Metropolization and stormwater management in Casablanca city, Morocco

By Dalila Loudyi and Saâd Azzaoui

Casablanca city is the economic capital of Morocco. With its 4.36 million inhabitants, the city has known significant pressure in terms of housing and related necessary infrastructure and utility services. To take control over a looming informal urban sprawl, a Master Plan for Urban Development, which is referred to by the acronym SDAU from its French name Schéma Directeur d'Aménagement Urbain, has been released in 2009.
The Plan launched the metropolization phase of Casablanca and its neighborhood in order to frame an unprecedented urbanization dynamic. The SDAU planned to open 20,000 ha to urbanization by 2030, including the creation of seven new towns in the city vicinity.

Casablanca metropolization and stormwater management problems

The increasing demographic development and related housing demand led to an update of the SDAU in 2014 that opened an additional 5000 ha to urbanization. Since 2009, the development rate of serviced lands has ranged between 300 ha/year and 800 ha/year, which considerably increased the impervious surfaces to be drained towards outlets mainly located on the Atlantic shores. Moreover, a number of urban centers were developed around the city implementing real estate projects in a geographic scattered way leaving thus many wide undeveloped land gaps between new real estate projects and already urbanized areas (Figure 1).

This horizontal development was also combined with vertical development as several villa zones were turned into high building zones. Therefore, impervious surfaces have increased and the existing stormwater networks in these zones have become undersized. The risk of urban flooding in such areas has then become higher urging the water utility to reinforce the stormwater system in order to evacuate the increased stormwater flows towards natural outlets.

Additionally, land constraints weigh heavily on stormwater drainage in peripheral areas. Indeed, 63% of the retention basins solutions recommended by the Stormwater Master Plan, require the use of various land, located in areas planned for urbanization. Land use controls and cost in these areas hinder the feasibility of the proposed solutions.

Despite the efforts made to support urban development and reduce areas prone to overflow problems, both at operation and investment levels, several projects could not be carried out due to the lack of funding.

In order to overcome these constraints and adapt to changing factors, a dual approach was adopted to support the city development: it consists of carrying out new infrastructure projects identified within the framework of the Stormwater Master plan, along with a rain event management approach for optimizing the operation of existing networks and structures, particularly in areas with deficiencies.

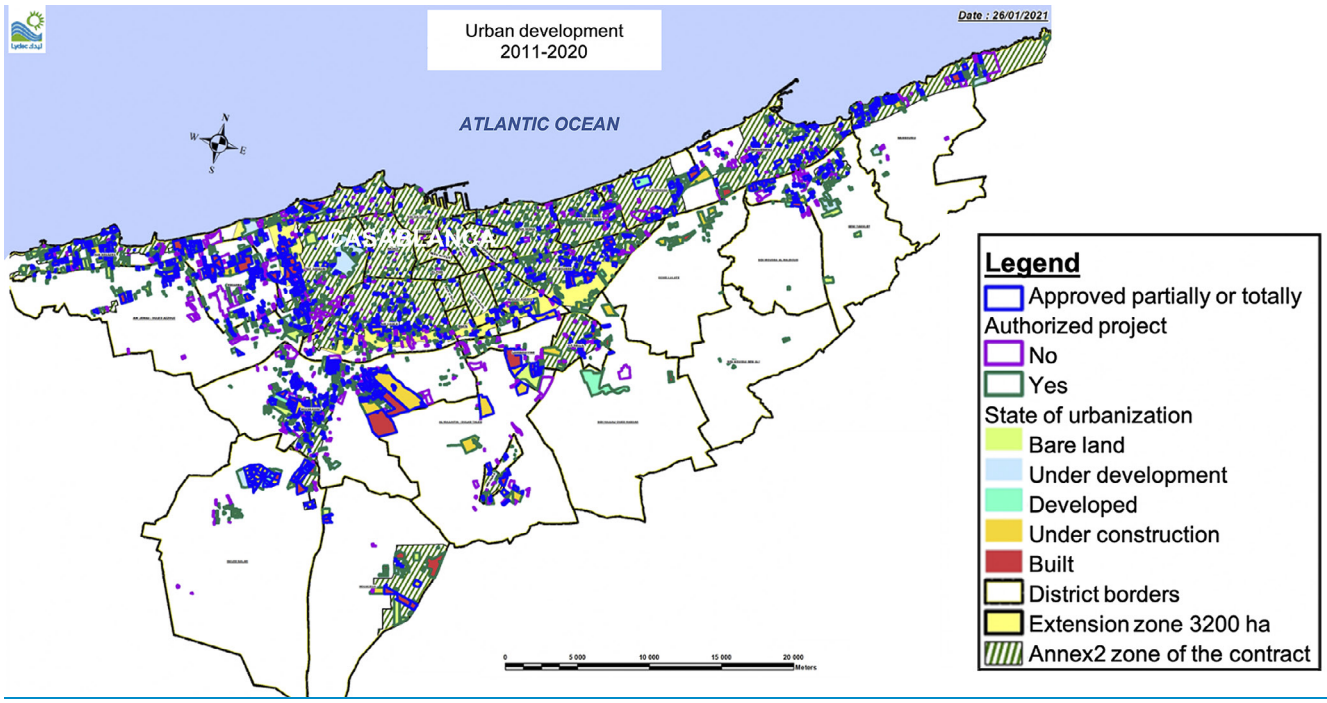

Figure 1 | Layout of real estate projects having submitted a sewer network connection request to Casablanca water utility LYDEC (2011-2020).

Urban Stormwater Master Plan measures to support the city metropolization

As part of the urban vision of Greater Casablanca drawn by the SDAU, the city water, sanitation and energy utility LYDEC, (a branch of SUEZ) produced an Urban Stormwater Master Plan (USMP) for extension zones in 2006, that was updated in 2011 in order to take into account new urban planning provisions. The main directives of the plan are new stormwater system development and runoff zoning.

1 | Stormwater system new development

Urban development of the city and its neighboring districts caused a population density increase and larger areas to be connected to sewer networks. Meeting this service demand requires both network extension and reinforcement.

A | Network extensions

• For the coastal extension zones located to the North of the axis formed by the urban highway, the Rabat-Casablanca highway to the East, and the National Road RN1 to the West where the discharge of rainwater towards the sea or few coastal wadis is possible without restricting the flow rate, a stormwater system based solely on the creation of collectors has been planned (**Figure 2**);

• For the extension zones located to the south of the Highway axis - RN1, the creation of storage basins will be necessary given the distance from the ocean and the inability of existing networks and wadis to accommodate the full flows generated by future zones open to urbanization. These basins will be emptied downstream into wadis or existing networks, infiltrating to the subsurface at a low rate (generally 1 l / s / ha), and sometimes by pumping when the topography requires it. The surface of the areas planned for urbanization within the scope of the SDAU can be estimated at nearly 25,000 hectares. The investments required for stormwater management of these extension areas have been summarily estimated at around 10.5 billion MAD excluding taxes.

B | Existing stormwater networks reinforcement

The USMP recommended the implementation of three large drainage culverts mainly because of their very low needs in terms of land mobilization and a better capacity to cope with odd rainfall events. These tunnels are (**Figure 3**):

• The SRO (System of Reinforcement of Western Casablanca): over a length of nearly 10 km, the SRO is designed to convey a ten-year peak flow of approximately 90 m³/s from the western basin of Casablanca to the Atlantic shores at the El Hank wastewater preliminary treatment station;

• The SRE (Reinforcement System of Eastern Casablanca): over a length of about 18 km, discharging into the sea at the point of Oukacha. This infrastructure is designed to evacuate a ten-year peak flow estimated at around 125 m³/s from the eastern basin of Casablanca;

• The SRM (Reinforcement System of Mohammedia city) allowing to evacuate a ten-year peak flow of around 25 m³/s.

These three reinforcement tunnel systems are supplemented by several local reinforcement storm sewer pipes operating as independent "local" reinforcement solutions.

The investments required for the implementation of the SRE, SRO, SRM reinforcement systems, including local reinforcement solutions has been summarily estimated at around 3.6 billion MAD excluding taxes.

Figure 4 shows part of the SRO stormwater drainage tunnel under El Jadida road in the south western part of Casablanca. The tunnel has a 3 m diameter and a length of 3.3 km.

Figure 5 shows the construction of the drainage well of the Hay Sadri neighborhood stormwater tunnel, part of the SRE system. The tunnel is at 40 m depth, and has 4 m diameter and 1.4 km length. The two infrastructures have been operational since December 2021.

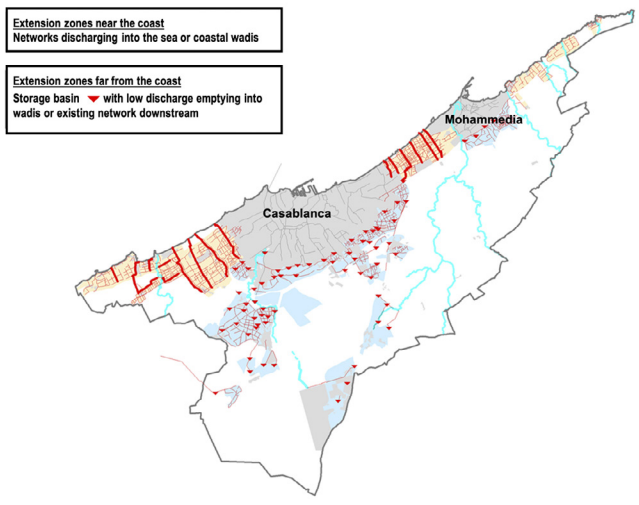

Figure 2 | Stormwater management provisions in extension zones.

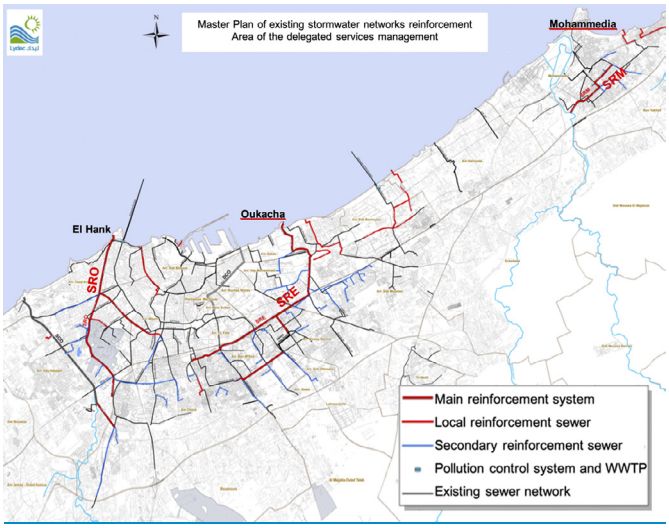

Figure 3 | Master Plan for reinforcing existing stormwater system in Casablanca and its neighboring municipalities.

Figure 4 | SRO stormwater drainage tunnel under *El Jadida* road in western Casablanca.

Figure 5 | A 4 m -diameter drainage well of the *Hay Sadri* neighborhood stormwater tunnel, part of the SRE system in eastern Casablanca.

2 | Runoff zoning

In order to update the USMP, an independent expert assessment was carried out for the implemented solutions for stormwater drainage, that aimed also at recommending optimal new measures within the boundaries of delegated management of the new extension zones. This study adopted a participatory and concerted approach between the various stormwater management stakeholders including the Ministry of the Interior, delegating Authority, municipalities, prefectures and provinces, the Urban Agency of Casablanca, the regional council of Casablanca –Settat, the River Basin Agency of Bouregreg and Chaouia, the water utility LYDEC and the National Meteorology Directorate.

Analysis of the various technical, urban and environmental constraints, the latest implemented developments, the projects in progress and the difficulties encountered during the completion of a number of solutions provided in the USMP, reconfirmed the need to use alternative infiltration and retention techniques upstream, establishing sectorial, integrated and multifunctional retention basins within the peripheral extension zones. These solutions should consider optimizing the drainage flow rates of the stormwater basins taking into account the capacity of the wadis and existing downstream networks. A runoff zoning study will then be carried out in order to:

- Differentiate between stormwater management systems and techniques according to each sector of Casablanca and its neighboring municipalities
- Adapt management methods according to the vulnerability of neighborhoods and the challenges of sustainable development
- Stormwater management rules adapted to each sub-basin
- Identify low-lying areas unsuitable for urbanization
- Integrate the water cycle in urban development decision making process.

Stormwater systems and infrastructures operational measures

The management of rainfall extreme events by the water utility in Casablanca and its neighboring districts, namely LYDEC, is carried out mainly through three type of actions that are preventive operations, mitigation/crisis management measures and Return on Experience (REX) or lesson learned/ postmortem documentation.

1 | Preventive measures

Flood preventive measures are based on the knowledge of flood risk-prone areas that are identified through a review of operational actions carried out by LYDEC. These measures concern the preventive cleaning of networks and checking the availability of operation equipment such as rain gauges, sensors, screens, pumps, etc., prior to each rainfall period. Furthermore, meetings with external services are organized and campaigns are deployed among the population for raising awareness with regard to the risk of clogging of different structures and its impact on the performance of stormwater systems in protecting against urban flooding.

2 | Flood mitigation and crisis management

The management of a major rain event requires a significant emergency response that depends on the "reaction time", which is the main element of management success. This requires precise knowledge of the flooding extent, related damages and the resources that can be mobilized by zone. Coordination plans are established at the district level to direct response teams to the most affected areas.

3 | Return on Experience (REX): flood events - networks modeling and improvement of hydraulic model calibration

As a final step in the management of flood events, the Return on Experience (REX) seeks to draw conclusions on the consequences of the flooding, to measure related human and economic impacts, and mostly to analyze the relevance of the means deployed during the crisis management phase. The REX step makes it possible to build and improve policies for flood risk control by achieving two main tasks:

– Summary of REX from field teams: Series of meetings are organized to collect and analyze observation data on overflows at the level of each district's zone. Overflow points maps are updated. The causes and impacts of each black point are analyzed and sketches of solutions are thus drawn up in collaboration with the operation teams. The main collected parameters are rain events characteristics (duration, intensities, return period, etc.);

flood zones and extents (flooded area, cause of the overflow, duration of the flood, etc.); solutions development (temporary solution, final solution, etc.) and required sectorial analyses for updating the stormwater master plan and the urban development master plan if necessary.

– Sewer networks modeling: Based on data of flow measurements, recorded rainfall and field observations, simulations of the events that have occurred are carried out to diagnose the networks and identify the causes of overflows (e.g., hydraulic deficiencies, operating problems, runoff, etc.). Comparison of on-site observations with the simulation models for several rainy events makes it possible on the one hand to refine the nature of observed dysfunctions, but also to improve the quality of the models taking into account urban development in the city and its neighboring areas.

4 | Towards dynamic management of Casablanca stormwater system: Interactions between the three components of the "Prevention-Mitigation/Management, and REX" process result in a cycle of continuous improvement of strategies, policies and means to prevent, manage and draw important lessons for future extreme rainfall events. In order to have greater capacity for analyzing network data in real time at the scale of the utility delegated management area, LYDEC uses the AQUADVANCED software, developed by SUEZ Environment. It is a modular software that provides a global view of real time network performance, while facilitating rapid and cross-analysis of any type of technical, asset or customer data. The AQUADVANCED tool is used to achieve the following tasks:

- Statistical analyses of rainy events
- Monitoring of main pipes: transit flows and filling rates
- Wastewater treatment plant: volumes of water treated, discharged, stored, etc.
- Stormwater weirs: Volumes discharged during rain event and in dry weather
- Storm basin: Max volume, filling rate
- Pumping stations: number of pumps in operation, maximum water levels reached.

By combining the results of hydraulic simulations, field findings and measurement data, the various forms of stormwater system deficiencies are analyzed to define areas for improving measures to control and manage flood risks. Such measures include adaptation of means and approaches to manage overflow areas; monitoring equipment to be added for completing data collection on AQUADVANCED models and updates of the final solutions provided by the stormwater master plan taking into account future urban development.

Recommendations

A more sustainable vision for the implementation and management of urban stormwater systems is becoming possible through an integrated approach involving all stakeholders. The objective is to find the right balance between urban development and the mobilization of investments while ensuring the safety of people and goods. Achieving such objective strongly relies on:

- Establishing appropriate financing modalities that enable building infrastructure while paying the related financial costs;
- Optimizing urban planning through provision of land and necessary easements for implementing infrastructures;
- Adopting alternative integrated resource management techniques to support urban development while limiting the impacts on existing networks downstream.

Low-lying areas are highly vulnerable to flooding. Therefore, it is recommended to reduce population density and limit compact urbanization in these areas, along with providing flood resilient infrastructure such as gardens, sports fields and playgrounds. Such infrastructures would operate as temporary retention areas during extreme rain events that exceed the capacity of stormwater networks, avoiding any negative impacts on local people. A large percentage of Africa's urban population lives in coastal cities and are facing climate change impacts particularly extreme rainfall events. Casablanca's stormwater management could serve as an example of good flood control practices for many coastal cities in Africa with similar climate and urbanization conditions (e.g., Abidjan, Dakar, Freetown, Lagos, Accra).

Dalila Loudyi

Dalila Loudyi is a Professor at the department of Water and Environmental Engineering at the Faculty of Science and Technology of Hassan II University of Casablanca since 1996. In 1995, she graduated from Mohammedia School of engineers, in Rabat, Morocco and got her PhD in environmental water management at Cardiff school of engineering in the United Kingdom in 2005. Prof. Loudyi was selected by the Moroccan ministry of higher education as a National Contact Point in environment, in 2010, to promote the use of the Seventh European Framework Program (FP7) for research and development at a national level. She was the IAHR council member for MENA/India Subcontinent region during 2019-2021 period and currently a council member of LYDEC (SUEZ-Casablanca) Foundation.

Saâd Azzaoui

Mr Saâd Azzaoui is the Director of operations and works supervision at LYDEC (SUEZ branch in Casablanca, Morocco), Chairman of the SUEZ Asset Management Technical Committee and 'The City of Tomorrow' company's project manager. Graduated in Environmental Engineering and Regional Planning from Agro Paris Tech, he also holds a Master's degree in Development Projects Management from Agropolis Montpellier, France. Mr Azzaoui participated in the technical negotiations for the revision of LYDEC's delegated management contract from 2005 to 2009, as well as in technical exchanges for the preparation of the new Master Plan for Greater Casablanca with the Urban Agency of Casablanca and the Institute of Urban Planning of the Ile de France Region in 2008 and 2009.