

FLOOD RISK ASSESSMENT AND PRIORITIZATION OF HYBRID INFRASTRUCTURE FOR FLOOD RISK REDUCTION IN THE TOCUMEN RIVER BASIN IN PANAMA CITY

Executive summary

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THE TOCUMEN RIVER CATCHMENT

Located on the eastern edge of Panama City, the Tocumen River basin contains some of Panama's key transport infrastructure, including the Tocumen International Airport, the Pan-American Highway and the newly built Line 2 of the city's Metro system.

Over the recent decades, the Tocumen catchment has undergone a process of rapid urbanization, with its population expanding from just 2,088 in 1960 to 114,425 in 2010 in a total surface area of 63 Km². With that urban growth has come a loss of natural land cover and degradation of the remaining undeveloped areas, including habitats that are important for regulation of water resources, floods and water quality.

PANAMA CANAL

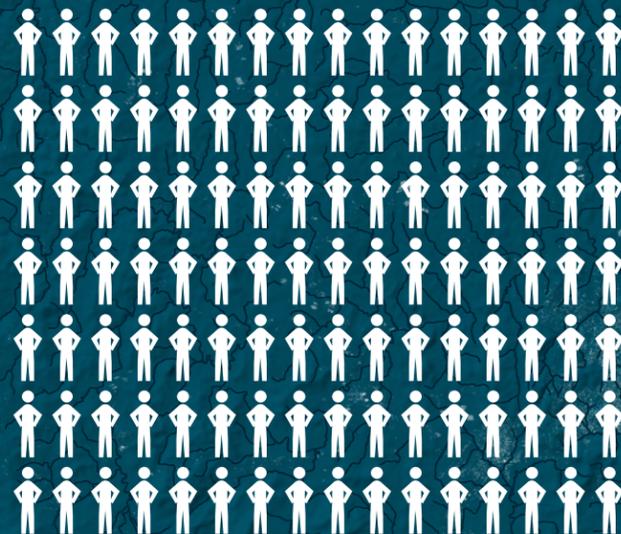
Panama City

Tocumen River catchment

Tocumen International Airport

Mangrove

2,088
habitants
1960



114,425
habitants
2015



Upper catchment

Deforestation and urban expansion into the steep-sloped forested headwaters of the upper catchment has led to increased velocity and runoff volumes during storm events.

Forest and other land covers

Urban area

Tocumen International Airport

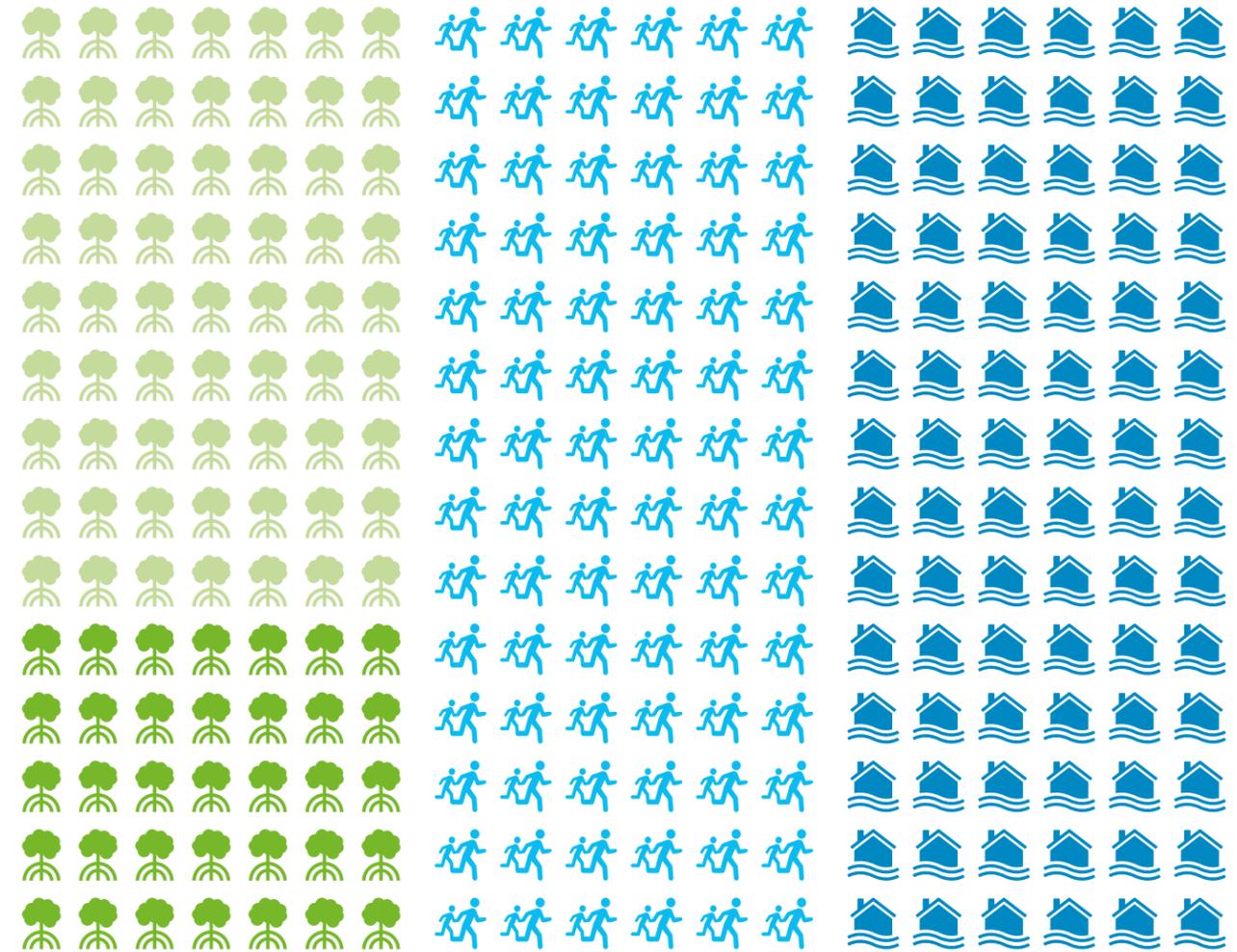
Mangrove

Middle catchment

Canalization of the river channel, coupled with a loss of connectivity between the river and the floodplain due to urbanization in the middle catchment, has resulted in both a loss of space for storing flood water and in degraded riverine habitats.

Lower catchment

Rapid loss of wetlands has led to increased coastal erosion and a significant loss of space for regulation of high river and tidal water levels.



90
ha 2000

37
ha 2015

13,021
people affected

3,209
homes affected

Mangrove loss is of particular concern, with a rapid decline from 90 hectares in 2000 to 37 hectares in 2015. This pattern mirrors the loss of coastal wetlands observed in earlier phases of urban expansion onto the coastal plain to the west, in the area known as Costa del Este.

The degradation of ecosystems, along with urban expansion within the floodplains, has led to an increase in both the frequency of flood hazards as well as the number of people, buildings, businesses and infrastructure exposed to floods. In particular, patterns of land occupation, characterized by construction of new developments in increasingly higher landfills, has significantly influenced the frequency and impact of floods. According to the DesInventar database of historical records, between 1990 and 2018 there were eight deaths, 13,021 people and 3,209 homes directly affected by floods in this catchment.



View of Panama City and mangroves of Panamá Viejo.
©Juliana Castaño-Isaza

Whilst there has been a serious loss of ecosystems and their associated services in the Tocumen catchment, significant natural areas do remain. As such, the catchment is at a crossroads, where decisions on planning and land use made now will have long-lasting impacts on natural systems, flood risk and sustainability of development. Policy makers must consider whether the natural environment continues to be lost and degraded, with the associated increase in flood risk, or alternatively, whether the benefits of natural areas within the urban catchment are recognized, valued, protected and enhanced.

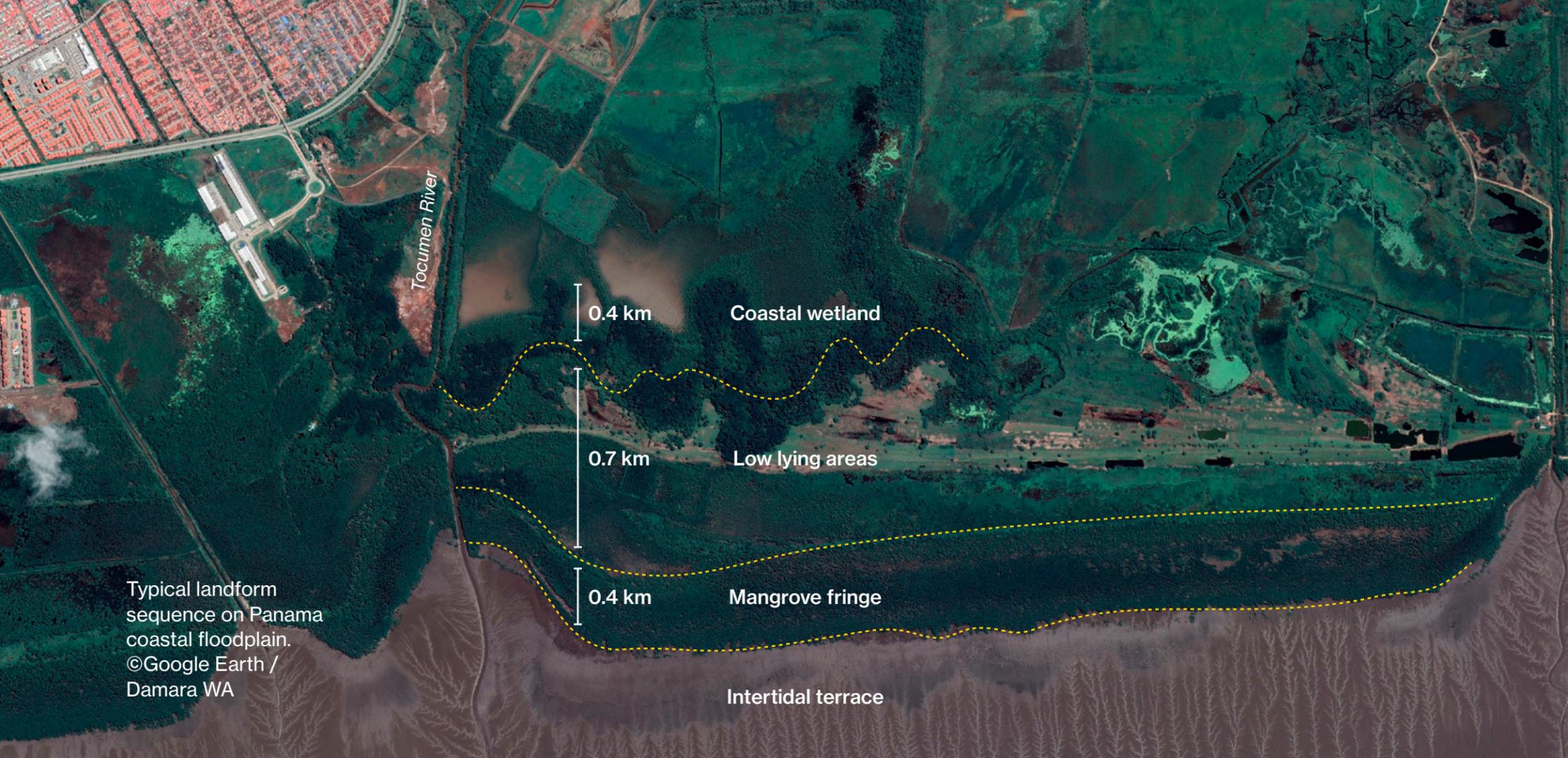
THE STUDY

This study has been undertaken as part of the broader initiative of the Panama City Waterfront Redevelopment and Resilience Program of the World Bank. The study aims to support Panama City to materialize the visions of the SEA (Coastal System of Open Spaces) initiative of the Municipality of Panama, in this case for the Tocumen watershed and its coastline.

The project aims to further support efforts to mainstream the implementation of Nature Based Solutions (NBS), in line with publications such as *Implementing Nature-Based Flood Protection: Principles and Implementation Guidance* (van Wesenbeeck et al, 2017) and *Managing Coasts with Natural Solutions* (Beck, M.W. and G-M Lange, 2016).

The overall objective of this study was to evaluate flood hazard and risk in the Tocumen catchment, considering both present-day and future risks, and to assess the potential of natural solutions, such as mangroves and riparian vegetation, and hybrid solutions, such as mixed green, grey, structural and non-structural interventions, for contributing to flood risk resilience.

Site visit with stakeholders.
©HQ Studio / The World Bank



Baseline flood hazard and risk assessment

The hydrological and hydrodynamic models were brought together to assess the frequency and extents of flood hazard from the interaction of fluvial, pluvial and tidal sources. Flood risks to people, property, infrastructure and the natural environment were assessed. This work built upon a detailed exposure database prepared by the Urban Risk Center (URC).

Evaluation of the potential for Nature Based Solutions

Building on the understanding of the coastal systems, the study further evaluated how mangroves may be incorporated into a suite of mitigation measures available for long-term management of coastal hazards along the Panama City and Tocumen coasts. Similarly, the potential for restoration and enhancement of the channels and floodplains of the Tocumen and Tapia rivers was considered, with two areas being identified as suitable for floodplain restoration.

HOW WAS THE STUDY CARRIED OUT?

 The study involved several phases of technical evaluations, in addition to the coordinated work among consulting firms and World Bank experts:

Appraisal of the coastal and riverine systems

The work commenced with a desktop study, supported by site visits that were conducted over two missions by the consulting team. The goal of this phase was to characterize the coastal

conditions within the Bay of Panama, and the relationship between coastal geomorphological processes and the mangroves. Change in coastal form and the extents of mangroves over time were also mapped.

Similarly, the geomorphology of the Tocumen River and its tributaries the Tapia and Tagarete were characterized, with an assessment of change over recent decades.

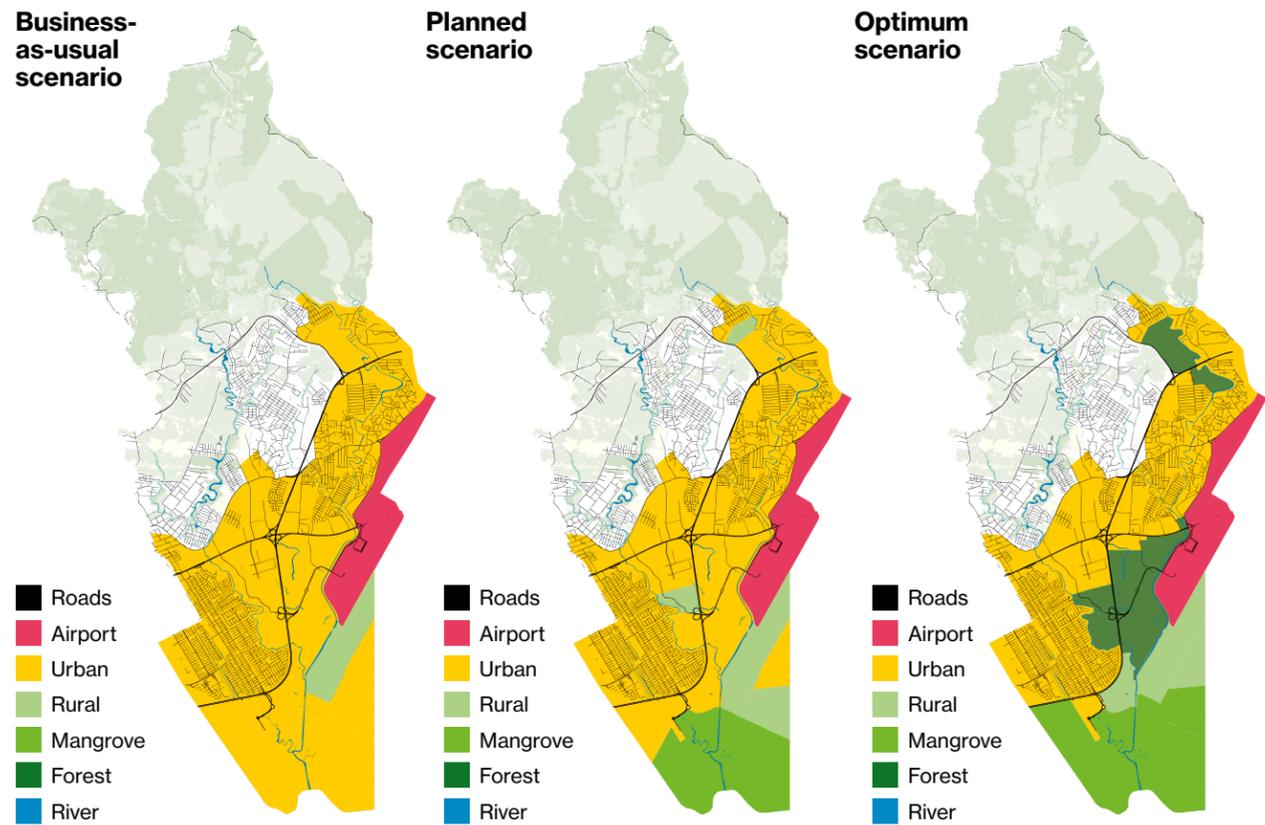
Flood hazard modelling

Hydrological and hydrodynamic models were generated of the Tocumen River, its tributaries and the middle and lower catchments to support the evaluation of flood risk in the study area and potential natural and hybrid solutions.

For the hydrodynamic model of the Tocumen River, a series of flood events were simulated with return periods between 1 in 1 year and 1 in 1,000 years, representing flooding from pluvial, fluvial and tidal sources. The study included the development of locally-specific design rainfall, rainfall-runoff estimates for the upper catchments and extreme sea-level and design tides for the coastal boundary.

Stakeholder engagement

The study included a joint review of the draft findings through a stakeholder workshop, which focused on validating a set of future scenarios from the perspective of flood risk and mitigation measures. Key stakeholders included the Tocumen Airport, the Municipality of Panama, BlueSky International, GeoMap, SINAPROC, Smithsonian Tropical Research Institute, the World Bank, Urban Risk Center and Wetlands International.



Future scenarios

Following the workshop, three potential future development scenarios were identified, evaluating the implications that these different options might have on flood risk, projected to the year 2050. The scenarios considered potential changes in land-use planning, levels of degradation or enhancement of natural habitats, urban drainage practices and climate change. These identified scenarios are described as follows:

Business-as-usual scenario

A scenario that represents continuation of business-as-usual in terms of continued urban expansion, degradation of the natural environment and highly vulnerable development in areas at risk of flooding.

Planned scenario

An intermediate scenario based on implementation of the plans and policies of the draft Local Plan (*Plan Distrital*).

Optimum scenario

A scenario based on a challenging but achievable application of good practice in terms of territorial and coastal planning, environmental protection and restoration, and urban design; i.e. a scenario in which urban development is managed to the benefit of all people while the limits of ecological systems are respected and protected.



Mangrove deforestation in Costa del Este as an example of the processes and impacts of the business-as-usual scenario in the coastal areas of Panama City. ©Smithsonian Tropical Research Institute

KEY FINDINGS AND RECOMMENDATIONS

Following the above work phases and associated analysis, the key findings for the study are highlighted below. These have been developed with consideration of key stakeholder groups involved in the process and with interests in the basin.

For spatial planners



Continuation of the recent development pattern along the city's coastal floodplain, involving mangrove landfilling prior to urban expansion, would substantially raise flood risks in the Tocumen catchment; most notably to the Tocumen International Airport and the neighboring community of Don Bosco.



Strict implementation of the land-use zoning proposed within the Plan Distrital would mitigate against the most damaging impacts of development by preventing further development within the wetlands. This prevention of urban expansion over the wetlands should be considered as a minimum requirement in order to manage flood risk and meet obligations to protect the Ramsar site.



Going beyond what is currently foreseen in the Plan Distrital, the study has demonstrated the benefits, in terms of flood risk mitigation, of protecting and enhancing the remaining mangroves and coastal wetlands, as well as utilizing areas of currently undeveloped floodplains in the Tocumen River to make space for water storage during flood events.



Financing mechanisms with the private sector may contribute to funding Nature-Based Solutions (NBS), including application of user fees to access protected areas, for-profit investments and income from commercial activities.

For coastal and river basin managers and engineers



In already highly developed coastal areas, the main benefits associated with mangroves are the mitigation of coastal erosion and the reduction of wave runup. Consequently, high land and infrastructure values provide a strong imperative for protection. For less developed areas, the main potential role for mangroves is to reduce the risks from coastal and riverine flooding.



Protection and enhancement of the mangroves has the potential to contribute to mitigating the risks of flooding and coastal erosion that will be faced in urbanized areas. However, mangroves on their own are not a complete solution, and providing adequate resilience against flooding and climate change will require a hybrid approach that combines NBS and other forms of mitigation, i.e. structural engineering solutions.



Mangroves cannot be protected in isolation; their future health is also dependent upon good coastal planning and proper water management throughout the catchment.



The study results show that the Don Bosco community, north of Corredor Sur, is exposed to particularly significant flood risks due to a



combination of rapid surface water runoff, very high coverage of impermeable surfaces, and restricted surface water discharge as a result of the construction of Corredor Sur and the landfilling of mangroves to the south of the Highway. This area should be considered a priority for local detailing of the modelling to include drainage asset data.



Canalized section of the Tocumen River in the lower catchment.
©GeoMap

For disaster risk managers and emergency responders



Present-day flood risks in the study area have been estimated to include:

- ★ Annual average damages to buildings due to flooding in the order of \$4.5 million dollars (in a 1-10 return period) to 8 million dollars (in 1-100 return period).
- ★ 3,500 people directly impacted annually by flooding to their homes, rising to 9,100 in a 1 in 100-year event.
- ★ Seven educational establishments and one fire station identified as at risk.
- ★ In a business-as-usual scenario, with continuation of the development pattern along the city's coastal

floodplain, total annual losses are estimated to increment by 750% by the year 2050 due to flooding (factoring climate change).

★ The outputs of this study should be made available to key stakeholder organizations, in particular those tasked with responding to flood events including SINAPROC, the Municipality, the Police and the Fire Brigade. In particular, this information can contribute to improving knowledge of risk and to the planning of concrete actions to reduce flood risk in the basin. The information has already been used to inform the Municipal Disaster Risk Management Plan recently drafted by the Municipality of Panama.

★ It is recommended that gauges or flow meters are installed along the main rivers in order to record flow and level data. This information will be useful not only for calibration of models in the future but also to build automated forecasting and flood warning systems.

★ Limitations have been identified in the vulnerability curves applied in this study. Further work is recommended to develop an appropriate set of vulnerability curves for the Central America region that consider a wider range of building types and take into account the impacts of velocity as well as depth.

For developers, architects and drainage engineers



★ In Panama City, landfilling of floodplains and coastal wetlands is a common practice prior to land development. This situation is removing space for water runoff and consequently increasing flood risk, particularly to existing low-lying communities and infrastructure.

★ Early engagement with existing landowners, potential developers and urban planners will be essential to develop plans for the two floodplain restoration sites proposed. These can encompass a mix of sustainably built areas and green spaces providing opportunities for flood management, biodiversity enhancement, recreation and sustainable transport routes.

★ The recommendations of the Municipality of Panama and Wetlands International in the Water Dialogues (Diálogos del Agua) regarding changes to urban drainage design standards have the potential to improve the management of surface water from newly developed and redeveloped sites.

★ The application of Sustainable Drainage Systems or NBS in Panama City is still in an initial stage of development. A successful

pathway to implementing NBS in urban design will require a combination of regulatory change, development of design guidelines specific to the needs of Panama, and capacity building amongst planners, landscape architects, architects, engineers and ultimately end users.

For ecologists, environmental managers and environmentalists



★ It is important to review the development proposals within and around the Tocumen International Airport that may have negative impacts on the remaining mangroves within the Tocumen catchment, in light of the strategic role they play in reducing flood risk.

★ This study focuses on the benefits of Nature Based Solutions for flood risk mitigation. In order to present a viable case for investment in such solutions, the benefits of flood protection should be considered alongside the benefits related to biodiversity, fishery, recreation, education, and air and water quality.

★ The proposed floodplain restoration measures would require careful consideration and planning, both to maximize their potential benefits and to prevent damage to existing flora and fauna. The next stage of assessment for these floodplain areas should consider the inclusion of an ecological appraisal including site visits, topographic surveys that include mapping of existing natural and built assets, and further hydrodynamic modelling.

★ Currently, opportunities for the public to visit, enjoy and learn about mangroves are very limited within the city. However, Panama City's Waterfront Conceptual Plan proposes a low impact visitor access into the Tocumen mangroves and provides a strong opportunity for public recreation and education, linked to the restoration and enhancement measures for the Tocumen mangroves.

For Tocumen International Airport



★ The realigned channel of the Tocumen River around the airport was designed to convey the flow of 1-in-100-year events. The model results indicate that the channel currently meets this standard of protection.

★ However, under future conditions of higher sea-level and increased rainfall intensity as a result of climate change, it is expected that channel capacity will be exceeded and fluvial and surface water flooding will be produced around the terminal buildings.

★ Several development proposals predict urban expansion around the southern end of the airport. Based on recent and current development practices, this is expected to be preceded by landfilling of low-lying areas, which are usually mangroves. The catchment-scale modelling in this study indicates that such development could pose a very substantial risk to the airport's operations, including flooding on the southern end of the runway. By contrast, protection and enhancement of mangroves and floodplains have the potential to mitigate against the impacts of further planned urbanization in the catchment.

★ As one of the country's key economic assets, disruption of the airport's operations as a result of flooding could have severe direct and indirect economic consequences. Any proposals for development within the mangrove area to the south of the airport, including expansion of the airport itself, should be considered as potentially high risk to both the natural environment and the airport's operations.

★ It is important to note that, for this catchment-scale study, simplistic assumptions have been made about the capacity of the airport's drainage systems, the potential for storage within the airport perimeter, and the ability of the airport drainage to effectively discharge at all tidal conditions. It is recommended that a detailed assessment be undertaken of the existing and future airport drainage following its expansion, which includes a new runway.

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