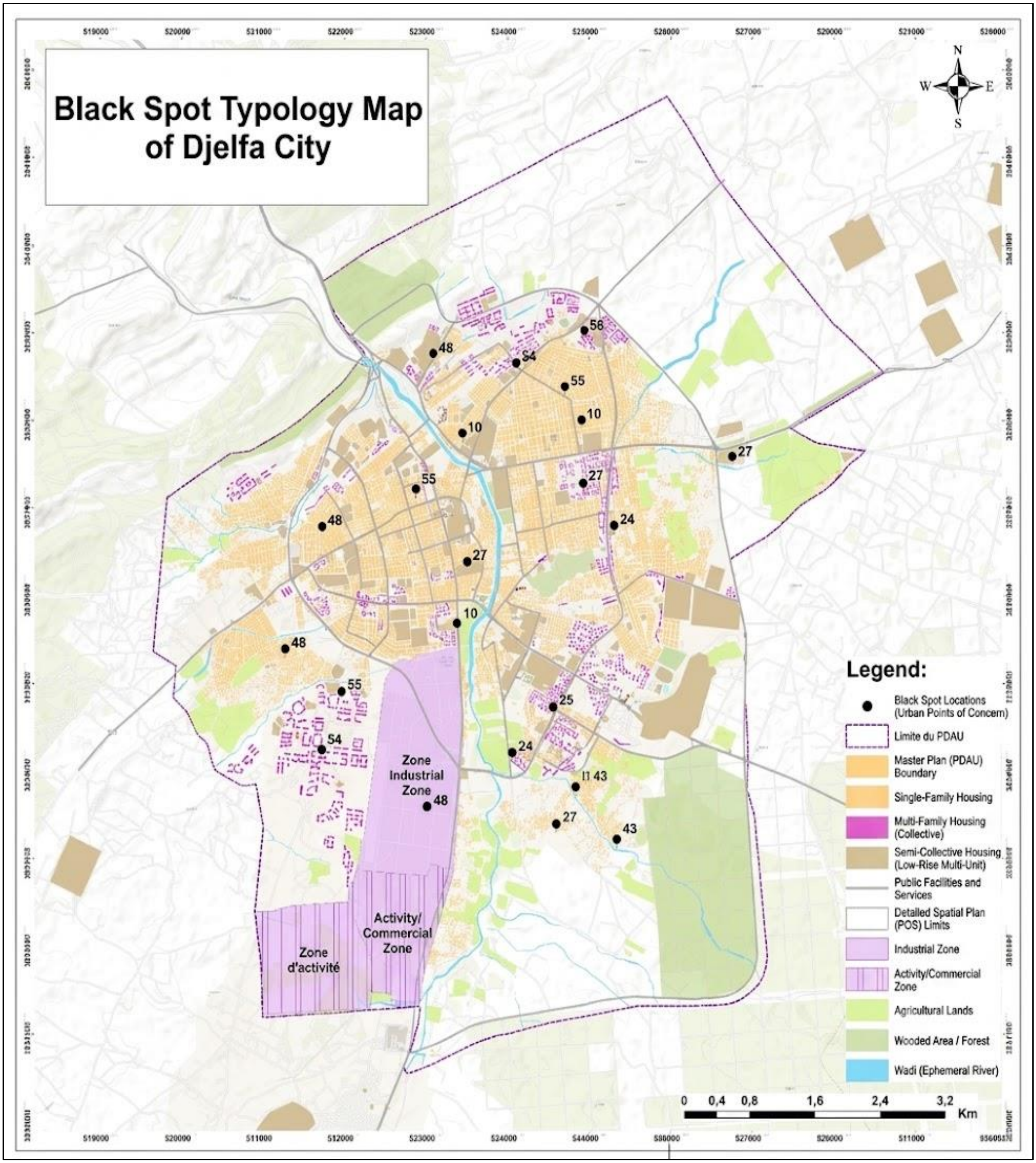
Source: Urban Planning and Developpement Center Urba-Tiaret

Map 9 : Emergency Managment plan (ORSEC)



Source: Urban Planning and Developpement Center Urba-Tiaret

Map10 : Black Spots Typology Map of Djelfa City



Source: By the student based on

3. Analysis of Limitations and Gaps (Technical, Administrative, and Social)

3.1. Technical Constraints

Municipal departments of Djelfa (APC) and local units of ONA are technically limited by outdated infrastructure and lack of current diagnostic tools. Their existing drainage systems are so degraded from structural deterioration and carbonization of concrete that their ability to carry water during Sudden Fall Rainfall Event (SFRE) has been seriously diminished.

These serious deficiencies have been made much worse because of no regular preventive maintenance to clean or remove accumulated silt from all critical components of those drainage systems. Seasonal dredging is not occurring on open Oued Mellah (waterway), Oued El Hadid (waterway) and the underground storm-systems; thus the amount of fine sand and clay being deposited into those water pipes/system is significant.

It is projected that at least 25-40% of the effective cross-sectional area of the various pipes/system has been lost because of silt build up thereby creating serious limitations to the amount of water that can be transported, particularly before the arrival of the Fall Rain season.

Municipal and provincial engineering departments lack advanced digital hydrodynamic and hydrological simulation tools. Local planners do not use modern multi-scenario routing models (e.g., SWMM or HEC-RAS) to dynamically calculate water surface profiles, discharge limits, and pipe surcharge conditions under various return periods, therefore relying on ancient, static, and highly generalized empirical formulas to make decisions.

The absence of this advanced computational software prevents engineers from determining the extent of underground bottlenecks and assessing the projected performance of infrastructure, allowing for the ongoing construction of undersized collectors that collapse the first time they are exposed to large-scale rainfall events.

3.2. Administrative and Institutional Gaps

The operational capability of risk governance in Djelfa suffers not only from limitations concerning technical constraints, but also from major institutional failure due largely to extreme fragmentation, a lack of transparency regarding data and a breach of environmental law. The water resource and sanitation management in Djelfa is comprised of three different entities with overlapping authority:

1) The DRE (Directorate of Water Resources), which serves as the state's MAST- planning agency;

2) The ONA (Office National d'Assainissement), an EPIC responsible for operating and maintaining wastewater collection systems and treatment facilities; and

3) The APC (l'Appel d'Offre pour Communes - municipal government) is responsible for issuing building permits.

The three houses have virtually no horizontal cooperation with each other. The ONA manages the infrastructure (physical pipelines), but has limited or no authority over land-use planning or zoning; the DRE coordinates and oversees large hydraulic works but has no involvement in local neighborhood planning; the APC issues building permits, but has no connection to the technical data from hydraulic agencies. Due to this fractured division of responsibility, an integrated drain strategy at the catchment-level cannot be developed.

The absence of a legally binding Flood Risk Prevention Plan for the Djelfa Commune is a direct consequence of fragmentation at the institutional level. The Flood Risk Prevention Plan is mandated under the provisions of Law 04-20 of December 25, 2004, which governs major risks in Algeria, and its subsequent revisions (Law 24-04 of February 26, 2024). The Department of Environment and Natural Resources (DRE) is required by law to implement this plan for all high-risk urban areas. The Flood Risk Prevention Plan is intended to be used as an enforceable land-use zoning document that identifies hazard zones and creates a non-building, or no-build zone, designation in each active floodplain.

Although Djelfa has experienced multiple major floods that resulted in hundreds of fatalities and considerable property damage in 1960, 1969, and 2015, the DRE has never developed or implemented a Flood Risk Prevention Plan for Djelfa. This persistent regulatory gap represents a violation of Algerian environmental law. The DRE's failure to have a current, enforceable Flood Risk Prevention Plan makes it difficult for APCs to deny building permits or restrict development in high-hazard areas based on risk.

The administrative failings that have occurred as a result of both ONA and DRE also present challenges due to each agency's overarching administrative culture of “Information Asymmetry” and “Defensive Bureaucracy.” In centralized, hierarchical public administrations, bureaucrats respond to agency theory by using information to create a monopoly and act as a shield against external oversight. In Djelfa, both ONA and DRE continually and consistently withhold the latest underground drainage maps, records collected from telemetry rain gauges and spatial databases of network blockages from local planners and other public sector partners.

The withholding of data is a deliberate, calculated act of defense that conceals ONA’s and DRE's entrenched patterns of operational neglect. The previous performance issues experienced at the Kaf Haouas STEP are representative examples. For years, the plant's pumps have failed, desanders have broken down, and there have been multiple occasions when the plant has been partially or completely out of service, releasing untreated wastewater directly into Oued Mellah and further exacerbating the siltation of the wadi. Both ONA and DRE facilitate their failure to properly operate and maintain the hydraulic infrastructure by restricting access to their historical hydraulic performance and network performance data, limiting access to fragmented, non-specialized, or obsolete printed documents—i.e. the “sovereignty of paper” over electronic databases—thereby insulating themselves from political and/or legal liability.

Nevertheless, this systemic obscurity virtually cripples transverse collaboration. The designers of the main urban development areas in URBA TIARET, such as POS 24 and POS 25, are constrained from access to the upgraded underground volume capacity plans after having already designed extensively for both residential projects, and in doing so, establish three very large homes over the existing septic systems. Additionally, as they experience additional crises, the Civil Protection Agency is not able to receive real-time hydrological information, and thus cannot alter the routes used for rescues. This disconnected sourcing of spatial information renders ORSEC planar flexibility obsolete; therefore, returning an emergency response from a potentially proactive responsive mode to being a completely reactive and uncoordinated way to recover from an emergency.

3.3. Lack of Social Risk Culture

Due to human need, rural-urban migration, and limited public education about the risks associated with natural disasters, there is not currently a culture of risk amongst the people of Djelfa. This social lack can be seen in how many individuals have illegally and informally constructed homes directly on the Servitude des Oueds. To have easy access to services within the city, thousands of low-income families have built weak and un-engineered masonry houses directly next to the banks and water body of Oued El Hadid and Oued Mellah, particularly in vulnerable areas such as Bensaid, Bernada, Chaoua, and Bloc 40.

They were built without a professional architect and used poorly constructed and unstable footings. When a sudden flood occurs, lateral forces applied by the flood will quickly exceed the mechanical strength of the structures causing them to collapse rapidly.

These physical encroachments additionally restrict the flow of water within the natural channel of the wadis and cause it to flow at greater speed while at higher elevations. This increases the rate of erosion and floodwaters to adjacent taxpayer-funded housing developments.

Widespread practices by the public of throwing municipal solid waste, agricultural waste, and plastic waste into open wadi channels and drainage inlets (avaloirs) greatly increase this hazard. As there is no effective localized waste management system for the community, locals treat the dry river bed of local wadis as a temporary dump. Waste collects each dry season in the dry wadi beds and in the gully pots until the rainy season arrives in the fall.

When the fall storms come, water flows through the channel; this rapid influx of water also carries the collected solid waste downstream creating significant structural blockages at bridge piers and underground box culverts. This creates a "backwater" effect where water builds up and flows back up to the bridge causing rapid increases in water levels upstream of the blockage, resulting in flooding of residential streets and commercial areas which, without the blockage would have remained dry..

4. Proposed Strategies for Urban Resilience

To turn Djelfa from an ongoing crisis to a model for enduring urban resilience, the municipality must implement a hybrid approach integrating NbS, instit/legislative reforms and decentralized digital technologies while moving away from purly reactive/emergency-based responses and 'grey' eng. methods.

4.1. Nature-Based Solutions (NbS)

Djelfa has traditionally used engineering methods to control torrents by diverting them into well-constructed concrete ditches. Although concrete ditches move water away quickly and raise the peak amount of water flowing downstream, there is no longer a natural means of recharging groundwater. To solve the problem of hydrological degradation in Djelfa, Nature Based Solutions (NbS) must be employed. NbS focuses on establishing a green infrastructure network and an ecological corridor along the banks of the Oued Mellah and Oued Sidi Slimane.

By building wider vegetated floodplain areas in place of the currently degraded wadi banks, the city will reduce the velocity and energy of the flow naturally by increasing the roughness of the channel's walls, thus giving the water a place to slow down.

Riparian wetlands or areas of bio-retention must also be constructed in these wadi areas. These green spaces will act like sponges during rainstorm events, absorbing large quantities of runoff, allowing for natural infiltration into the underlying Djelfa Synclinal aquifer and also reducing the peak discharge flowing downstream.

Importantly, the ecological corridors being constructed on the streets will serve a second important purpose: by providing physical separation between areas within the wadi and adjacent to the wadi that are designated as public and municipal parks, the state will create a continuous and visible physical barrier to informal development by preventing the construction of informal settlements on wadi easements and thus, addressing the issue of informal encroachment into the wadi corridor.

4.2. Institutional and Legal Reforms

The Government of Algeria must undertake substantial institutional reforms at both the municipal and provincial levels to implement these physical interventions. The first of which will see the Directorate of the Environment (DRE), in direct coordination with the ANRH, accelerate developing the long stalled Flood Risk Prevention Plan (PPRI) for the Commune of Djelfa. The PPRI must be drafted using current hydrological modeling techniques with dynamic multi-scenario modeling to reflect the actual runoff coefficients for each of the watersheds. Once developed, the PPRI must have supreme legal authority, thereby making all hazard zones, as well as the non-aedificandi servitudes, binding over all other documents.

The APC must legally integrate the risk-based zoning of the Flood Risk Prevention Plan (PPRI) into all future iterations of the PDA (Plan of Regional Development) and the POS (Plans of Site Development). The plans must render null and void any spatial planning conducted by URBA TIARET that places either residential or industrial growth zones within high-susceptibility floodplain areas.

Further, to warrant compliance, the Judicial Police powers established in Article 87 of Law 24-04 must be enforced aggressively. The powers granted to the municipal and hydrological engineers will allow them to stop any illegal construction activities occurring in the wadi easements immediately; and impose severe criminal penalties to any Public Official who issues building permits in the wadi easements, contrary to the provisions of this PPRI.

4.3. Centralized Web-GIS Platform

The Djelfa business environment will ultimately benefit by providing a single, centralized web-GIS platform. This platform will enable immediate access to information shared and developed by the APC, DGPC, DRE, and ONA on a real time basis. The web-GIS platform must also serve as an open source repository by enabling users to store, retrieve and create interfaces that link all of the spatial GIS layers with each of the agencies; e.g., the drainage black spots, pipe capacity, and topographic data shapes.

The live monitoring of hydrological conditions through telemetry rain gauges, wadi level sensors, and SCADA systems located at the Kaf Haouas treatment plant must be utilized by this web-GIS platform to develop a complete and current database of hydrological information. As a result, this web-GIS platform will eliminate typographical errors associated with separate databases and will prevent agencies from withholding data that may indicate lack of operational effectiveness. Furthermore, during storm events, the web-GIS platform will facilitate the transformation of the ORSEC Plan from a paper-based document into a more flexible and predictive model for decision making.

The Civil Protection command center will have the ability to track water levels under critical bridges, anticipate inundation of transport routes along RN 01 and RN 46, redirect rescue units as needed, and evacuate high-risk informal neighborhoods in advance of flooding. This type of real-time coordination will provide the most comprehensive integration of spatial analysis, legal accountability and administrative synergy and sets the stage for a resilient & safe future for Djelfa.

Conclusion of the chapter

This study shows that the Djelfa flood isn't just about bad weather; it's also about bad governance and planning. The way people are building in the flood-prone areas based on the AHP flood risk map isn't sustainable. There are also problems with the way in which flood infrastructure has not been built correctly. The study also showed that the ORSEC Plan isn't working since there is too much information asymmetry and no legally required PPRI. Because of this, flood risk management continues to be a reactive and fragmented cycle of poor decision-making. Djelfa's future will be different from what it is today because Djelfa needs to get away from technical improvements and make a major paradigm shift in governance so that the use of digital and shared access processes and rigorous enforcement of eco-regulations will be part of future planning. This means that this study will help guide the way that both legal and organizational frameworks are developed in the future so that they are more than just tools to manage urban safety; they can also be used to create safe and sustainable urban environments.

GENERAL CONCLUSION

Conclusion

This master's thesis, it has performed an extensive analysis of spatial, legal and institutional flooding crisis management within the Djelfa Commune, in which it has compared the abstract Norwegian national doctrine for risk management with the tangible deficiencies of the urban environment of the Djelfa Commune.

By utilizing empirical geographic analyses and public policy analyses together, the research confirms that repeated crises caused by flash flooding within the Djelfa Commune are fundamentally structural in nature; i.e., that they result from a systemic disconnect between dynamic hydrologic processes and rigid master planning practices, as well as fragmented institutional governance.

The findings of the spatial and physical analysis validated the first hypothesis (H1) that the semi-arid climate and unique geomorphological characteristics of Djelfa Commune contribute to its being a closed syncline which contributes to rapid surface run-off during episodic and very intense convective storms. Thus, the naturally hazardous conditions of flash flooding are significantly increased due to human actions; e.g., the rapid population growth within the Djelfa Commune over the last 30 years has resulted in massive soil impermeability and caused large changes to how land is used in the Djelfa Commune.

We found that human actions cause significant spatial conflicts to arise because of formal planning tools including: master plans (PDAUs) and permitting zoning ordinances (POS) which authorize urban expand and the construction of infrastructure in the original drainage corridors and to replace very necessary permeable drainage channels with rigid concrete bases and legally encroaching into the statutory floodway easements.

In addition, the legal and operational diagnostics confirmed that there was significant strength behind the second and third hypotheses (H2 and H3) - which demonstrate that despite Law No. 04-20 creating the theoretical framework with regards to Water Resource Management being structurally absent at the local level; there are no localized, updated regulatory by-laws pertaining to semi-arid climate conditions.

The governance of risk in Djelfa is severely impacted by massive institutional fragmentation and widespread administrative siloing within government departments. The empirical field stage of this study highlighted these limits through the extreme level of information asymmetry and bureaucratic defensive behaviour observed within both the National Office of Sanitation (ONA) and the Directorate of Water Resources (DRE). The chronic lack of accessible technical data, together with a reliance upon outdated documentation and the lack of a binding Flood Risk Prevention Plan (PPRI), prevents municipal authorities from having any enforceable spatial mechanisms.

Therefore, where convective storms produce immediate structural blockades upon the primary national transport corridors (RN 01 and RN 46), the Emergency Relief Plan (ORSEC) executions occur at lower levels of management entirely reactively as opposed to proactively in relation to local rescue operations.

Strategic Recommendations for Urban Resilience

This dissertation suggests an integrated framework of action for Djelfa to change this chronically crisis-stricken territory into a long-term model of resilient sustainability. The following actions have been proposed to do so:

1. Align Urban Planning with Hydrologic Risk: Future revisions to spatial planning instruments (PDAU & POS) must be subjectled to current, dynamic hydrographic maps and all current statutory no-aedificandi servitudes (i.e., restrict construction) along oued beds must be enforced vigorously in order to prevent the construction of further informal and formal forms of concrete encroachment.

2. Overhaul Structural and Operational Infrastructure: Local municipal technical services in conjunction with ONA, must implement a systematic approach for seasonal dredge and maintain flood tunnels to eliminate siltation; and to expand their pipe cross-sectional capacity to accommodate excess volume resulting from extreme convectional run-off (rain).

3. Modernize Institutional Inter-Sectoral Responsibilities through Web-GIS Deployment: Break-down the administratively isolated approach currently being employed by DRE, ONA, Civil Protection and Commune (APC) by creating an open, Digital Web GIS Platform which acts as a central repository for structural

configurations and real-time data – including transforming the rigid and divorced ORSEC Plan to a collaborative (web-portal) predictive decision support system (DSS).

4. Localized Prevention Protocols (PPRI) - Implement the PPRI Administrative Framework for speedy development of a localized, specialized Flood Risk Reduction Plan for Djelfa, focusing on establishing horizontal communication channels and eliminating the hoarding of technical data.

In closing, to achieve urban safety in the fragile environment of Djelfa, there is a need to move beyond reactive engineering solutions and support a paradigm shift from governance that combines spatial transparency; accountability; & proactive legislative enforcement into one cohesive framework (i.e., Governance 3.0) for a resilient and sustainable urban future.

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