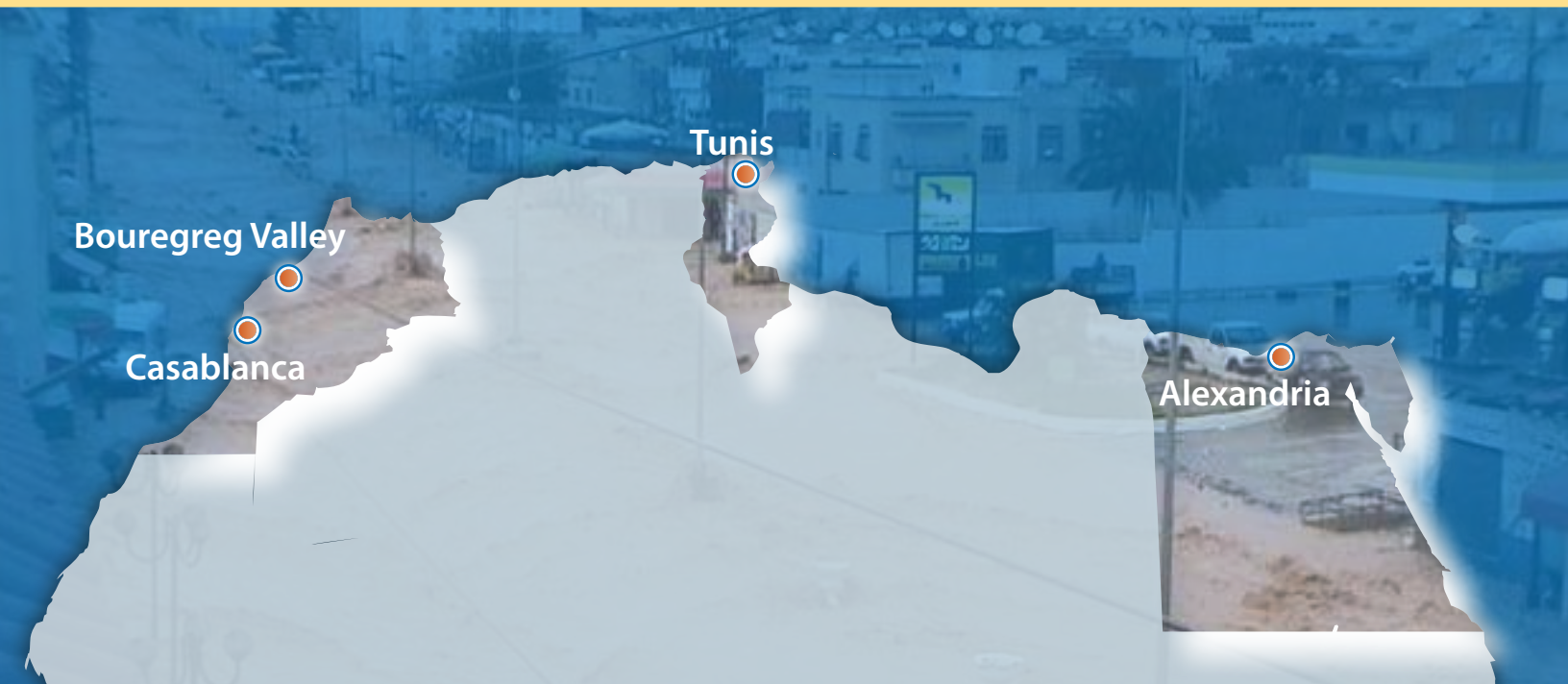


# NORTH AFRICAN COASTAL CITIES

Address Natural Disasters  
and Climate Change



Climate Change Adaptation and  
Natural Disasters Preparedness  
in the Coastal Cities of North Africa

Summary of the Regional Study  
June 2011



THE WORLD BANK



MARSEILLE CENTER  
for MEDITERRANEAN INTEGRATION

## A STUDY BUILT ON BROAD BACKING, PARTICIPATION

**The study has been directed by Anthony G. Bigio, Senior Urban Specialist and Lead Author for the Intergovernmental Panel on Climate Change, with a World Bank team comprising Stephane Hallegatte, Lead Climate Change Specialist, Salim Rouhana, Junior Professional Officer, Asmita Tiwari and Osama Hamad, Disaster Risk Management Specialists, and Tim Carrington, communications adviser.**

The study is one of the foundational programs of the **Marseille Center for Mediterranean Integration (CMI)**. Created in 2009, the CMI is a regional knowledge and learning platform supporting evidence-based public policy choice. Its urban programs support dialogue, new knowledge and its use among the public and decision-makers. The study will provide the basis for future work under the programs.

The study benefitted from peer-reviews by the following specialists from the World Bank and the Global Facility for Disaster Risk Reduction and Recovery (GFDRR): Alex Bakalian, Henrike Brecht, Isabelle Forge, Jaafar Friaa, Francis Ghesquière, Philippe Huc, Alex Kremer, Michel Matera, and Edward Tschan. Overall guidance was provided by Anna Bjerde, Urban and Social Development Sector Manager in the Middle East and North Africa region of the World Bank.

The study was carried out by a consortium of French consulting companies headed by **Egis-BCEOM International**, directed by Denis Carra, and including **IAU-RIF** and **BRGM**. Its project team was led by Yves Ennesser, and comprised Michel Abientz, François Beauchain, François Bertone, Ion Besteliu, Dominique Cataliotti, Jean-Michel Cathala, Guillaume Dulac, Fabrizio Ferrucci, Eric Huybrechts, Azzedine Motia, Mirelle Raymond, Victor Said, Monique Terrier, Mohsen Tounsi, Nadra Tounsi, Terry Winter and Franck Zangelmi. **Météo-Maroc**, the national

meteorological agency, carried out the detailed climate down-scaling models, in consultation with the Tunisian and Egyptian meteorological agencies.

Co-financing partners include the **Global Facility for Disaster Risk Reduction and Recovery** (GFDRR), the **Norwegian Trust Fund Private Sector and Infrastructure** (NTF-PSI) and the **Trust Fund for Environmentally and Socially Sustainable Development** (TFESSD), administered by the World Bank.

Partners generously providing specific support include the **European Space Agency**, which provided earth observation via the service companies Altamira and TRE, and the **Arab Academy of Science, Technology and Maritime Transportation**, which has collaborated in the Alexandria urban risk assessment.

Within the three participating countries, institutional support and technical contributions of the relevant agencies was critical to carrying out the research and defining the policy responses.

In **Egypt** the Environmental Affairs Agency (Coastal Zone Management Department), alongside the Alexandria Governorate, has provided support for the study.

In **Morocco**, the State Secretary for Water and the Environment, the Wilaya of Greater Casablanca, and the Agency for the Development of the Bouregreg Valley played an equivalent role.

In **Tunisia**, such support came from the Ministry of Environment and Sustainable Development (Environment and Quality-of-Life Department), the Ministry of Development and International Cooperation (Infrastructures Department), and the Municipality of Tunis.

# OVERVIEW: URBAN COASTAL RISKS ON THE RISE

North Africa’s coastal cities, long benefitting from their ready access to commerce and culture, also face distinct vulnerabilities due to their location. Natural hazards and extreme weather patterns impose risks on coastal areas that inland areas seldom encounter. North Africa’s increasingly populous cities face tangible risks today, but these will be amplified as the impacts of global climate change further manifest themselves over the decades to come.

To better understand both the risks that these cities face by the 2030 time horizon, and to help prepare the required adaptive responses, the World Bank has conducted a regional study focused on three cities critical to the region’s economic, social and political life: Alexandria, Casablanca and Tunis. The study also examined the Bouregreg Valley between Rabat and Salé in Morocco, an area which is undergoing large-scale urban development and is slated for further growth in the next decade.

The study, “**Climate Change Adaptation and Natural Disasters Preparedness in the Coastal Cities of North Africa**,” analyzed the exposure of all four loca-

tions to natural disasters, such as floods and storm surges, earthquakes and tsunamis, as well as to the increasingly frequent weather extremes associated with climate change. The project, which has taken place from June 2009 to June 2011, has provided tools for evaluating the risks, costing out potential losses, and moving toward specific reforms and investments designed to adapt the cities to a changing climate and increase their resilience to natural hazards.

## Rise in Natural Disasters Already in Evidence

Already, the southern Mediterranean and Middle East have seen a measurable rise in natural disasters. From an average of three natural disasters a year in 1980, the region experienced a steady increase to an average of more than 15 in 2006. All told, the region was been hit by 276 disasters in this 25-year time period, of which 120 occurred in the last five years. By any measure, the risks associated with natural catastrophes are on the rise, also on account of increasing population and assets exposure.

### Urban Risks Increase Over Time in All Urban Locations under the Study

Urban Risks	Alexandria		Tunis		Casablanca		Bouregreg Valley	
	Current	2030	Current	2030	Current	2030	Current	2030
Seismicity/ground instability	Low	Low	Low	High	Low	Low	Low	Low
Tsunami/Marine submersion	Low	High	Low	High	Low	Low	Low	High
Coastal Erosion	Low	High	High	Very High	High	High	Low	Low
Flooding	Low	Low	High	Very High	High	High	Low	Very High
Water Scarcity	Low	High	Low	Low	Low	Low	Low	Low

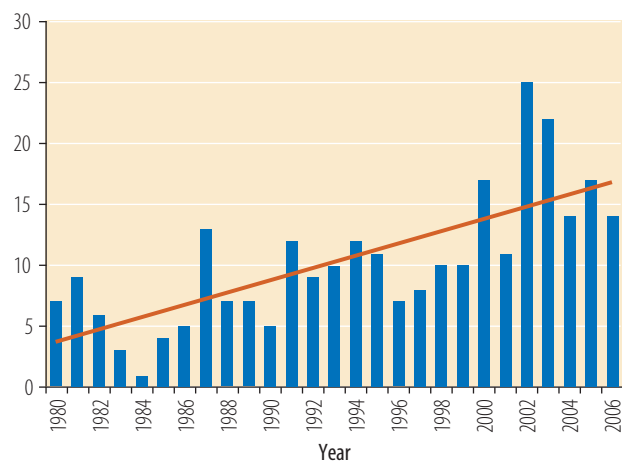
■ Very High   
 ■ High   
 ■ Medium   
 ■ Low   
 ■ Very Low

In North Africa's coastal cities, urban managers, businesses and households have had to cope with numerous costly and destructive episodes of extreme weather.

### Recent extreme weather events

On November 30, 2010, Casablanca was deluged by a record 18 centimeters of rain overnight—equal to about six months of rainfall under normal patterns. The resulting floods forced the shutdown of various facilities, including the international airport, businesses and schools throughout the city. Companies lost inventories. Streets became swirling rivers, with cars mostly submerged, and citizens struggling through waist-high water to reach places of security. More than 2,500 families had to be accommodated in various public structures. After the disaster, city councilors called for an urgent review of infrastructures, services, and institutional systems implicated in emergency response.

On December 10–12, 2010, heavy rains, storm surges and strong winds hit Alexandria, causing the partial collapse of 28 buildings, with 18 people dying in the catastrophe and dozens more injured. Streets were inundated, harbor activities suspended. A factory col-



Natural disasters affecting Middle Eastern and North African countries have increased significantly since 1980. (Source: EMDAT)

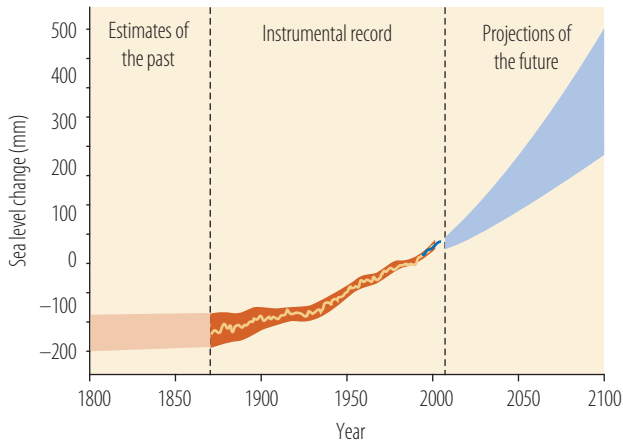
lapsed on a group of workers after the rains damaged the structure.

For Tunis, the scope of natural disaster risks hit home in September, 2003, when a particularly severe storm swept the coastal city. In a 24-hour period, Tunis took in about five times the volume of rain as typically fell in the entire month of September. The catastrophe damaged buildings, cost lives, and overwhelmed the limited drainage systems of the city. Following the disaster, the Tunis authorities analyzed weak points in urban structures and initiated studies and investments to help the city withstand similar catastrophes in the future.

### Risks Likely to Increase Over Time

Two trends confirm that the cities will be increasingly vulnerable to flooding and other natural disasters over the next two decades:

- **Climate change**, whose future magnitude and impacts necessarily remain somewhat uncertain, adds to the frequency and intensity of extreme weather events, so that historical patterns no longer function as indicators of future weather-related risks. According to the International Panel on Climate Change, North Africa is the second most vulnerable area in the world to emerging climate-related risks.
- **Rapid urban population growth** throughout the Middle East and North Africa raises the stakes by increasing the potential losses from natural disasters and climate-related damages. Some 60 million people inhabited the region's coastal cities in 2010, but the number is expected to swell to 100 million in 2030, placing more people, livelihoods and structures at risk. Alexandria, Casablanca and Tunis—home to about ten million people in 2010—can expect a combined population of around 15 million in 2030. The Bouregreg Valley anticipates an influx of up to 140,000 people in an area that has remained virtually uninhabited for centuries.



Projections for the 21st century carry uncertainty, but even at the low end of the range, sea level rise will compound current risks for North African coastal cities. (Source: WRI)

### Urban Risk Assessments

The study took into account climate change projections, urbanization and demographic shifts, and examined coastlines, structures, and neighborhoods that will face increasing risks. Looking at specific threats, such as flooding or coastal erosion, the study team found that most risks increase over the 2010–2030 period. Sea level rise—a critical climate-change risk for coastal cities—is an important unknown but is assumed in the study to be 20 cm by the year 2030.

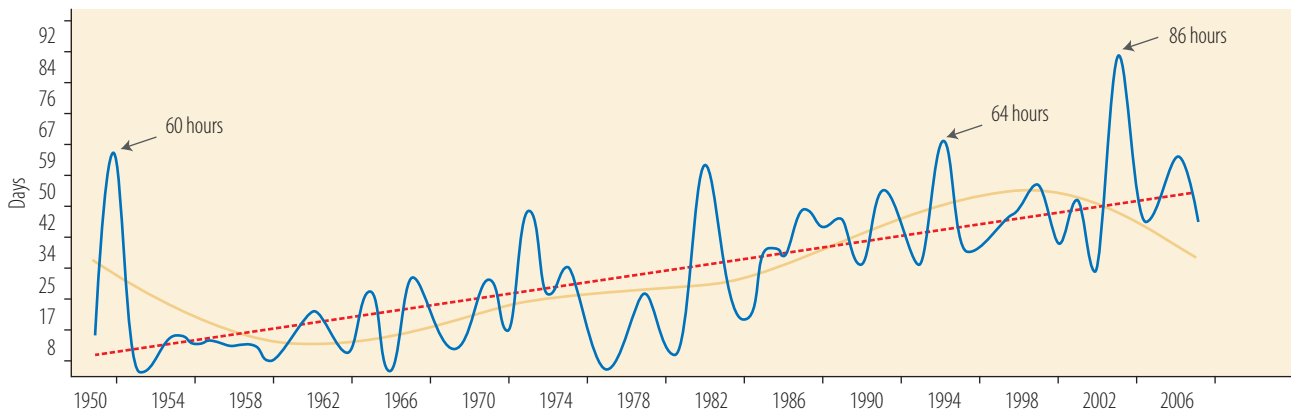
The higher seas would compound storm surges, increasing the risks for marine inundation and coastal erosion.

The report has identified specific risks within each of the four urban areas, and proposed adaptive actions that would mitigate potential damages and losses. Risks have been quantified, along with the costs of adaptive and climate-resilient actions, so that planners can calculate the costs and benefits associated with the particular courses of action recommended. Although the study focuses on four specific locations only, the analytical processes it employs are relevant to many other coastal cities in the region.

### Economic valuations

The study found that over the 2010–2030 period, the three cities each face potential cumulative losses of well over \$1 billion from the risks, which include floods, earthquakes, coastal erosion, ground instability, marine inundation, tsunamis and water scarcity. Meanwhile, the planned development of Morocco’s Bouregreg Valley could place communities, houses and industries at risk—unless the project follows a path of climate-smart development.

The bulk of the risks are related to natural disasters to which the coastal cities are already vulnerable,



Heat waves are becoming longer lasting, with higher peak temperatures, as this record for Tunis shows, increasing impacts on public health, including more respiratory diseases.

but by 2030, about 20% of the potential losses would be attributable to various impacts of climate change. Given that by all scientific accounts climate change manifestations are going to increase significantly by mid-century and further, it is very likely that a much greater percentage of losses will be attributed to climate change for the 2050 or 2070 scenarios.

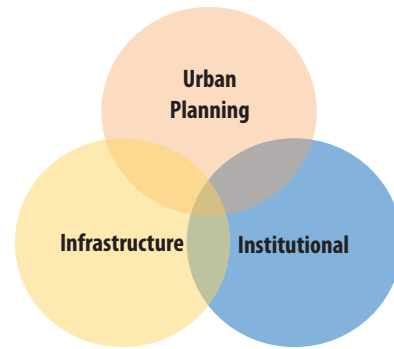
### Acting to Make Cities Resilient, Adapted to Climate Change

The study’s first phase focused on future climate projections, probabilistic risk assessments, and hazard and exposure measurements, leading to the formulation of current and future urban risk assessments. The second phase has generated Adaptation and Resilience Action Plans that would make all three cities, and the Bouregreg Valley, more resilient to natural disasters and better adapted climate change impacts.

Lessening the risks requires actions in three overlapping spheres: urban planning initiatives; institutional reforms and capacity building; and strengthening infrastructure.

- **Urban design plans** will have to take into account the risks of placing communities or enterprises in low-lying and risk-prone areas, and

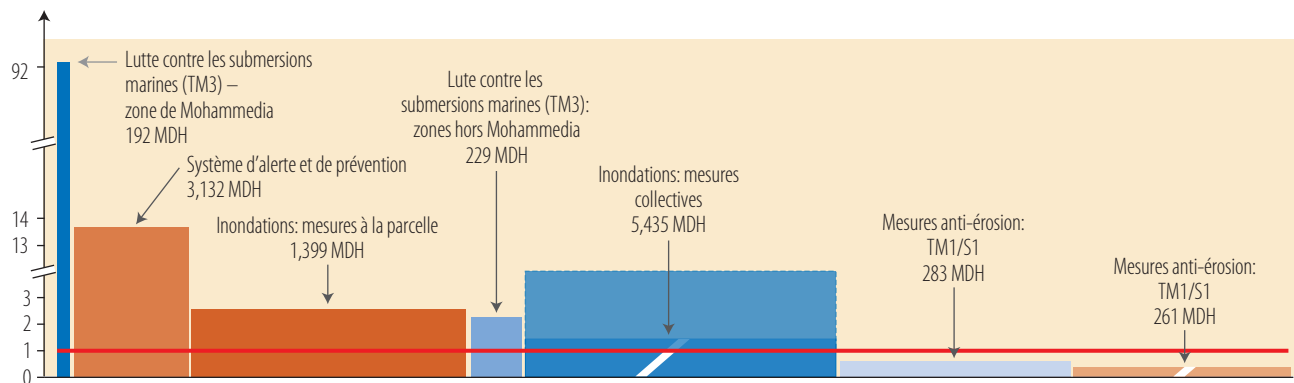
### Lessening the Risk: Overlapping Spheres of Action



provide climate-appropriate solutions for future urban expansions.

- **Institutions** will need to function at higher levels of efficiency and coordination to prevent and lessen damages, with improved early warning systems, effective communications, and clear lines of responsibility.
- **Urban infrastructure** such as coastal defenses and drainage systems will require upgrading and reinforcement.

These three areas of adaptation and resilience are often overlapping and mutually reinforcing, and have to



Adaptation cost curves, like this one for Casablanca, allow cities to weigh the benefits of measures proposed within the action plans. The vertical column shows the ratio of benefits-to-costs for investments in specific processes, institutions, and infrastructures. The horizontal red line shows the break-even point, above which benefits, under current conditions, outweigh costs.

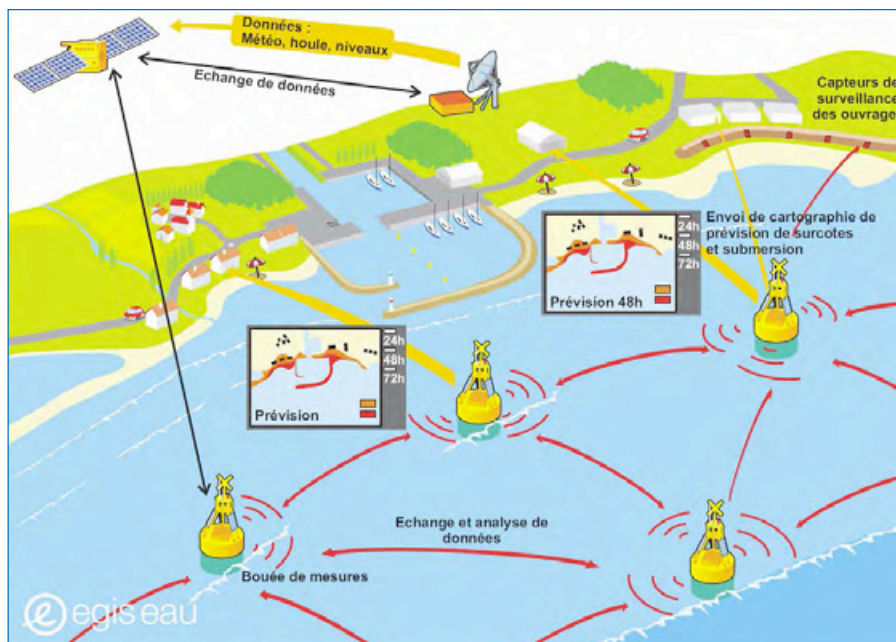
be managed and implemented simultaneously.

Action plans drawn up in partnership with local officials in the three countries have set the foundation for policy responses and investments to limit current and future urban vulnerability. Economic evaluations can assist decision-makers in weighing the costs and benefits of particular preventive actions, after factoring in the potential losses in taking no actions.

### Tools for Reducing Uncertainties

On this basis the study has generated “adaptation cost curves” which rank the cost effectiveness of each remedial measure proposed. Many of such measures pass the cost-benefit test and are confirmed to be economically effective and promise to deliver high returns in terms of risk reduction. In particular, all “soft” measures, such as urban planning and strengthening the institutional preparedness, offer a high return on investment. Some of the infrastructure measures proposed turn out to be more costly than the damages that would be off-set, but can still be justified in terms of the intangible values of some urban locations, for instance on heritage grounds.

The study reduces the scope of uncertainty facing decision-makers with regard to future climate and urban risks, but it cannot eliminate it entirely, given that the local impacts of climate change will be greatly affected by the scope of the worldwide mitigation measures



**Improved early warning systems help coastal cities lower potential damages from sea surges, storms and tsunamis. Systems of “smart buoys” linked to satellites, such as this one proposed for Alexandria, offer real-time surveillance and greater preparedness.**

reducing greenhouse gas emissions over the next two decades. The most effective responses, therefore, take the form of so-called “no-regret” actions, which are sensible and cost-effective under a variety of future climate scenarios. Of course, Adaptation and Resilience Action Plans should be updated periodically to respond to further findings and evolving scenarios.

### Moving Towards Implementation

With the study completed, the tasks ahead involve creating political consensus and mobilizing financial resources for the most critical planning and policy initiatives and investments, so that these cities, which have historically contributed so profoundly to the identity of the region, may be better prepared to face the challenges of the future.



## STEERING URBAN GROWTH AWAY FROM AREAS AT RISK

The ancient city of Alexandria is home to a population of 4.1 million, with an expectation of 6.8 million inhabitants by the year 2030, a surge of 65%. The original city, built by Alexander the Great in 331 BC, has grown enormously over the centuries with steady expansions along its water front. From the coastal village of Abu Quir in the northeast to the village of El-Deir in the southwest, the Alexandria agglomeration consists mainly of high-density settlements along a partially elevated ridge facing the sea, backed by low-lying rural areas containing a number of lakes and wetlands. Many of these areas fall below sea level and are also highly vulnerable to flooding, which is controlled by pumping stations ejecting water into the Mediterranean Sea.

### Patterns of Urban Growth

It is expected that Alexandria's expansion will tend to take place westward, along the Al-Bouhayra Lake, with further urban sprawl towards the south. Poorer communities are likely to increase along certain shoreline areas, in the Abu Quir depression and near the Maryut Lake. Other areas likely to house future population growth are in low-lying spaces subject to ground subsidence and increasing climate-related risks. Expansion south of the Al Montaza and Sharq areas is likely to increase the number of people and value of structures exposed to seismic and flooding risks.

The city's recent reconstruction of its sea-front roadway in the form of a ten-lane coastal highway has intensified already evident patterns of coastal erosion and storm surges, by steepening of the slope of the seabed. As a result of future sea-level rise, such events are likely to have further impact into the city's built front, exposing new areas to risk.

### Urban Risks Increase Over Time in All Urban Locations under the Study

Urban Risks	Alexandria	
	Current	2030
Seismicity/ground instability/	Low	Low
Tsunami/Marine submersion	Low	High
Coastal Erosion	Low	High
Flooding	Low	Medium
Water Scarcity	Low	High

High Medium Low

### Key Risks

One element of Alexandria's critical exposure to risks are its informal settlements, which currently house one third of the city's total population, and which are likely to increase with population growth. More



people are expected to crowd into deteriorating structures in the old parts of the city, with others settling into surrounding wetlands and other vulnerable, low-lying areas. With greater urbanization, the overall ground area will become increasingly impermeable, adding to runoff and drainage problems.

Satellite images provided by the European Space Agency show that as much as 9% of the measured ground points in the Alexandria agglomeration are subject to significant land subsidence. The phenomenon is particularly notable along the northern border of Lake Maryut and between the Gharb district and Abu Quir, making these areas more vulnerable to ground instability.

Meteorological data collected over the past 30 years show trends of increasing heat waves and more instances of torrential rainfall. As was evident in the December 2010 disaster, storm surges not only submerge stretches of the coastline, but reach low-lying areas located well in from the coast.

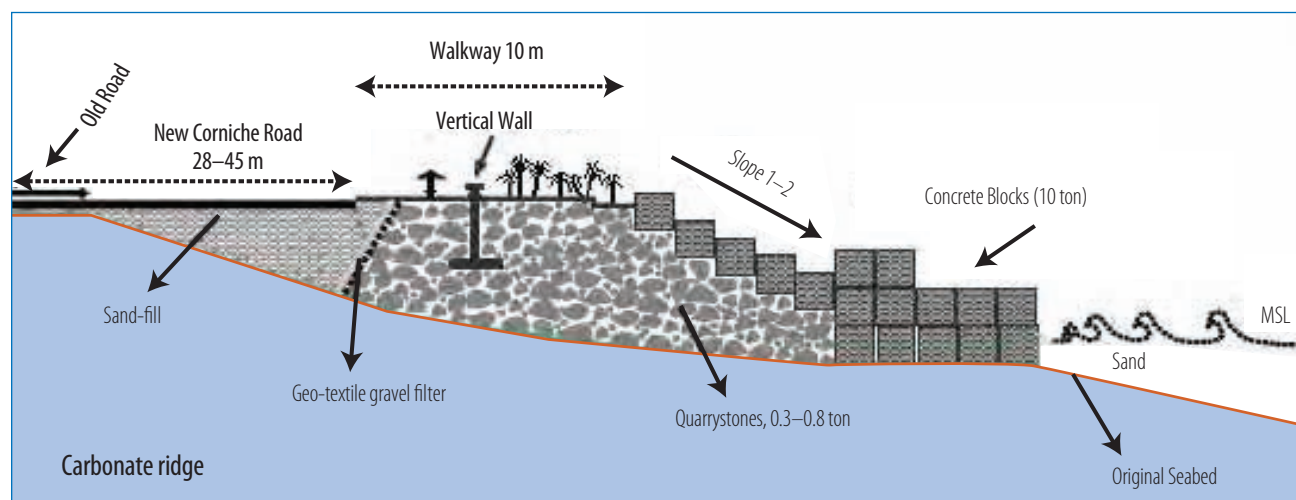
Since the 1990s Egypt has tasked various central coordination entities with managing disaster response and risk management, establishing a structure that

reaches to the Cabinet level, with interactions through the key ministries. The approach contributes to relative clarity with respect to which agencies are responsible for which tasks.

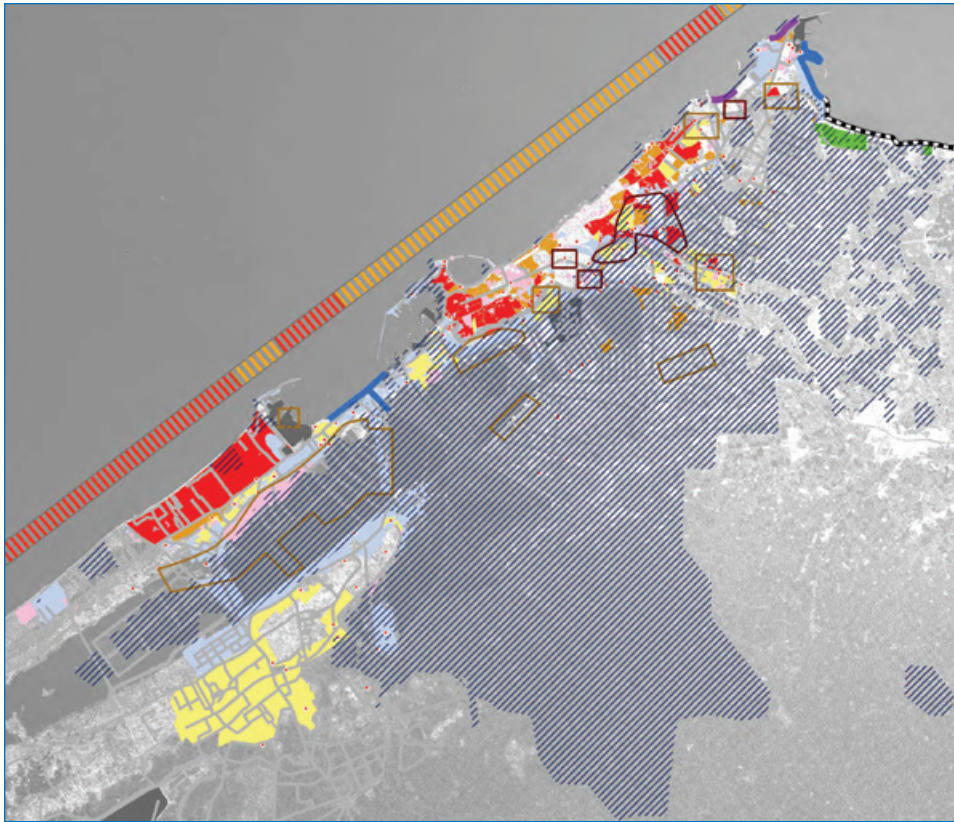
The Information and Decision Support Center plays a key coordinating role, and since 2000, an entity for Crisis and Emergency Management Affairs provides a disaster response command structure. However, the study found that the structure emphasizes command and control aspects of disaster response, but underplays communication and early warning capacities and a decentralized response capacity. For instance, the 2010 Sinai flash floods event exposed Egypt's shortcomings in forecasting and early warning systems, especially vulnerable when a series of weather-related events follow one another in a short time period.

## Urban Risk Assessment

The study reached the following assessments covering specific urban risks for Alexandria, as measured in 2010 and forecasted for 2030:



Alexandria's recently constructed corniche road, built over the sea, remains vulnerable to storm surges on account of the steeper slope of the seabed—despite the addition of parallel breakwater structures. (Source: Frihy et al.)



This multi-risk map of Alexandria highlights critical vulnerabilities. The large shaded area indicates low-lying, flood-prone lands; red represents high-density residential areas; yellow shows slums and informal settlements; blue shows areas most subject to marine submersion. The diagonal line off the coast represents different degrees of coastal erosion risk.

- Flooding:** Vulnerabilities are evident in recently urbanized areas that are below sea level, including an area between the hydro-dome and Abu Quir, at the edge of the former Abu Quir lagoon, and in the Sharq and Al Montaza districts. Without careful planning for the use of areas below sea-level, informal settlements will multiply, and with more frequent and more intense extreme rainfalls, flooding will escalate to a medium risk in 2030 from a low risk in 2010.
- Seismic threats and ground instability:** Northern Egypt faces moderate earthquake and seismic risks. However, subsidence combined with increasing informal settlements raise the potential losses from structural damage, increasing the rating to a medium risk in 2030 from a low risk in 2010.
- Tsunami and marine submersion:** Seafront buildings along the densely urbanized coastline are exposed to structural damages, while low-lying areas risk marine submersion. Coastal areas near Abu Quir are directly threatened by marine submersion, with specific worries that the 18th century Mohammed Ali sea wall could rupture in case of a major earthquake or tsunami, putting areas below sea-level at risk of inundation. With increased settlement of the shoreline, along with a likely expansion of residential developments over current natural areas, such threats rise to the high-risk category by 2030, up from a medium risk in 2010.
- Coastal erosion:** Over time, Alexandria's beaches have been receding, with increasing risk of structural damage to shoreline buildings. There are significant erosion risks between El Dekhiela Harbor and the western harbor of

Alexandria, and at Abu Quir. With the higher sea levels associated with climate change, coastal erosion and the beaches retreat are likely to accelerate. As a result, erosion rises to a high-risk category in 2030, from a medium-risk in 2010.

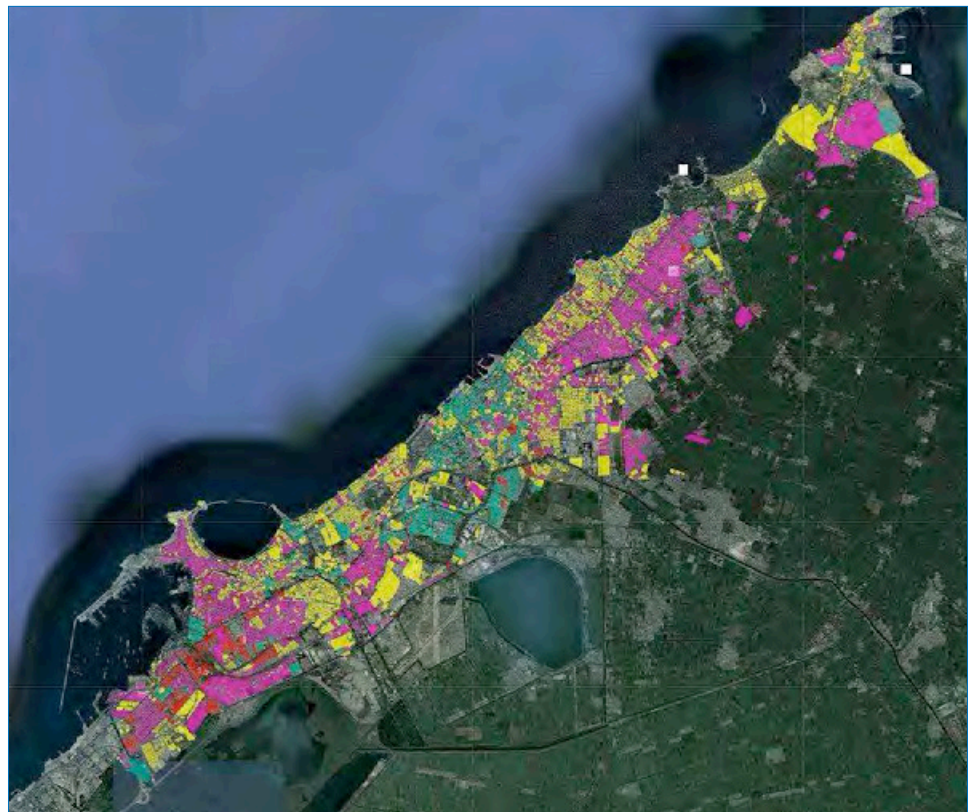
- **Water resources scarcity:** With Egypt's growing population and a constantly increasing industrial demand for limited Nile water, water scarcity problems are likely to occur. Water demand surged by 50% over the past decade, and with nearly half of Egypt's industrial activity centered in Alexandria, urban demand for limited water resources is certain to grow. Meanwhile, local aquifers are becoming exhausted and are subject to salinization. Unmediated competition for Nile resources with upstream countries could exacerbate shortages, so that by 2030, the city's current supply from the Nile could become insufficient, and water resources scarcity is rated as a high risk in the future from a low risk today.

For Alexandria, the cumulative potential damage from natural disasters and climate change impacts is estimated to be \$1.72 billion in Net Present Value for the period 2010–2030. An estimated 18% of that total is attributable to climate change impacts alone.

### Adaptation and Resilience Responses

There is much that decision-makers can do to protect the well-being of the city's population and lessen the potential harms to the economy of natural disasters and climate change. Broadly, the study encourages Egyptian policymakers to shift from mainly responding to natural disasters and weather events after they occur to focusing on preventive actions to limit the damage natural disaster might cause and to prepar-

Alexandria's building stock mostly consists of older and low-quality structures vulnerable to natural disasters, represented by red and magenta in the map. Patterns of high-density occupancy in these areas multiply the vulnerabilities. (Source: GOPP)



ing for the progressive impacts of climate change. The study also provides tools for pricing the costs of various actions, comparing these costs to damages that might occur if no adaptive actions are taken.

### Urban Planning

Adequate urban planning and land-use policies will be critical to limiting the Alexandria's exposure to risks, damages and losses. The 2030 Greater Alexandria Master Plan, currently being prepared, is an excellent opportunity to incorporate the results of the study's urban risk assessment, and to re-orient the city's future expansion away from the areas identified as most at risk. The Master Plan should also direct future urban growth, define city limits, and establish a land-use program with rules for densities, building heights and open space ratios taking into account future climate scenarios.

### Institutional Preparedness

Upgrading early warning systems covering all types of disasters emerges as a particularly sound investment. Improved management of coastal areas also

emerges as critical. For example, a system of "smart buoys" along the coastline could help generate timely data that could help protect people and property from coastal storm surges. Improved communication among agencies involved in disaster prevention and response could strengthen timeliness and coordination, leading to more robust responses.

### Infrastructure Investments

Investments in making existing structures more resilient would benefit coastal marine defenses. Some key urban infrastructures and buildings, along with water supply and drainage systems, could be made more robust and better able to withstand the damages that can occur in storms such as the one that hit Alexandria in 2010. Like other cities, Alexandria can lower flood-related risks by taking steps to improve control of runoff and discharge sources, and routine maintenance of the sewage system all would lower risks during flooding periods. In addition, areas slated for development can be sited and prepared to minimize the vulnerability. Investment in special equipment—such as mobile water pumps—can help with drainage problems during flooding.



## CONFRONTING FLOODING, COASTAL EROSION AND MARINE SUBMERSION

Casablanca is home to 3.3 million people, with another 300,000 in nearby rural areas. In the period 1994–2004, the population surged by more than half a million. According to estimates based on historical patterns, the population of Greater Casablanca will swell by 55% to 5.1 million by 2030.

### Patterns of Urban Growth

Economic expansion and population growth will continue to fuel a sharp rise in the number of households. As a result, the urban area is expected to expand by as much as 1,000 hectares a year. Significant urban development is also expected to occur along the Casablanca waterfront and in low-lying areas that are vulnerable to sea storm surges and flooding.

### Key Risks

Casablanca is particularly vulnerable to flooding, coastal erosion and marine inundation, and is experiencing significant pressures linked to rapid urban growth. The city also houses many precarious structures, some older and poorly maintained, some newer and poorly constructed. A number of the slums and densely populated neighborhoods are located in low-lying neighborhoods, and have encroached on areas legally protected for water catchment.

Morocco has experienced climatic shifts in recent years, including warmer average temperatures and overall decreased yearly rainfall. Projections for 2030 envision warming for Casablanca of up to 1.3 degrees centigrade, with annual rainfall accumulation decreasing by 6% to 20%. However, it is also expected that the warmer temperatures and lower levels of annual rainfall will be accompanied by more frequent and more intense episodes of extreme precipitation, further overwhelming the already stressed urban drainage systems.

The town of Mohammedia, subject to devastating floods in 2002, requires special attention. An analysis

### Urban Risks Increase Over Time in All Urban Locations under the Study

Urban Risks	Casablanca	
	Current	2030
Seismicity/ground instability/	Low	Low
Tsunami/Marine submersion	Medium	Medium
Coastal Erosion	High	High
Flooding	High	High
Water Scarcity	Medium	Medium

■ High   
 ■ Medium   
 ■ Low   
 ■ Very Low

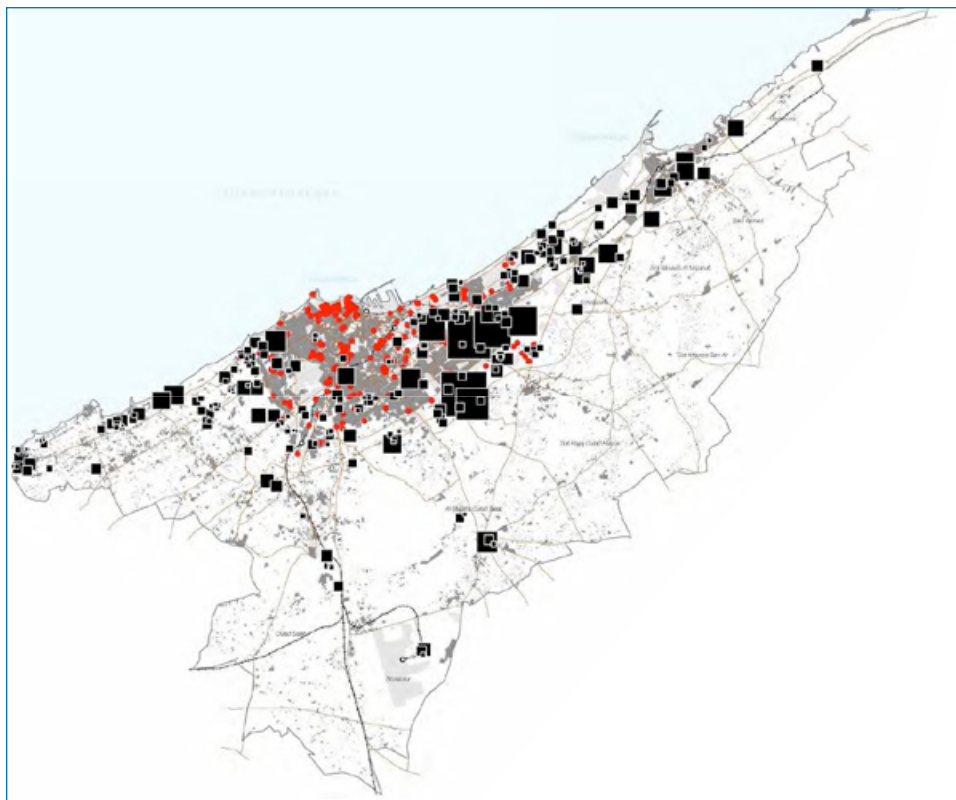
of the vulnerabilities and structural fragilities underscored the need for improved drainage facilities and greater physical protection against sea surges.

Morocco's Disaster Risk Management has become significantly more effective as a result of changes carried out since early 2009. A restructured General Directorate of Civil Defense and a new Supervision & Coordination Committee have generated positive reviews from a mix of stakeholders. Improved disaster preparedness and more accurate warnings from the Department of Meteorology, Morocco enabled a much improved response to torrential rains and flooding between December 2009 and March 2010.

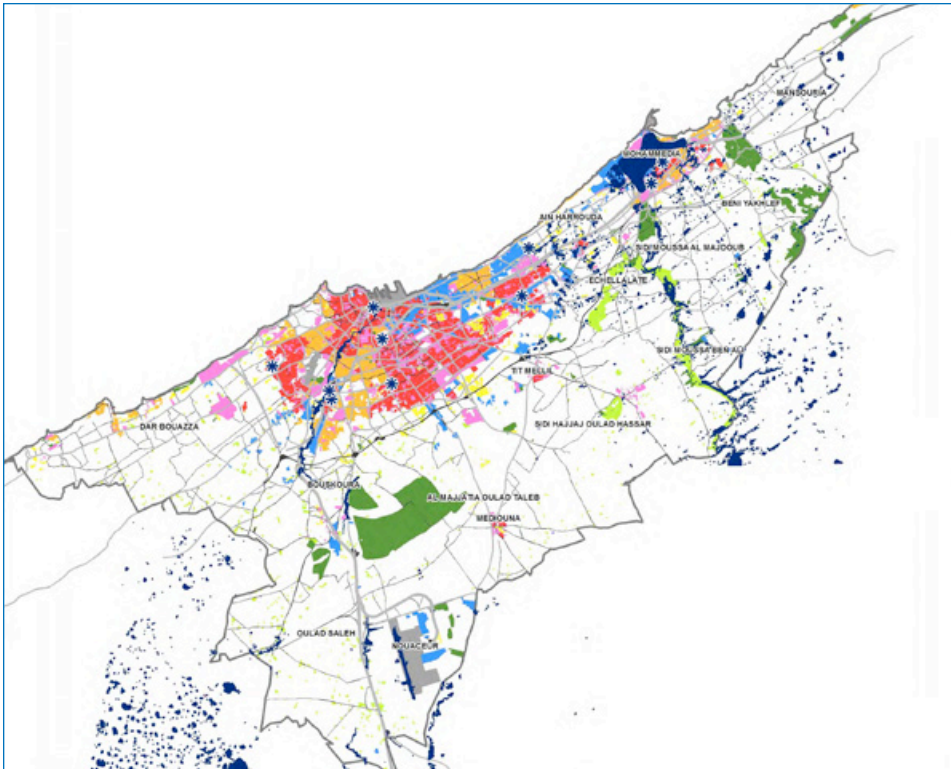
### Urban Risk Assessment

Following are the key results of the risk assessments for Casablanca, as measured in 2010 and forecasted for 2030:

- **Flooding:** Casablanca has been regularly disrupted by floods, given its current level of protection, limited to a level of rainfall recurring every five years. This is due to insufficient city-wide drainage systems and the informal urbanization of catchment areas. The study has identified specific areas of Greater Casablanca that are particularly vulnerable to periodic flooding: slums and structures built with cheap or inferior materials are of particular concern. Flooding is considered a high risk in 2010, and will remain high for the 2030 scenario.
- **Tsunamis and marine submersion:** For Casablanca, the risks posed by tsunamis and marine submersion are considered medium, given the historical record of relatively recent tsunamic events, and are expected to remain so by 2030. Marine submersion risk is significant for specific segments of the coastline, in particular for Mohammedia, where storm surges can cause



Areas of substandard dwellings, indicated by red, constitute 28% of all housing stock, with 11% categorized as slums. These extend across Greater Casablanca, but are concentrated in the northeast outskirts. Black squares (not drawn to scale) indicate the size of slum areas.



Flood-prone areas, indicated by the dark blue, are sprinkled throughout residential, industrial and mixed-used parts of Greater Casablanca. The most critical areas are the town of Mohammedia and the course of the Oued Bouskoura cutting across the city to the harbor. Already planned infrastructure improvements are expected to reduce exposure to flooding.

the inflow of sea-water inland with severe consequences for the productive and administrative center of the city. Storms, intensified by higher sea levels, will be likely to damage the city's sea-front and put more areas at risk of marine submersion. The low-lying areas near the outlets of the main ephemeral streams of Mehla and Nfifich face distinct risks.

- Coastal erosion:** A ten-kilometer coastal segment stretching between the eastern end of Casablanca and the Mohammedia power station now faces a strong risk of erosion, with another thirty to forty kilometers of coastline segments also considered at risk. Expected sea level rise intensifies such vulnerabilities in the future. The risks of coastal erosion will increase, with sand beaches expected to retreat by as much as 15 meters by 2030. Erosion risk is ranked as high risk today as well as for the 2030 scenario.

- Water resources scarcity:** Water insecurity, ranked as a low risk in 2010, would become a medium risk by 2030, assuming current estimates of population and industrial growth. This is in relation to the overall decrease in rainfall which the country is expecting, with the consequent decrease in resource and additional pressure over the apportioning of water for urban and rural usages.

The potential aggregate economic losses for the 2010–2030 period due to natural disasters and impacts of climate change in Casablanca would have a Net Present Value of \$1.39 billion, the bulk of which is associated to flooding. Such losses would be commensurate to losing 7% of the gross domestic product of Greater Casablanca. Potential economic losses attributable to climate change impacts would represent an estimated 18% of the total.



All along the Casablanca seaboard, low-lying areas such as the town of Mohammedia, are subject to high marine submersion risks. Blue areas indicate present risks, red areas, additional exposures coming on by 2030.

## Adaptation and Resilience Responses

The study calls for an integrated approach for the detailed land use planning and urban design of Casablanca's neighborhoods, reconciling the expected growth of population and economic activities with environmental considerations. This approach has already been embraced by the 2030 Master Plan which was recently approved, and now needs to be applied in greater detail as the zoning plans are being designed. Climate-related vulnerabilities and natural risks have to be factored in when the city considers potential uses of vacant land or identifies areas for new housing construction. Flood-prone areas should be carefully screened to avoid worsening inundation and drainage problems.

### Urban Planning

The study also suggests the creation of eco-neighborhoods to demonstrate approaches to environmentally sustainable, climate-resilient design and construction, which could serve as models for new development in Casablanca and beyond. Meanwhile, areas subjected

to repeated flooding would undergo detailed plans to protect key structures and buildings. It is expected that slums would eventually be redeveloped under the national slum up-grading program, and that other overcrowded areas would undergo rehabilitation.

### Institutional Preparedness

Moroccan institutions can take specific actions to become more effective in responding to natural disasters. Risk factors are already incorporated in the organizational and regulatory framework, but the country would benefit from further steps to remove overlapping ministerial functions, to simplify operations, and to separate civil defense and the roles of state and local institutions.

Casablanca also needs new information systems, including improved strategies to alert citizens and enterprises of rapidly changing weather conditions, along with plans for protecting lives and property. The study has strongly recommended upgraded systems for surveillance and early warning, with greater use of satellite



imagery and regular measurement of land subsidence, temperature changes and shifts in water levels.

### Infrastructure Investments

The studies attach special urgency to addressing physical vulnerabilities along the coastline, particularly the stretch of about 40 kilometers that is already subject to erosion and sea storm surges. A vulnerable coastal span between Mohammedia, and Casablanca, where protective dunes are considered particularly fragile, could benefit from steps to reinforce the natural barriers, coupled with the managed retreat of some illegal coastal housing.

Casablanca would also benefit from improvements in the drainage system to ensure its viability during flooding crises, along with expanded infrastructure

for accommodating runoff and drainage. A critical flood prevention project is the construction of the drainage canal dubbed “Super Collector West”, which has already been designed and quantified, and which would increase the flood protection of the city to a 20-year level. This infrastructure would drain a number of basins that tend to overflow during heavy rainfall and potential floods in the western part of the city.

New dam structures would be necessary to assure long-term protection of communities and property against the sea. Casablanca should also extend the current programs aimed at reducing water leakages, favor water conservation, and link water storage facilities into an integrated system that would include enable the use of harvested rainwater for watering green areas.



## ADDRESSING MULTIPLE RISKS, ONSET OF CLIMATE CHANGE

Residents of Tunis expect hot, dry summers followed by mild, wet winters. But they also have come to anticipate weather extremes. Following a series of damaging storms over thirty years, Tunis encountered a devastating storm in 2003, with major flooding across the city, and losses amounting to hundreds of millions of dollars. That same year, the city experienced one of the most intense heat-waves on record. The city drew up new disaster response plans and initiated infrastructure improvements. But with climate change, extreme episodes as occurred in 2003 are expected to become more frequent, requiring a fresh look at the city's level of preparedness.

### Patterns of Urban Growth

Population growth in Tunis is more modest than in other cities in the region, but still a significant factor in assessing future risks. The urban population of 2.25 million is expected to increase 33% to about 3 million by 2030. However, the tectonics and soils of the city itself present profound challenges. In downtown Tunis, land subsidence leaves some buildings tilting visibly to one side, and seismic risks are considerable. The coastline is seriously threatened by erosion, requiring reinforced beach defenses. The coastline itself is continuously shifting despite sea defenses and beach nourishment which have been built and implemented regularly.

### Key Risks

Topographical data shows that urbanized and industrial areas in the lower downtown, Rades, Ezzahra and Hammam Lif Ouest are vulnerable to marine submersion under certain storm conditions. Extreme rainfall events could increase by 25% under widely accepted scenarios for climate change by 2030. Tunis could be facing the occurrence of 50-year weather events that formerly occurred once every one hundred years. Similarly, intense rains that might once have come every fifty years could arrive once every twenty in the near future. The return period for less violent weather episodes would be telescoped in the same way.

#### Urban Risks Increase Over Time in All Urban Locations under the Study

Urban Risks	Tunis	
	Current	2030
Seismicity/ground instability/	Medium	High
Tsunami/Marine submersion	Medium	High
Coastal Erosion	High	Very High
Flooding	High	Very High
Water Scarcity	Medium	Low

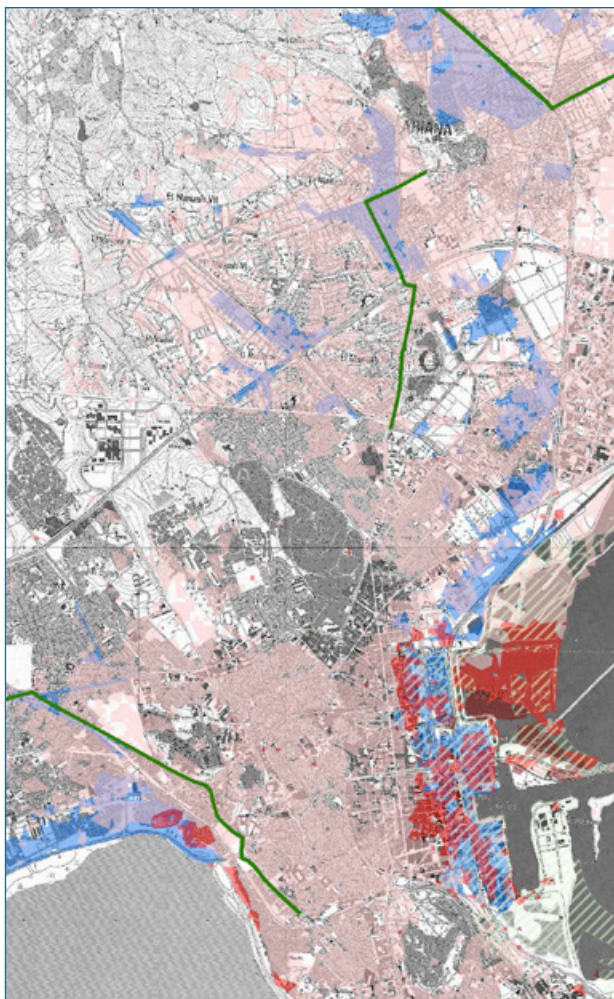
■ Very High   
 ■ High   
 ■ Medium   
 ■ Low

Institutional strengthening can help better manage the risks. The National Office for Civil Protection leads various agencies in the prevention and management of disasters, but the structure of this arm of government has barely changed over the decades. Past episodes of natural disasters haven't been followed by assessments and regulatory or operational improvements. Cartographic information and geographical data bases remain largely absent, along with texts covering specific risks.

## Urban Risk Assessment

Following are the key results of the risk assessments for Tunis, as measured in 2010 and forecasted for 2030:

- Flooding:** Floods, a recent and major problem for the city, would likely intensify, rising from a current high risk to a very high risk by 2030, despite the full implementation of the trunk drainage system upgrades under way, on account of the likely 25 percent increase in extreme precipitation events, which can generate flood levels of more than one meter in certain areas of the city. Certain drainage basins will face a severe risk of flooding, exacerbated by inadequate local drainage and rapid urbanization. Meanwhile, as the city expands, new construction on hillsides and in flood-prone areas could be adding to runoff volumes and consequent damages, unless planned in a climate-appropriate way.
- Coastal erosion:** Erosion, already a high risk along the Tunis shoreline in 2010, is ranked as a very high risk by 2030. The coastline of the Gulf of Tunis has been receding for half a century, despite offshore protections mitigating the trend. In some stretches of the coastline it can recede by as much as 10 meters a year. By 2030, 27 kilometers of the urbanized seafront would be considered at a high risk of erosion, up from 16 kilometers in 2010. Sea level rises projected under climate change would accelerate coastal erosion, with beaches receding by as much as



In economically important central Tunis, subsidence indicated in red combines with flooding risks indicated in blue to multiply potential impacts. Major storms overwhelm the center-city drainage, inundating streets and buildings.

15 meters by 2030. The coastline between Kalaat Landalous and Raoued Beach could be severely eroded by 2030.

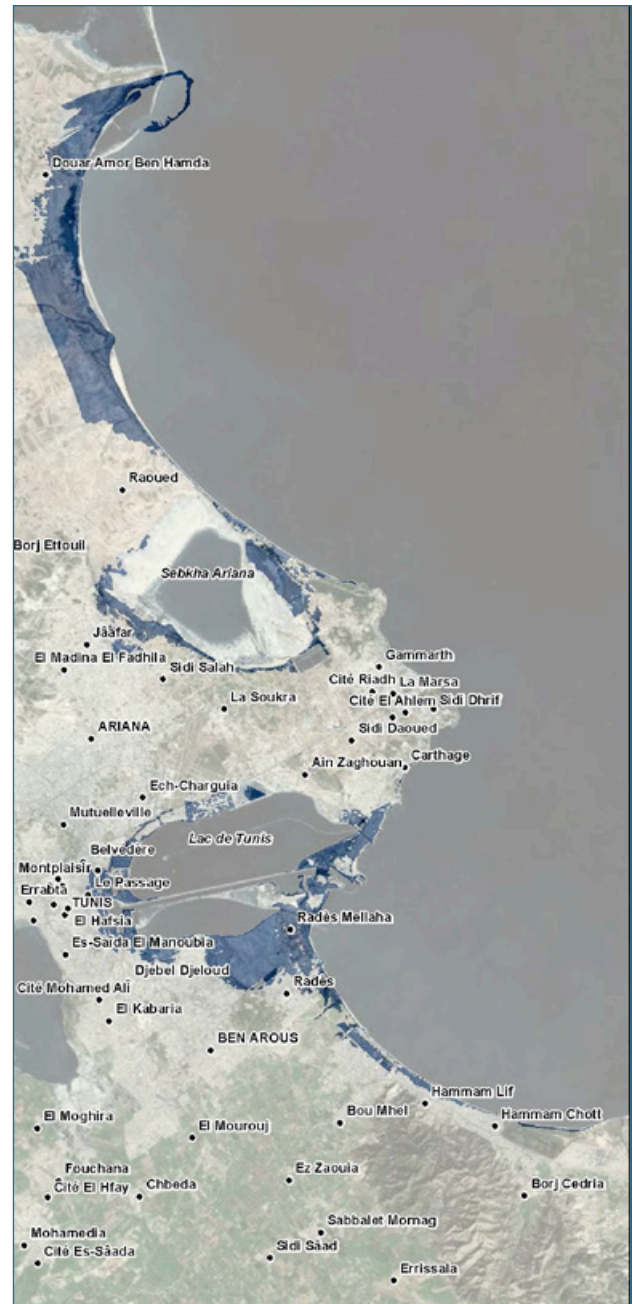
- Tsunamis and marine submersion:** The study assumes a global sea level rise of 20 centimeters by 2030, which could intensify the damage to sea barriers, raising the risk of submersions for the city. By 2030, the study estimates that an expanded stretch of the urban seafront would be at a high risk of submersion. Taken together, the risks rise from a medium-risk category to high-risk by 2030.

- Earthquake and ground instability:** Tunis faces in general a moderate earthquake risk, but on account of the poor geotechnical quality of Tunis' soils, the damage risks would be considerably higher. Subsidence in the downtown area presents distinct challenges to the neighborhoods built on land reclaimed from the Lake of Tunis during the French colonial period, rich with architecture which is part of the cultural patrimony of the city. According to the study, the related risks increase from medium to high between now and 2030.
- Water scarcity:** Water demand will increase in Tunis, on account of a bigger, wealthier population by 2030, simultaneously with an expected considerable drop in average rainfall at the national scale. Despite excellent water resource management at the national level, urban usage will place more strains on the resource, with the result that water scarcity rises to a medium risk in 2030, from a low risk in 2010.

The likely aggregate economic losses from all the risks amount to a Net Present Value of \$1.05 billion, or 8% of the urban economy of the capital city. About 59% of the potential losses relate to submersion risks, with 26% reflecting seismic risks and 14% from storm surges. An estimated 25% of the potential losses by 2030 would be attributable to climate change, with most involving flooding.

## Adaptation and Resilience Responses

Overall, climate-resilient urban planning will be crucial for Tunis to manage the risks caused by natural hazards and climate change. Areas of the city that are low-lying and subject to flooding will require further upgrading of drainage systems before further development is allowed. Illegal housing development at the



By 2030, factoring in climate change and sea level rise, significant stretches of the Greater Tunis seaboard, indicated in darker shading, could be submerged during mega-storms likely to occur every hundred years.

periphery will need to be contained, in line with the recommendations of the Master Plan. Careful zoning, with allowance for green spaces, along with rigorous enforcement of standards, will be critical.

## Urban Planning

Zoning decisions would also factor in the city's significant subsidence problems, which undermine its resilience to storms, seismic risks and extreme weather. Future developments will have to be designed so as to minimize additional loads to runoff, by providing for on-site absorption of rain-water via green roofs, rainwater storage and other environmental devices.

## Institutional Preparedness

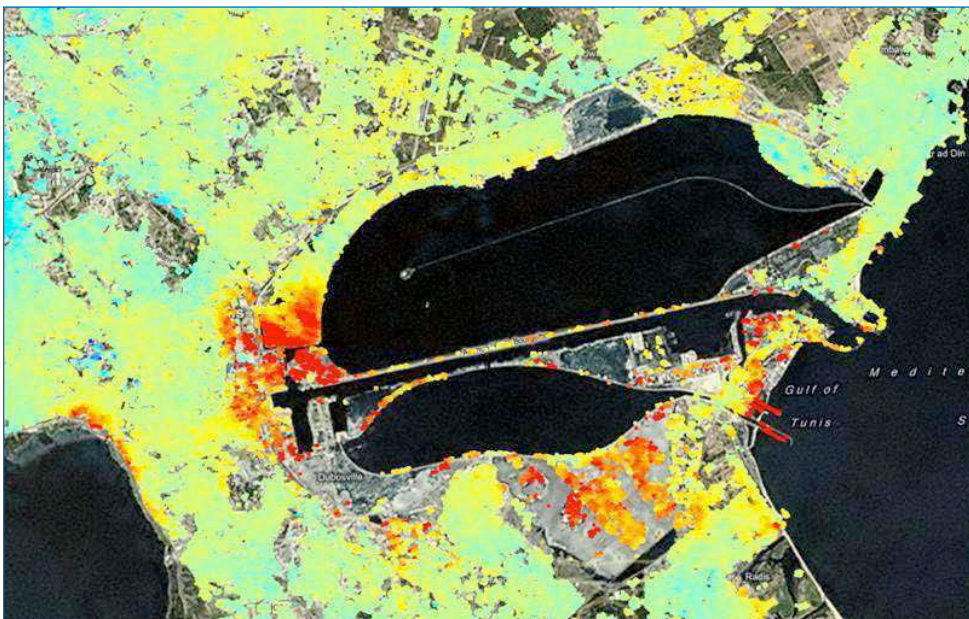
Because of the potential damage from earthquakes, sea surges and tsunamis, the study recommends that a system of monitoring and early warning, coupled with communications plans for alerting citizens and enterprises, be installed. For the most exposed areas, sirens and other emergency systems would be necessary. Concurrently, the city should begin to assess in detail the vulnerability of existing buildings to the various risks so that specific actions may be carried out to increase their resilience. Some areas will likely require an urban requalification strategy.

Tunis also needs monitoring systems to track the retreat of beaches and threats to its coastal barriers.

Modern air-based surveillance can provide valuable contributions in such systems. The city will need a specific plan for reversing already observed erosion in the vicinity of Rades, and in certain other areas. The study advanced a series of specific recommendations for other stretches of coastline that have been degraded over time, by storms and changes in the coastal profile. Overall, Tunis would also benefit from a better legal framework for the management of coastal zones.

## Infrastructure Investments

Infrastructure strengthening will be critical in certain areas. Sewerage and drainage structures in Tunis will require upgrading, within an overarching master plan. Better equipment to manage water levels at the lake and harbor will be necessary and in some areas, dikes will be the required part of the solution. Tunis will also need to invest in reinforcing existing drainage and sewage systems so that they can manage the more frequent extreme weather events. To address increasing pressures on limited water resources, a system for optimizing water uses and better managing consumption will be needed, including revised pricing policies.



Central Tunis, former and present industrial areas on the southern shore of the lake and the port of Rades have experienced significant subsidence as measured via satellite observation, raising risk levels. Source: ESA.



## INCORPORATING RISK REDUCTION IN THE PLANNING

Climate-smart planning is particularly relevant in the case of the Bouregreg Valley, since it is possible to mitigate many of the risks affecting the site before infrastructures are built and buildings erected. Broadly, the project is a high-end development of a quasi-virgin site, and therefore it is entirely possible to expect that a high level of protection be built into its plans from the start. The planned development envisions about 140,000 inhabitants and 90,000 new jobs—all to be located in an area vulnerable to natural disasters and climate-related risks. The project site is located at the estuary of the Bouregreg River, with a major dam behind it, the open sea in front, and two steep slopes on either side.

With some settlements planned for the mouth of the river, and other areas slated for construction currently vulnerable to flooding and landslides, the development could end up putting more people and assets at risk. However, the opportunity to adopt climate-resilient land-use policies and building designs creates the prospect of mitigating the risks significantly as part of the planning process.

### Urban Risk Assessment

Following are the risk assessments for the Bouregreg Valley for the current, pre-project scenario, as well as for the 2030 scenario:

- Flooding:** The Bouregreg Valley has been a flood-prone valley since time immemorial, and consequently has remained practically undeveloped. Since the construction of the Sidi Moulay Ben Abdellah dam, water flows are regulated and controlled, including at times when the dam capacity is attained and large volumes of water have to be released downstream. This currently happens with little hindrance to people or assets, but could become a major problem given on one side the expected increase in the frequency and intensity of extreme weather events, and on the other the land-use and construction plans for the Valley. The related risk rating would jump from the current low to very high for the 2030 scenario.

### Urban Risks Increase Over Time in All Urban Locations under the Study

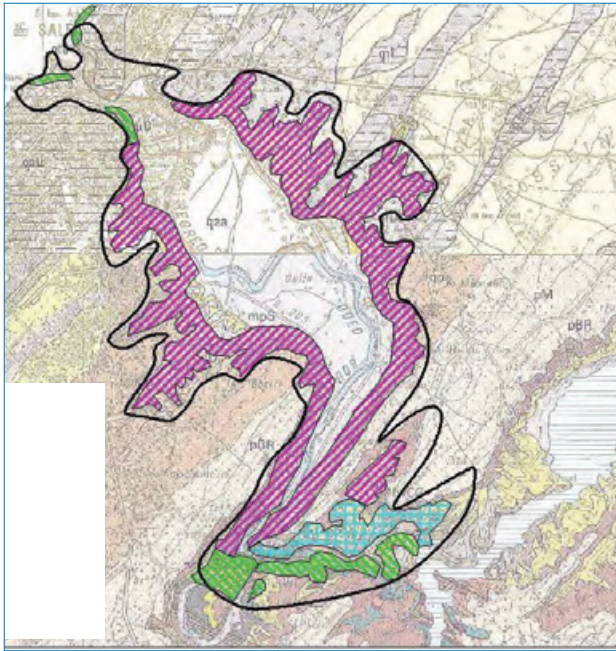
Urban Risks	Bouregreg Valley	
	Current	2030
Seismicity/ground instability/	Low	Medium
Tsunami/Marine submersion	Medium	High
Coastal Erosion	Medium	Low
Flooding	Low	Very High
Water Scarcity	Low	Medium

■ Very High   
 ■ High   
 ■ Medium   
 ■ Low



The Bouregreg Valley project, as envisioned in this map, represents one of the most substantial developments in North Africa, with 140,000 new inhabitants and 90,000 jobs expected in a site with high natural risks.

- Tsunamis and marine submersion:** Tsunamiic episodes have hit the Moroccan coastline in relatively recent times, however this risk is considered currently as medium on account of the low level of population and assets in the Valley. The same applies to marine submersion related to storm surges. Such risks become high by 2030 on account of the implementation of the project itself.
- Coastal erosion:** Current risks, rated medium, would be lessened to low by 2030, on account of the measures which have already been integrated into the development plan, and which include the construction of sea defences against beach and coastal erosion.
- Seismic risk and ground instability:** Two issues affect the Bouregreg Valley: on one hand



The valley is hemmed in by steep slopes, which are subject to landslides and rock slides. These would threaten buildings within the planned development. Risks could increase with climate change and more frequent torrential storms.

the low geological quality of the soils, which risk liquefaction and that thus amplify a relatively low seismic risk; on the other, the risk of landslides from the steep slopes surrounding the valley. Such risks are considered low on account of the current level of population and assets exposure, but are rated as medium for the 2030 scenario.

- **Water resources scarcity:** Water supply is subject to few pressures today, but water scarcity would be considered a medium risk by 2030, assuming current estimates of population and industrial growth. The development of the Bouregreg Valley could in itself contribute significantly to pressures on limited water sources for coastal Morocco.

## Adaptation and Resilience Responses

Data on low lying areas can help planners avoid locating populations and properties in parcels of land likely to be inundated during episodes of torrential



By 2030, marine submersion risks related to an exceptional 100-year storm would extend beyond the presently vulnerable areas indicated in blue to include additional areas indicated in red.



rains or floods. For other areas, structures can be designed to withstand the expected stresses. Buildings can be sited, adapted and reinforced in ways that would lessen the damage from natural disasters and extreme weather.

### Climate-smart Planning

The assessments necessarily reflect the dynamic nature of the various risks. For example, downstream from the Moulay Hassan bridge, there are significant flooding risks from weather events historically considered likely only once every century. Although precise adjustments do not exist, there is a broad understanding that under most climate change scenarios, episodes of extreme weather will happen more frequently, so that a 100-year event soon may be likely to occur as often as once every fifty years. Planning new infrastructures and buildings in the Bouregreg Valley should take into account such

changes, as well as the expectation that the sea level will rise by as much as 20 cm by 2030 and continue to rise.

Development plans will have to take into account water flows, ground absorption and drainage challenges in the areas most subject to flooding. Aspects of the current development plan raise concerns. For example, plans for the Kasbat Abu Raqraq area envision housing construction on part of a flood plain, with as many as 50,000 people potentially exposed to flood risks.

Overall, an audit and review of zoning, building and infrastructure plans for the Bouregreg Valley could lead to a series of project adjustments that could render the development far less vulnerable. Investing in climate-smart planning at this stage, before structures are in place, would surely generate significant savings over time.





To learn more about the study, download the full reports  
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