Baseline Assessment – Krong Kratié / Cambodia

Towards a Sustainable and Water-Sensitive Krong Kratié, Cambodia.

Baseline Assessment

Findings and Strategy Development

September 2023

POLYURBAN WATERS

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Towards a Sustainable and Water Sensitive Krong Kratié, Cambodia

Polycentric Approaches for the Management of Urban Waters

Baseline Assessment

September 2023

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Kratié, Cambodia

Location:
Northeast Cambodia, Kratié Province

Population (2020):
31,843

Municipal Area (Krong Kratié) :
5 Sangkats (Kra Kor, Kratié, Roka Kandal, O'Russey, Koh Trong)

Figure 1. Location of Krong Kratié and Kratié Province (Source: Own work, 2020)

Executive Summary

Major Findings

Krong Kratié serves as a representative example of water-challenged cities in Cambodia, where 19 out of 31 cities face similar urban development issues.

Kratié is faced with several challenges in its urban development. After thirty years of steady growth and infrastructure development, the capital of Kratié Province is tasked with redefining its urban role in line with the economic and social developments occurring across Cambodia.

In the context of regional integration and economic development, most of Cambodia's provincial capitals are undergoing a comprehensive urban transformation.

- With accelerated market integration in the region, domestic and foreign direct investments, job creation, migration from rural areas, infrastructure development, tourism and new urban lifestyles, the characteristics and functions of these secondary cities are rapidly changing.
- Securing water-related basic needs services such as water supply and wastewater management or flood protection is a complex task not only in the context of dynamic urbanization but also in the context of climate change.
- At the same time, only to a limited extent have urban and infrastructure development so far followed urban planning guidelines that are adequate to the complexity of the challenges and problems of cities that are considered secondary and tertiary.

For Krong Kratié to harness its potential mainly in transportation, agriculture, mining, and tourism, it requires urban development that enhances livability and quality of life for its inhabitants, while also presenting itself as an attractive location for businesses and a city that ensures good livelihoods for its communities. Capitalizing on its rich biodiversity is strategic for realizing its tourism potential while contributing to improving the livability of the 'Krong' for its residents.

This base-line assessment indicates that achieving such urban modernization while aligning with the development goals of the legislative guidelines, such as the National Strategic Development Plan 2019 to 2023, necessitates an urban development approach tailored to Krong Kratié's unique natural, economic, and social traits and challenges.

The management of urban waters poses significant challenges to Krong Kratié's modernization efforts:

1) Krong Kratié's location on the Mekong River and its elongated riverbank geography result in regular flooding of extensive parts of the existing urban area and the area intended for future urban development. The area's vulnerability to hazardous flood events might increase due to upstream developmental changes, climate change impacts, land use alterations, especially in the area around Krong Kratié's Lake Area[1], and inadequately developed infrastructure.

2) While urban planning guidelines exist, their implementation is limited presenting challenges to urban development. The existing master plan 2030 is relatively schematic and insufficiently addresses water-sensitive parameters, such as flood protection, drainage, open space development, and climate change adaptation.

3) Krong Kratié still falls short of comprehensive coverage of infrastructure development and comprehensive basic needs services. Significant improvement, such as water supply, drainage, sewage, waste management, and the development of green infrastructure are crucial for enhancing the livability and attractiveness of the city.

4) Decision-makers have acknowledged significant deficiencies in stormwater and sewage management in comparison to current urban development standards. The downtown area primarily relies on infrastructure

1 This term refers to the Boeungs – lakes and / or wetlands that are situated close to the urban centre, specifically Boeung Romleach [Meleach] and Boeung Kbal Dun Soun [Koko Nimol]. The term Lake Area in this document refers to these areas relatively close to the urban centre.

developed during the colonial era for drainage, and untreated sewage mostly flows into and around Krong Kratié's Lake Area. This prompts concerns among residents as to the effects on public health and the environment as urbanization progresses. More efficient infrastructure for stormwater and sewage management is under technical and financial planning. However, questions remain about the long-term financial sustainability, maintenance, operation, and coverage of the entire urban area.

5) Krong Kratié lacks well-developed green spaces and green infrastructure. The riverside, Promenade (Preah Soramarith Quay), while lined with trees, primarily serves as a public gathering and leisure space for the local population. Urban greenery is mainly restricted to private and public building plots, which are facing increasing pressure due to building densification. Overall, there is a lack of green public spaces, which are vital for a pleasant urban climate, the development of an urban society, and high-quality tourism.

6) Increasing urban sealing and densification are likely to intensify 'urban-heat islands', especially given the current increase in average temperatures due to climate change, and the lack of well-developed private and public urban green spaces. The so-called heat-island effect could be further amplified by unplanned filling of the wetland area, which currently serves as a natural cooling system.

7) Urban development planning and decision-making have only just started to acknowledge the value of so-called wetlands for sustainable urbanization, infrastructure development, and Kratié's economic and social development. Boeung Romleach, in particular, functions as a catchment basin for floods from the Mekong River during the wet season. Poorly controlled urban development that impedes the flow regime, coupled with inadequate infrastructure development and significant reduction in catchment capacity, could greatly increase the city's vulnerability to hazardous flood events. Increasing pollution from sewage and agricultural runoff and land use changes are exerting increasing pressure on ecosystems. These ecosystems, with their services for water quality preservation and biodiversity, are essential for the livelihoods of communities and potential tourism development.

8) The province of Kratié is predominantly agricultural. Even within Krong Kratié, large segments of the communities have a relatively low income level, making them particularly susceptible to economic crises and climate change impacts. These are also key benchmarks for Krong Kratié's economic and urban development planning. Without better understanding of the value of such ecosystems to local communities, significant changes in the flow regime or reductions in inflows to the Boeungs (lake and/or wetlands) could have considerable negative impacts on community livelihoods.

9) A key challenge is to win over communities in urban and peri-urban areas and investors for sustainable urban modernization. The sustainable financial viability of water-related basic needs services depends to a large extent on the substantial participation of users, who in turn make their willingness to pay highly dependent on the reliability of the service. This will not be possible without robust business models on the part of the operators. To varying extents, communities in the peri-urban areas practice livelihoods that still manage and depend on natural resources. Any urban greening strategy or sustainable tourism destination development will need to recognize and build on these capacities.

10) As exemplified by other Krong in Cambodia (secondary and tertiary towns or cities), for example Siem Reap, despite Cambodia's decentralization policy, comprehensive urban and infrastructural modernization—especially in terms of water-sensitive and green urban development—is heavily reliant on decision-making and resource allocation at the national government level. However, city and provincial governments still have significant scope to implement low-threshold, proactive measures, such as preventing construction activities in flood-sensitive urban areas or unchecked land sealing.

Strategic Interventions:

Urban development planning: municipal and provincial government of Kratié should use "water" as a strategic element of its redefinition and modernization as a livable city, attractive tourism destination and a place to run successful businesses. Especially with regard to a balanced urban development, water is of strategic importance. Considering the extensive challenges, urban and development planning should transcend purely sector-specific planning, such as ensuring and enhancing efficient water supply or wastewater treatment, even though these sector-focused efforts remain important. The planning should adopt a more integrated approach, factoring in various interconnected elements for a more holistic development.

Flood management: the city should strengthen its resilience to hazardous flooding events. Although today it is still difficult to predict the expected extreme water levels as the Mekong Basin continues to develop and climate change occurs, the urban area should be prepared for extreme flooding. Planning and technical measures include securing the flow regime to the lake area and the implementation of an effective city-wide urban drainage system. Restricting the sealing of surface areas should mitigate stormwater run-off. In addition to the expansion of the Spean Sor / White Bridge Channel, which is already in the planning stage, sufficient flow through new development areas should be ensured and the water absorption capacity of the wetland area should be maintained. Here strong monitoring from the local government side is needed to avoid uncontrolled filling of the lake area.

Lake Area as a strategic asset for urban development: the Lake Area should be brought out of its perception as an underdeveloped area. It ought to be incorporated into urban planning and development initiatives, not only for its role in flood management, but also as a source of abundant biodiversity, a livelihood base for communities, and an essential natural cooling system for the urban climate. Additionally, its prospective significance as a leisure and tourism destination should be recognized and exploited. In order to develop the area strategically, an action plan is needed that ensures strong buy-in from local stakeholders.

Green urban development: To mitigate the degradation of the urban environment or the escalating heat in the urban climate, especially in the face of climate change, there should be a systematic enhancement of urban greenery to avoid the detrimental effects to the most vulnerable residents, such as children, the ill and infirm, and elderly. As evidenced by other Cambodian cities, well-developed urban green spaces integrated within a wider infrastructure framework, such as pedestrian-friendly street systems, contribute significantly to well-being and livability. Green infrastructure planning in addition to developing public green spaces, should also actively involve homeowners, communities, and investors ensuring a comprehensive engagement of both public and private stakeholders. This is especially needed because public financial and institutional capacities are very limited.

Water supply: The existing water supply networks of Krong Kratié, which predominantly cater to mainland residents, form a robust foundation for future development and enhancement but challenges to maintain a potable water quality persist. Uncertainties remain regarding the readiness of residents in underserved areas to pay for potential future connections, and the feasibility of network expansion into less populated areas. These considerations stem from the high operational costs, compounded by the need to minimize non-revenue water (NRW). A key strategic intervention is to establish connections to areas that still rely on wells, particularly given the probable contamination of groundwater.

Wastewater management: The viability of centralized wastewater treatment options for Krong Kratié, presently under consideration at the national level, must be demonstrated beyond just the initial financing costs, technical designs, and long-term maintenance and operation. There are pertinent questions, such as identifying the local level operator, that require answers. However, for the foreseeable future, major urban areas are unlikely to benefit from centralized systems. Decentralized system solutions should, therefore, be considered for these urban areas, and particularly for pollution hotspots, including the slaughterhouse and the referral hospital. The development of city sanitation plans for these respective areas could underpin such planning. Capacity building for local governmental entities is crucial to create these plans collaboratively with local stakeholders and to oversee their implementation.

Solid waste management: Two-thirds of Krong Kratié is already benefitting from a solid waste management (SWM) service despite inefficiencies in collections. However, while the current SWM service is challenged to manage the existing urban waste, plans are in place for a new landfill site that will adhere to higher management standards. With significantly improved waste separation at source and localized composting of organic waste, there is an opportunity to extend the lifespan of the new landfill by incorporating these methods. The systematic capacity building of local governments will help create a conducive environment for waste collectors, thus ensuring the financial sustainability of the entire waste management system. Comprehensive awareness campaigns, leveraging both traditional and digital media, will serve to educate the population and communities on the importance and benefits of waste separation and management at the household level.

List of Abbreviations and Acronyms

ADB	Asian Development Bank
AFD	Agence Française de Développement
BMBF	German Federal Ministry for Education and Research
BOD	Biochemical Oxygen Demand
CCCSP	Cambodia Climate Change Strategic Plan
CDB	Comune Database
CDIA	Cities Development Initiative for Asia
CIUS	Cambodian Institute of Urban Studies
COD	Chemical Oxygen Demand
CSDGs	Cambodian Sustainable Development Goals
CSO	Combined Sewer Overflows
DWQS	Drinking Water Quality Standard
EPI	Economic Potential Index
FDI	Foreign Direct Investment
FSM	Faecal Sludge Management
GDP	Gross domestic product
GGGI	Global Green Growth Institute
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GMS	Greater Mekong Sub-region
GMSCTDP	Fourth Greater Mekong Subregion Corridor Towns Development Project
HDPE	High-Density Polyethylene
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resource Management
Lao PDR	Lao People's Democratic Republic

LMB	**Lower Mekong Basin**
MoWRAM	**Ministry of Water Resources and Meteorology**
MPWT	**Ministry of Public Works and Transport**
MRC	**Mekong River Commission**
MSW	**Municipal Solid Waste**
NbS	**Nature-based Solutions**
NCSD	**National Council for Sustainable Development**
NDC	**Nationally Determined Contribution**
NRW	**Non-Revenue Water**
NSDP	**National Strategic Development Plan**
PAH	**Polycyclic Aromatic Hydrocarbons**
PUW	**Polycentric Management of Urban Waters**
RGC	**Royal Government of Cambodia**
SDGs	**Agenda for Sustainable Developments**
SNA	**Sub-National Administration**
SWM	**Solid Waste Management**
UNDRR	**United Nations Office for Disaster Risk Reduction**
UNFCCC	**United Nations Framework Convention on Climate Change**
USD	**United States Dollar**
VND	**Vietnamese dong**
VRG	**Vietnam Rubber Group**
WLE	**Water, Land and Ecosystems**
WSUD	**Water Sensitive Urban Design**
WSUG	**Water and Sanitation User Groups**
WWTP	**Waste Water Treatment Plant**

Terminology and Definitions

Adaptation: is the process of adjusting within natural or human systems to new or changing environments (MA, 2005). This multifaceted concept encompasses a range of approaches, including anticipatory and reactive strategies, both within private and public spheres, while also distinguishing between autonomous and planned methods (MA, 2005). In human systems, adaptation entails the process of responding to actual or anticipated climate changes and their impacts, with the aim of mitigating harm and harnessing potential benefits (IPCC, 2023). Similarly, in natural systems, adaptation refers to the adjustments made in response to existing climate conditions and their consequences, with potential facilitation by human intervention to address expected climate alterations and their effects (IPCC, 2023).

Adaptive capacity: The combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm and cope with consequences, or exploit beneficial opportunities (IPCC, 2012; MA, 2005).

Baseline/reference: The baseline (or reference) is the state against which change is measured. It might be a 'current baseline,' in which case it represents observable, present-day conditions. It might also be a 'future baseline,' which is a projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines (IPCC, 2012).

Catchment: An area that collects and drains surface run off (for example through precipitation or snowmelt) (IPCC, 201; EEA, n.d.) or the area of land bounded by watersheds draining into a river, basin or reservoir (EEA, n.d.)

Climate change: A change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2012).

Climate: in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (IPCC, 2023). In various chapters in this report different averaging periods, such as a period of 20 years, are also used.

Climate extreme (extreme weather or climate event): encompass occurrences when a weather or climate variable surpasses or falls below a defined threshold, typically situated towards the upper or lower limits of the observed range for that variable. These extremes can manifest differently across locations and may persist over time, like an entire season, leading to the classification of an extreme climate event. Notably, if the prolonged pattern results in a notably high or low average or total (e.g., extensive heat, prolonged drought, or heavy rainfall), it may be termed an extreme climate event. To simplify, both extreme weather and climate events are collectively referred to as climate extremes (IPCC, 2023).

Disaster management: Social processes for designing, implementing, and evaluating strategies, policies, and measures that promote and improve disaster preparedness, response, and recovery practices at different organizational and societal levels (IPCC, 2023).

Disaster risk: The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery (IPCC, 2023).

Drought: A period of abnormally dry weather long enough to cause a serious hydrological imbalance (IPCC, 2023).

Exposure: The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas that are thereby subject to potential losses (UNISDR, 2009).

Flood: The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods (IPCC, 2023).

Green Infrastructure: Strategically planned and intensively managed systems and networks of natural, semi-natural and man-made land-based features such as terrestrial protected areas, field margins in intensive agricultural land, ecoducts and tunnels for animals, parks, rain gardens, pearmeable pavements, trees and green roofs in cities (Lucius et .al, 2011). These systems or networks aim to capture and infiltrate rainfall at its soure, mitigating runoff and enhancing waterway health. It now predominantly aligns with cities' broader environmental and sustainability objectives, manifesting through diverse natural strategies (Fletcher et al., 2015). The GI concept not only influences urban planning by optimizing green space hubs and corridors but also seeks to identify and leverage the potential ecosystem services offered by these green spaces (Fletcher et al., 2015).

Green and Blue Infrastructure (or Blue-Green Infrastructure, or short: BGI): BGI, serving as a comprehensive framework, is closely interconnected with the notion of "Green Infrastructure" (Ghofrani et al., 2017). Blue-green networks comprise water-based 'blue' elements and vegetated 'green' elements, incorporating low-carbon, climate-resilient infrastructure and technologies. 'Blue' elements encompass water features like rivers, streams, storm-water drains, and wetlands, while 'green' components may include trees, parks, playgrounds, and forests. These networks span catchments and down to micro-catchments within urban blocks, aiming to recreate natural water cycles and enhance urban amenity through integrated water management and green infrastructure. The overarching objective is to preserve hydrologic and ecological values, offering adaptability to changing environmental conditions. In essence, Blue Green Infrastructure integrates water and vegetation systems to provide urban resilience and ecological benefits (Rowe & Hee, 2019).

Grey Infrastructure: This term is often used to oppose what is called “Green-blue (or natural) infrastructure”. It refers to any hard structure or traditional engineering solutions (UNEP, 2019) that is used to dispose rainwater.

Greywater: is the total volume of water generated from washing food, clothes and dishware, as well as from bathing, but not from toilets. It may contain traces of Excreta (e.g., from washing diapers) and, therefore, also pathogens. Greywater accounts for approximately 65% of the ***wastewater*** (see definition below) produced in households with flush toilets (IWA, 2016).

Hazard: : A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation ([UNDRR] United Nations Office for Disaster Risk Reduction, 2020).

Hydrological/water cycle: The cycle in which water evaporates from the ocean and the land surface, is carried over the Earth in atmospheric circulation as water vapour, condenses to form clouds, precipitates over the ocean and land as rain or snow, which on land can be intercepted by trees and vegetation, potentially accumulating as snow or ice, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams and, ultimately, flows into the oceans as rivers, polar glaciers and ice sheets, from which it will eventually evaporate again. The various systems involved in the hydrological cycle are usually referred to as hydrological systems (IPCC, 2023).

Land use: encompasses the entirety of arrangements, activities, and inputs applied to a specific land parcel. The term also extends to the societal and economic purposes guiding land management, including activities like grazing, timber extraction, conservation, and urban habitation. In national greenhouse gas (GHG) inventories, land use is categorized following the IPCC's land-use classifications, which include forest land, cropland, grassland, wetlands, settlements, and other lands (IPCC, 2023).

Land-use change: The transition from one land-use category to another involves a shift in land utilization. It's important to note that in certain scientific literature, land-use change encompasses alterations not only in land-use categories but also in land management practices (IPCC, 2023).

Nature-based solutions (NbS): have been defined as “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (IUCN, 2016). NbS are not intended to replace grey infrastructure and technical solutions but rather to integrate with them in order to form resilient combinations that adapt to complex systems and changing environments (Haase, 2015), (Bai, 2018) recommends applying a “kaleidoscope” approach when working with NbS. An approach that connects to the principles of urban ecology and acknowledges existing settings (governance, social systems & infrastructure) while initiating truly creative interconnections that go beyond a grey, blue or green focus.

Polycentric management of urban waters (PUW): The concept of PUW considers the challenges for urban areas and settlements to include "water" as a cross-cutting issue requiring cross-sectoral solutions. PUW brings together security of supply of water-related services (water supply, wastewater and waste management, flood management, etc.), resilience to the impacts of climate change, and the creation of livable and inclusive urban spaces in an integrated approach to sustainable water resource management (IWRM) and participatory urban development planning. The solutions are developed and implemented according to the specific natural and socio-economic characteristics of the respective urban areas, the regulatory frameworks, and the financial and institutional capacities of the towns and local stakeholders.

Progressive Implementation: This principle follows the Agenda 21 of the United Nations Conference on Environment & Development Rio de Janerio, 1992. Infrastructure development should be guided in accordance with local capacities and the local context in order to ensure sustainable maintenance and operation (UNSD, 1992).

Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning, and transformation progressive Implementation (Sutton et al., 2011). The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions (IPCC, 2012).

Risk: Potential for adverse consequences for human or ecological systems as a result from dynamic interactions between hazards, exposure and vulnerability of the affected human or ecological system (IPCC, 2023).

Runoff: The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ ice melt that does not evaporate, transpire or refreeze, and returns to water bodies (IPCC, 2023).

Urban heat island: The relative warmth of a city compared with surrounding rural areas, associated with heat trapping due to land use, the configuration and design of the built environment, including street layout and building size, the heat-absorbing properties of urban building materials, reduced ventilation, reduced greenery and water features, and domestic and industrial heat emissions generated directly from human activities (IPCC, 2023).

Urban Waters: is a concept of sustainable urban water management. Urban waters within the city (including reservoir and aquifer water, desalinated water, recycled water and stormwater) are managed in a way that maximises the achievement of urban livability outcomes and resilience to unexpected social, economic or bio-physical shocks (IWA, 2016)

Vulnerability (in this Baseline Assessment often mentioned the term vulnerable): The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2022). The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard (UNEP, 2019)

Wastewater: a combination one or more of: domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater); water from commercial establishments and institutions, including hospitals; industrial effluent, stormwater (if there is a combined sewer system (Henze & Comeau, 2008)) and other urban run-off; agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter (United Nations Environment Programme, & United Nations Human Settlements Programme, 2010; & Raschid-Sally, & Jayakody, 2008). Although, using this definition, the term 'wastewater' clearly encompasses domestic, commercial, industrial, agricultural components and also faecal sludge, these are sometimes covered separately in order to clarify or highlight the importance of the individual components or wastewater streams (UN Water, 2015).

Water security: is defined here as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UNU-INWEH, 2013).

Water sensitive urban development: refers to a comprehensive and integrated approach to urban development that prioritizes sustainable and efficient management of water resources within the urban environment. It facilitates urban centers in transitioning toward ecologically based systems, simultaneously tackling the effects of climate change and mitigating adverse consequences of urbanization and population growth. This approach fosters the creation of resilient and habitable urban environments (IWA, 2016). One of the core principles of the Water Sensitive Urban Planning is the Water Sensitive Urban Design (WSUD) approach. WSUD is the interdisciplinary cooperation of water management, urban design, and landscape planning (Hoyer, Dickhaut, Kronawitter, & Weber, 2006). It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design (Hoyer et al., 2006). It develops integrative strategies for ecological, economical, social, and cultural sustainability (Hoyer et al., 2006). The goal of Water Sensitive Urban Design (WSUD) is to integrate sustainable stormwater management with urban planning, bridging the urban water cycle towards a more natural state. Initially, WSUD encompassed the comprehensive management of water systems, including drinking water, stormwater runoff, waterway health, sewage treatment, and recycling. However, its primary focus remains centered on effective rainwater management (Hoyer et al., 2006). WSUD achieves multiple benefits, including elevated water supply quality, improved stormwater quality, flood control, enhanced landscape amenity, healthy living environments, and ecosystem health (Sharma, Gardner & Begbie, 2018).

Introduction

In the Royal Government of Cambodia’s current and sixth iteration of the National Strategic Development Plan, the Government indicates its strong commitment to the implementation of the 2030 Agenda for Sustainable Development by adopting approximately half of the SDG’s indicators as Cambodian SDGs. By providing such performance measures linked to budget outcomes, the Royal Government of Cambodia is a notable example of innovation among countries in the region.

The Royal Government of Cambodia’s aim is to fully integrate Cambodia into the regional economic network by promoting improved infrastructure connections and address the climate change risks to urban areas via multi-sector approaches to urban development. Nevertheless, significant challenges remain to effectively develop the capacity of the subnational level to effectively and efficiently implement such multi-sectoral approaches to ensure water security and the lilveability of the towns and cities across the country. As a result, SDG 6 “Clean Water and Sanitation”, SDG 11 “Sustainable Cities and Communities” and SDG 13 “Climate Action” are prominent targets.

The aim of the "PolyUrbanWaters” Project, funded by the German Federal Ministry of Education and Research (BMBF), is that “polycentric approaches to urban water resource management contribute to the water-sensitive transformation of secondary and tertiary cities in SEA towards resilient, inclusive and livable urban areas”.

The project has been invited by the Kratié provincial and municipal governments and the Ministry of Public Works and Transportation to contribute to the localization of the SDGs and to the realization of improved livability through the sustainable management of urban waters. There is an emphasis on “PolyUrbanWaters” contributing to urban planning through improving the understanding of how the natural environment interacts with the urban area in Krong Kratié, as with many urban areas in Cambodia endowed with natural water resources, and how this understanding can contribute to improved urban planning processes and approaches that address specific conditions and existing capacities. Such approaches should identify strategic fields of action for urban development and realistic options for their implementation.

The baseline study presented here responds to the interest of the national and local government in strengthening the information base and capacity for informed decision-making. The study was developed in collaboration between stakeholders from Cambodia and an international research team. It not only comprehensively identifies the challenges and opportunities of sustainable water management in the context of Krong Kratié‘s urban development but is the starting point for strategy development and capacity building processes supported by "PolyUrbanWaters" until 2024.

The study provides an overview of the characteristics of the urban environment followed by a detailed assessment of the major water challenge findings in Krong Kratié in the context of a dynamic urban development process. To address these challenges and the municipality‘s development goals, recommendations for action are derived. Each section details the specific natural, water-related, and urban planning and regulatory characteristics of the urban development context of Krong Kratié as well as potential solution pathways.

As in Krong Kratié, similar processes are being carried out simultaneously in Sleman, Indonesia and Sam Neua, Laos PDR, the results of which will be made available to the interested public in a series of upcoming publications.

September 2023

Background and Objectives of the Study

In 2021, the "PolyUrbanWaters" project was invited by the Sub-National Administration[2] of Krong Kratié to contribute to the implementation of the mainstreamed 2030 Agenda for Sustainable Development (SDGs).

There has been increasing recognition that infrastructure exclusively driven by the development of water-related hardware, such as the expansion of the water supply network and water drainage, would only partly develop the resilience that Krong Kratié will need in the future.

Ineffective approaches that promote 'ideal-typical' urban planning are to be overcome and relevant approaches are to be developed for the specific conditions of Cambodia's cities. Such approaches should include the identification of

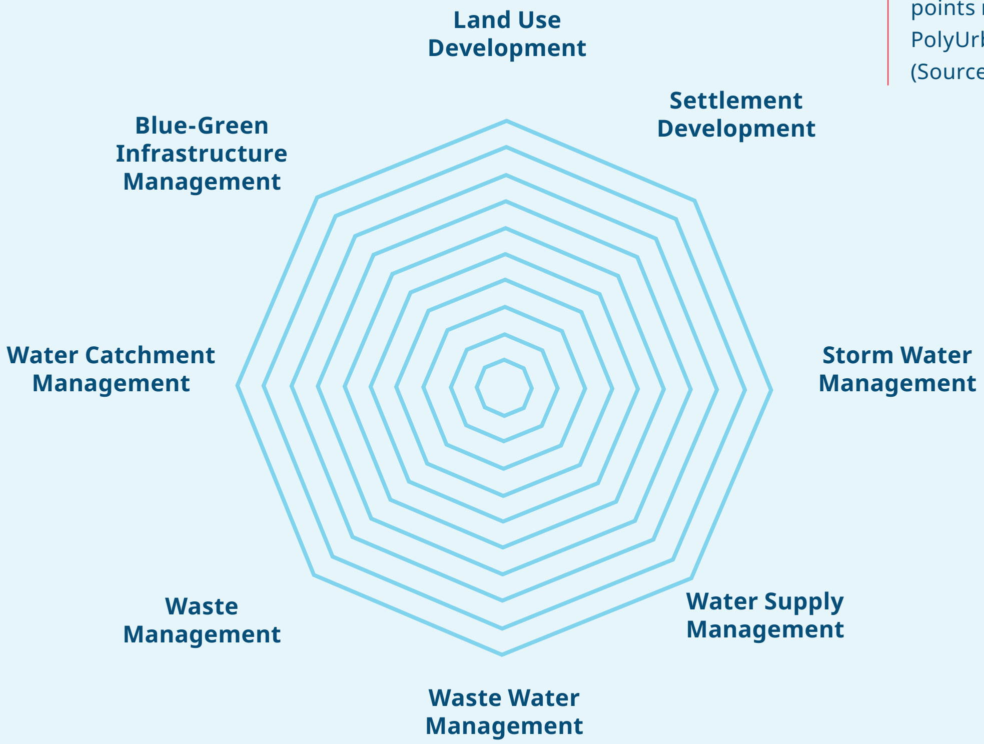


Figure 2. Strategic Interventions as entry points refer to the PolyUrbanWaters approach (Source: Own work, 2022)

2 In this instance, Sub-National Authority (SNA) refers to provincial and municipal administrations.

strategic fields of action for urban development and realistic options for their implementation.

To enable informed decision-making and strategy development for the comprehensive management of urban waters in Krong Kratié, the unique characteristics of the Krong need to be taken into account. Therefore, to fully understand this uniqueness, a baseline study was conducted to:

- Build a qualitative and quantitative understanding of “water” within urban development dynamics by providing information on current water resources, water use patterns, and water-related vulnerabilities as well as existing and emerging water challenges for Krong Kratié;
- Elaborate a comprehensive understanding of the water cycle within the natural context of Krong Kratié, the context of the urban development dynamics and urban spaces;
- Elaborate a robust information base for informed decision-making;
- Identify strategic interventions as entry points for the future water-sensitive development of Krong Kratié (See Figure 2)

Methodology

The findings presented in this report are the result of a research process initiated in 2019. These findings present essential parameters for the management of water resources and their economic, social and ecological impacts in the context of Krong Kratié's development dynamics.

The conceptual framework for this study is based on the Driving-Force/Pressure/State/Impact/Response method. This framework allows a well-structured analysis of natural, social and economic information in the context of an urban transformation process (See Figure 3).

Driving forces, such as demographic, economic, social and climate change induced causes of urban transformation, may translate into pressure on water and natural resources, such as higher demand for construction land. The state of water resources is captured by information on water quantity and quality and overuse of natural water resources that may have an impact on public health and ecosystems. Improved land use planning and infrastructure development may be appropriate responses to mitigate pressures and to achieve development targets.

PolyUrbanWaters Project Stages and Baseline Study Process

The concrete localization of the polycentric management approach to urban waters is guided by a co-production process consisting of three main steps (See Figure 4):

1. Baseline assessment - what is the current status of water resources in the city? (Insights from local stakeholders)
2. Vision building - what might the city look like in 2030 and 2045? (developing scenarios and visions together)

3. Transition pathways - how can we formulate concrete steps to achieve the vision? (co-design approach)

The Baseline Study represents the initial project stage of the PolyUrbanWaters research in Krong Kratié. Study findings are fed into the subsequent Vision Building stage whereby the Project's teams work with local stakeholders to collaboratively produce clear, realistic achievable visions and scenarios for the town (krong). With these to guide the transition pathways, in cooperation with local stakeholders, the interface of urban planning and water management is explored, and actionable interventions designed.

The "baseline study - scenario building - transition pathways" process is guided by a strong science-policy dialogue and continuous capacity development while being investigated from the perspectives of:

- Urban water resources (supply, demand, quality);
- Social-ecological systems (e.g. Nature Based Solutions);
- Participatory methods;
- Governance models and SDG-oriented planning.

The development of the Baseline Study has followed four main stages as shown in Figure 5. Each Stage has been designed carefully and collaboratively with local partners in Cambodia ensuring their agreement.

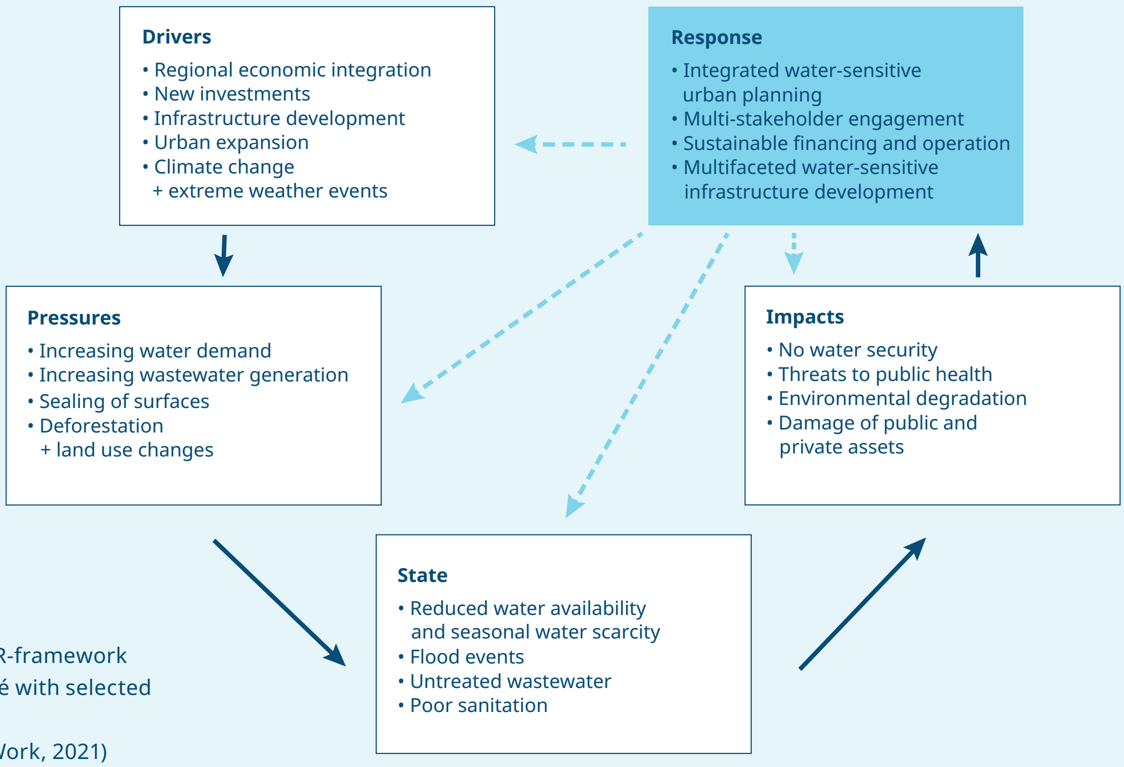


Figure 3. DPSIR-framework for Krong Kratié with selected parameters (Source: Own Work, 2021)

The first field visits took place in 2019 with the goals of establishing communication between project partners and conceiving a preliminary project design. Several research visits by international teams were planned for 2020 and 2022 to prepare the first draft of the baseline study. However, due to COVID-19 pandemic travel restrictions, these could not be carried out. As a result, the data collection, essential for the research process, had to be reorganized as below:

- Field data collection by international researchers could not be conducted, and so BORDA-Cambodia staff fulfilled this role while remaining in constant exchange with the international team via video conferences and other virtual communication tools. The data was primarily collected through interviews with relevant stakeholders from the municipal administration in Krong Kratié, as well as provincial and national government departments.
- BORDA-Cambodia staff complemented this process through field visits to specific sites in Krong Kratié.
- Important data, official documents and background studies with valuable information were provided by government agencies in Cambodia and international development partners.

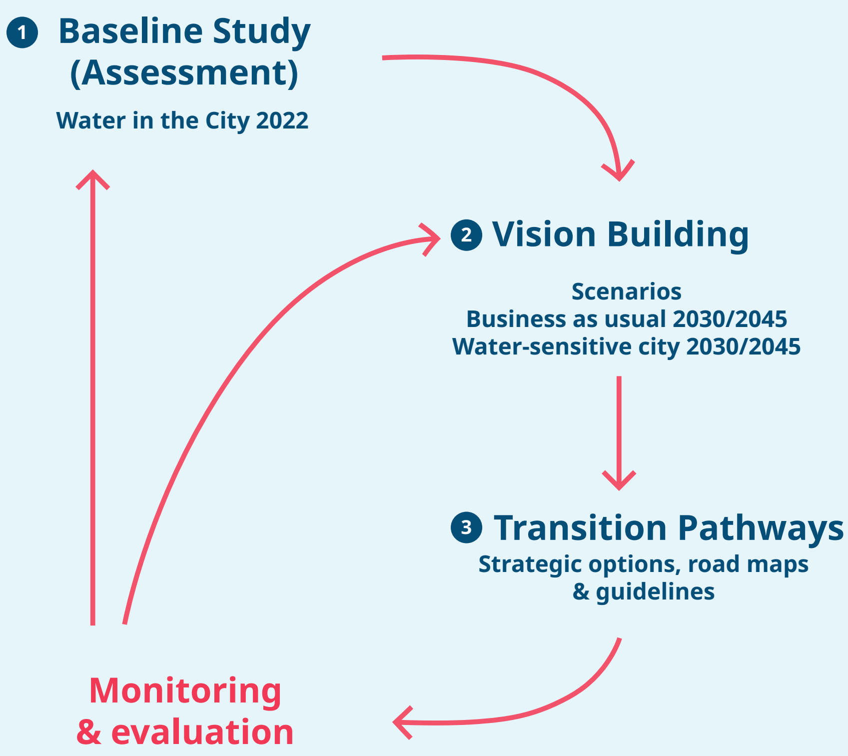


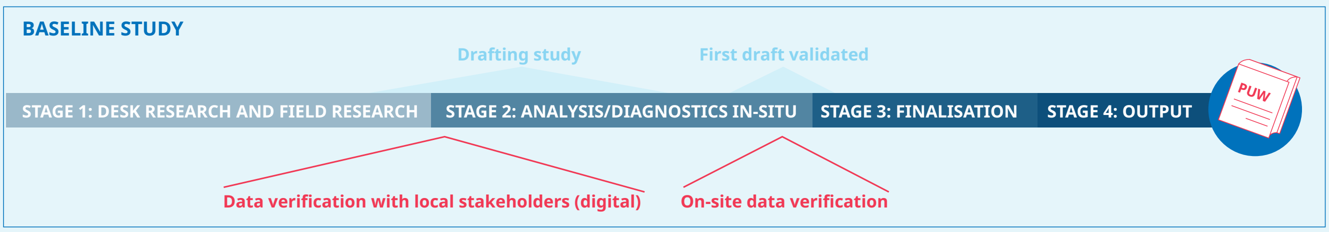
Figure 4. Main working process stages of PolyUrbanWaters project (Source: Own Work, 2019)

- In addition, the international research team developed data for the project that is accessible for research via international databases.
- The entirety of this data was then analysed by the international research team with continuous feedback loops with the partners in Cambodia in order to come to essential conclusions about "Living with Floods“ in Cambodia.

The initial draft of the Baseline Study with preliminary results of the research process was submitted and presented in person by the Cambodia and international PolyUrbanWaters Teams in February 2023 during a scheduled field visit. The draft provided the partners in Cambodia with an initial orientation of the research findings and a basis for communication of further development of the Baseline Study.

Once COVID-19 pandemic travel restrictions were lifted, a field visit by the international team members was conducted providing opportunities to conduct important discussions to validate data, gather feedback (written and oral) and collect additional necessary information. During this visit, data verification used various methods, such as field visits, planned and random field interviews, manual mapping in the field (on printed maps), digital mapping in the meetings (mymaps.com), drone flights, as well as participatory mapping workshops. The feedback and input from local partners in Cambodia and Phnom Penh, as well as the additional data collected on site, were crucial to the further development and finalization of this version of the baseline study

Figure 5. Main stages of Baseline Study development (Source: Own Work, 2021)



Policy Framework and Capacities for Localization of SDGs in Krong Kratié

Key Messages of Section

1. While the Royal Government of Cambodia is committed to implementing the SDGs and has made progress in their achievement, significant vulnerabilities associated with urban development and weak public services need to be overcome.

2. The RGC's National Strategic Development Plan's monitoring and evaluation framework adopts approximately 50% of the SDGs' indicators (88 out of 169) with the Cambodian SDGs providing performance measures and budget outcomes: an innovative step by connecting the SDGs to public sector-budgeting.

3. The RGC's strategic planning documents for socio-economic development address the risks from climate change by promoting multi-sector approaches to urban development bringing together critical factors that contribute to improvements in socio-economic development currently at risk from poorly planned urbanization, environmental changes and climate change ultimately impacting public health and the livability of urban residential areas.

4. Although substantial progress has been made in decentralization policies, significant challenges remain to ensure the water security and livability of cities, including at the governance level.

5. While comprehensive urban modernization in Cambodia, including water-sensitive and green development, largely depends on national government decisions and resources, city and provincial governments can still take proactive, low-threshold measures.

The following section highlights the relevant policy frameworks that align with and support the realization of water-sensitive urban development in Cambodia.

In its most recent version for the six mandate of Government the National Strategic Development Plan (NSDP) 2019 to 2023 (See Figure 6), Royal Government of Cambodia (RGC) indicates its strong commitment to the implementation of the Sustainable Development Goals (SDGs) and has provided a review of the progress and achievements to date of the Cambodian Millennium Development Goals and localisation and mainstreaming of the SDGs in the RGC's Cambodia SDG Framework 2016 to 2030 (RGC, 2018). Cambodia's Updated Nationally Determined Contribution (NDC) identifies at least five adaptive actions (#31, #33, #34, #35, #37) to address these to be developed by the Ministry of Land Management, Urban Planning and Construction and for resilient cities (#39) by the National Committee for Democratic Development and at least two relevant mitigating actions for the Ministry of Land Management, Urban Planning and Construction. Nevertheless, despite these achievements significant challenges are recognized from a 'growing vulnerability, both economic and environmental' and from 'industrialization/ urbanization, migration, [and] public service weaknesses' (Ibid, p. 46).

According to Cambodia's Voluntary National Review 2019 of the Implementation of the 2030 Agenda, the Cambodian SDGs have been fully integrated within planning and policy-making (Ibid). This is through their inclusion in the 2019 to 2023 NSDP Monitoring and Evaluation framework, where around 40% of the indicators have been adopted; and via ministry and agency Budget Strategic Plans, where the CSDGs will provide the performance measures for budget outcomes. The latter, undertaken via national public financial management reforms, is especially innovative, marking Cambodia out globally for offering a concrete connection between the SDGs and public sector budgeting.

The NSDP promotes a multi-sectoral approach in urban areas posing health, environmental, and climate change risks in order to provide effective responses. It gives priority to improving services in cities through waste and wastewater management (RGC, 2019).

The National Strategic Plan on Green Growth 2013 to 2030 focuses on promoting economic development based on green growth principles and environmental sustainability (RGC, 2013).

Figure 6. National Strategic Development Plan (NSDP) 2029-2023 (Source: RGC, 2019)

The Rectangular Strategy – Phase IV –places a high priority on formulating infrastructure master plans for main cities and urban areas to support the development of roads, railways, and water ways as well as electricity networks and sewerage and wastewater treatment system (RGC, 2018).

In June 2023, the RGC has announced that its upcoming mandate will see the introduction and execution of a more comprehensive "Pentagon" strategy. This new strategy is aimed at laying out Cambodia's pathway to becoming an upper-middle-income economy by 2030 and a high-income economy by 2050 through the modernisation of the government and stimulating future economic growth. A major emphasis of the Pentagon Strategy is the effective use of trained resources, along with a concerted effort to develop domestic human resources that meet global standards and societal demands (MoI, 2023; Samban, 2023; Kang, 2023).

The Cambodia Climate Change Strategic Plan (CCCSP) 2014 to 2023 was developed as the first comprehensive policy document to respond to climate change issues. Strategic Objectives detailed in the Plan include: Promotion of climate resilience through improving food, water, and energy security; Promotion of low-carbon planning and technologies to support sustainable development; Improvement of capacities, knowledge, and awareness to respond to climate change (RGC, 2013).

The National Program on Sub-National Democratic Development Phase II 2021 to 2030 is the national strategy for decentralization with the municipal administration's responsibilities relevant to urban planning, developing urban infrastructure, garbage and wastewater management, and environmental protection (RGC, 2021).

The National Policy on Water Supply and Sanitation, issued in 2003 and currently under review, identifies areas for update based on the emerging context and global good practices. It gives particular reference to coherence and adequacy of policy, functional mandates, institutional and sector capacity, achievement of increased coverage, delivery models, planning and investment, tariffs and regulations, institutional coordination, consumer engagement, and water tenure (RGC, 2003).

The 2017 Sub-Decree (#235) on the management of drainage systems and wastewater treatment systems, currently regulates wastewater management. Once the draft law on wastewater is ratified by the National Assembly and Senate, 'newer' relevant Sub-Decrees and Prakas will be prepared to support this law[3].

Despite efforts to decentralize and strengthen governance structures at the local level, considerable challenges remain. Thus, for example, responsibility for managing water issues is scattered and dispersed across multiple agencies with limited coordination between the involved actors at national levels. While functional responsibilities have been transferred to municipal and district levels by the 2019 Sub-decrees 182 and 184, it is premature to say how effective this has been, as limited guidance has been provided to effectively take up the roles and responsibilities associated with water and other issues. The roles and responsibilities for the municipal and sangkats' authorities are being strengthened. Provincial line departments will have to improve their understanding, capacities, and

3 Publication pending approval

resources to address identified water issues as well as for municipalities and sangkat to address the population's demands. Effective technical guidance and tools to facilitate inclusive water planning processes are missing and need to be developed and elaborated.

For effective infrastructure development and sustainable operation (and maintenance), the mandate and capacities of local governance structures (municipality and sangkats) must be strengthened, and they must be better resourced to be able to meet public (local resident) demands, and more systematically involved in higher order decision-making processes that have so far taken place largely at the national level.

In Cambodia, the water governance structures are currently underdeveloped. This is clearly reflected in present conditions and is substantiated by the lessons learned from recent wastewater treatment infrastructure development experiences. These challenges in the wastewater management sector exemplify the substantial obstacles faced when attempting to localize SDG 6 (Clean Water and Sanitation). This situation impacts many ongoing and potential investments in cities in the country.

Some of the main issues are:

- **Sustainable Investments needed in Wastewater Management:** Wastewater management often needs more sustainable investments. These investments should focus on factors, such as connections to houses, a suitable tariff system, and an institutional framework capable of overseeing operations.
- **Operational Management Constraints:** The operational management of wastewater often encounters limitations due to lack of capacity and inadequate financial resources.
- **Limited Adoption of City-Wide Inclusive Sanitation:** Comprehensive sanitation concepts that span entire cities have not been widely adopted.
- **Unclear Accountability:** The responsibilities between the unit responsible for wastewater management and the Provincial Administration are not clearly defined.
- **Deficient Performance Indicators and Agreements:** There is a lack of performance agreements and indicators to assess and guide the functioning of wastewater management systems.

- **Human Resource Management Issues:** Human resource management is not up to par, which negatively impacts operational efficiency.
- **Limited Managerial Autonomy:** There is a lack of managerial autonomy, which hampers decision-making and implementation of necessary improvements.
- **Absence of Strategic and Activity Plans:** There is a lack of strategic and activity plans, largely due to inadequate financial resources and the absence of an advisory group.
- **Need for Sustainable Finance:** Sustainable financing is crucial to deliver good service consistently.
- **Insufficient Policies and Systems:** While some basic systems and policies are in place, they are either inadequate or need to be strengthened or further developed to make the unit effective in service delivery (Kov, 2022).

The Rapidly Changing Characteristics and Challenges for Cambodian Cities

Photograph of Phnom Penh, taken in 2022

Key Messages of Section

1. Generally, cities experience accelerated urban growth, but Cambodia's urbanization rate in smaller urban areas is still relatively low.
2. Smaller 'Krong' in Cambodia (secondary and tertiary cities) are challenged in their roles and functions in the context of policy reform, dynamic economic development, and rapid population growth.
3. Urban growth barely follows any urban development guidelines that address the challenges to create towns and cities with high livability and balanced development.
4. Impacts of these largely unguided urban growths translate into an increased water security and an increased vulnerability to water-related disasters.
5. Multiple initiatives have been launched to improve the resilience of the cities by fostering green growth and green urban development.

Urbanization Dynamics in Cambodia and Trends

The urbanization process in Cambodia is characterized by very particular features. As of the current data, the urbanization rate in 2022 was 25.1% (World Bank, 2023) (See Figure 7), a figure notably lower than expected for a country with an equivalent GDP per capita. This discrepancy implies a substantial potential for accelerated urbanization in the future.

Urban regions in Cambodia follow a distribution model commonly seen in the Greater Mekong Sub-region (GMS), characterized by a prominent metropolitan city, namely Phnom Penh, with over 2 million residents, along with a dispersed array of smaller secondary cities and smaller towns known as krong.

Larger secondary cities also referred to as krong, such as Sihanoukville, Siem Reap, Battambang, and Poipet (See Figure 1), have significantly smaller population sizes ranging from 100,000 to 200,000, a notable contrast with the capital. These urban centres, however, are experiencing their unique growth patterns, propelled by factors including export-oriented manufacturing, tourism, and border trade, leading to urbanization growth rates of between 3-5% (World Bank, 2018).

Despite the promising economic prospects of these secondary cities, they encounter substantial barriers that hinder sustainable growth. The primary challenges include a lack of robust inter-city regional transport networks, underdeveloped infrastructure and services, and a deficit in institutional capacity spanning policy-making, financing, planning, implementation, and enforcement.

In addition, urban planning, or rather the lack thereof, poses another critical challenge. Urban expansion has outstripped the capacity of cities to adapt, leading to urban sprawl, traffic congestion, and deficient delivery of basic urban services. It is becoming increasingly obvious that Cambodia's future development will depend on its ability to create livable, sustainable, and inclusive urban centers capable of driving future economic growth.

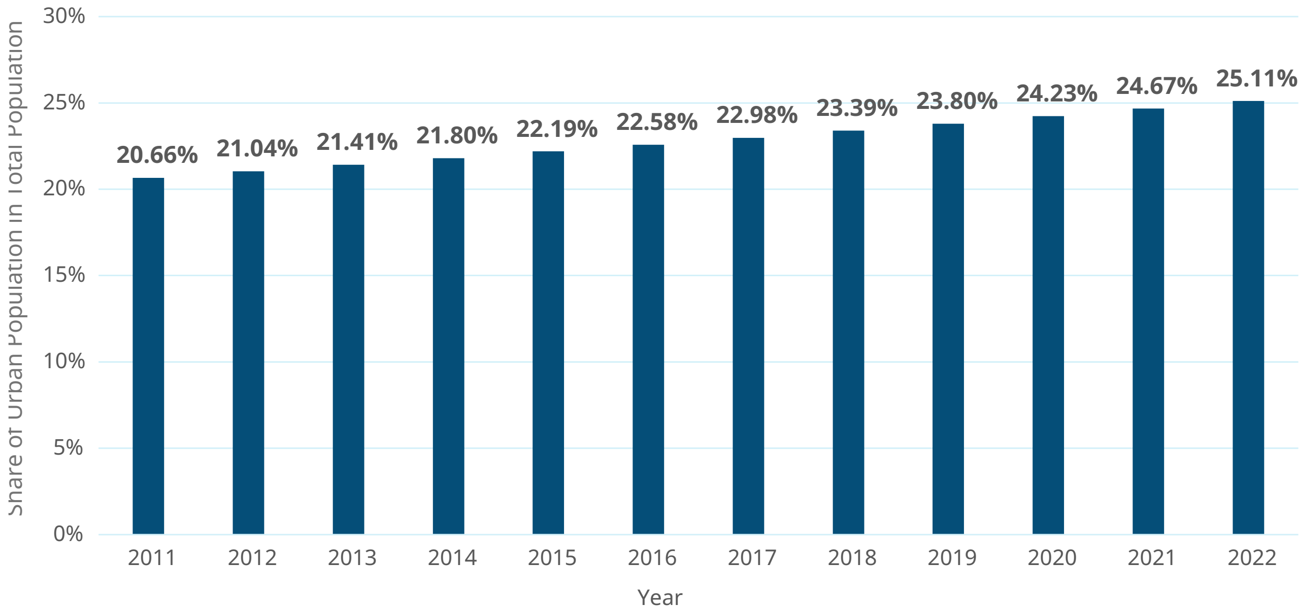
The administrative structure of Cambodia is organized into three distinct tiers, reflecting a clear sub-national governance model.

- At the top administrative tier, there are 24 provinces and one special administrative unit dedicated to the capital region, Phnom Penh. This top tier forms the fundamental framework for administrative responsibilities and jurisdiction in Cambodia.

- The intermediate tier of administration consists of 26 municipalities, also referred to as 'krongs,' along with 163 districts, also known as 'khans' in the capital. The term 'cities' typically refers to either the capital region of Phnom Penh or these 26 municipalities/krongs, which also serve as the provincial capitals in most instances.
- At the base of the administrative pyramid, there are 1,652 communes, and referred to as 'sangkats' in urban areas. These form the most granular unit of administration, often serving as the first level of governance and administration for Cambodian citizens.

This tri-level structure allows for a clear delineation of responsibilities and authorities across the different layers of government. Despite this, challenges remain, particularly in relation to resource allocation and capacity-building at the local level. Efforts to streamline local governance continue to be hampered by various issues. Despite the implementation of numerous legislative measures and a government-led decentralization reform program, limitations persist in policy implementation, resource allocation, assumed responsibilities, and availability of skilled professionals. Particularly notable is the disproportionate resource allocation, with smaller cities receiving significantly fewer resources than more populous areas, such as Phnom Penh.

Figure 7. Cambodia's urbanization from 2011 to 2022 (Source: World Bank, n.d)



Impacts of Largely Uncontrolled Urban Development and Responses

The increasing impact of an urban development that gives little consideration to environmental impacts is becoming more apparent in Cambodia's urban centres. For instance, in Phnom Penh, where commercial developments have not appropriately planned for the inclusion of existing green spaces, natural lakes or wetlands, flash flooding has intensified. Historically, these areas served as natural flood control and wastewater management systems.

Urban growth in Cambodia has largely occurred without suitable planning, which brings several challenges. Unplanned growth can lead to issues including urban sprawl, congestion, and the formation of slums, vulnerable to flooding, pollution, and inadequate service delivery. These challenges, if not addressed, can hinder long-term economic growth and development (Ibid). While urban growth has stimulated Cambodia's economic growth and poverty alleviation, it is also associated with an increasing need for basic urban services, settlements, and employment; as well as contributing to new environmental challenges and new forms of social exclusions (RGC, 2019).

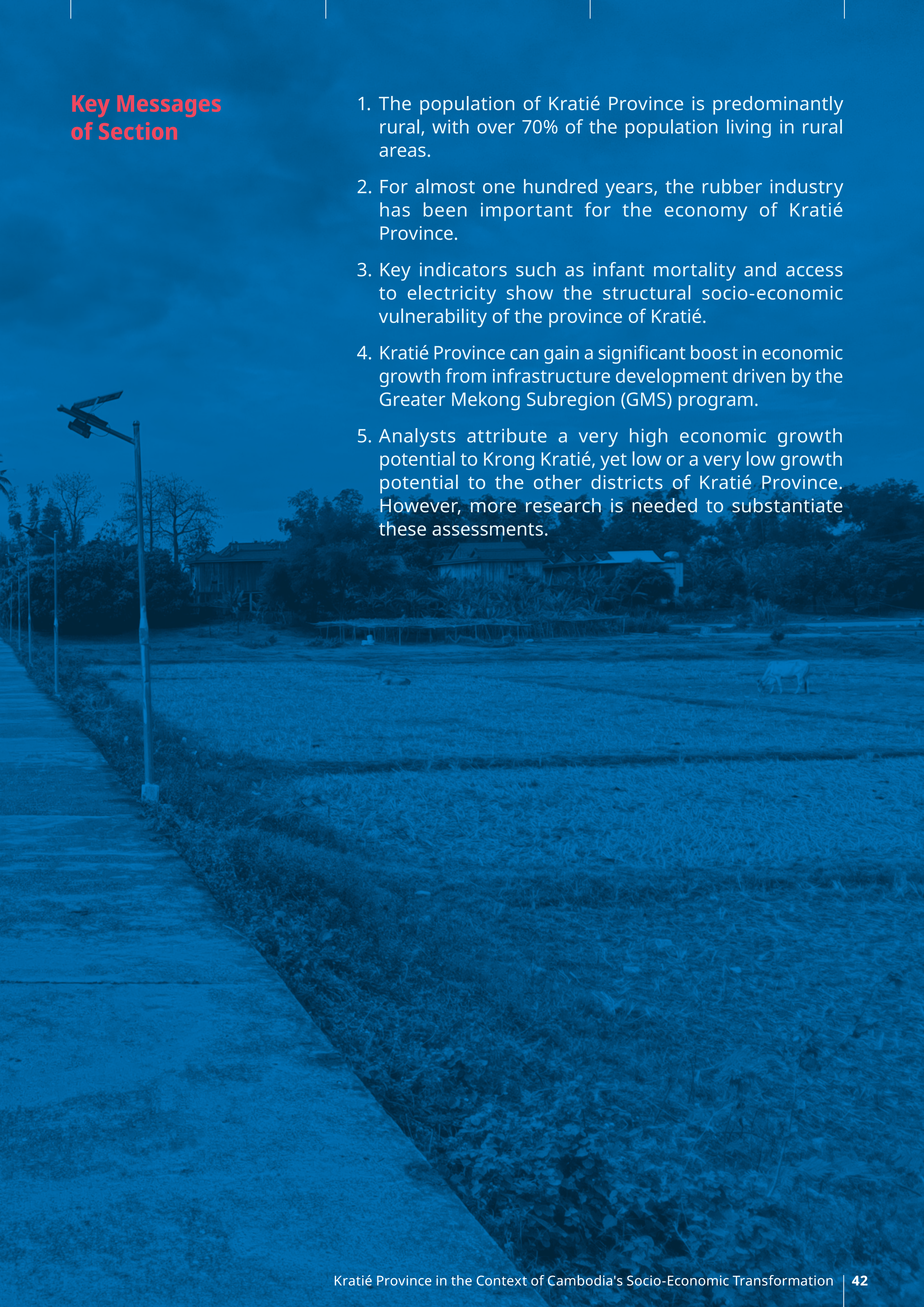
Investing in green infrastructure that may include public spaces and walkability is becoming an urgent need. Such infrastructure should be designed from the outset with flood management, disaster risk, and climate change objectives or co-benefits as overarching planning factors. Retrofitting or redeveloping green infrastructure could be costly, therefore, proactive urban planning is gaining in importance. Hybrid approaches that effectively interlink grey and green infrastructure development unlock economic potentials for many Cambodian urban areas because it may stimulate green economy development models, augmenting sectors such as tourism and industry.

Aligned with the Royal Government's Rectangular Strategy for Growth, Employment, Equity, and Efficiency, Phase III (RS-III), which acknowledges the importance of environmental and climate change issues in achieving sustainable economic growth, Cambodia has endorsed green growth principles. The National Green Growth Roadmap, established in 2010, sets a path for green growth in Cambodia. The development of green and sustainable cities has thus become a key policy priority for the Department of Green Economy of the National Council for Sustainable Development (NCSD) and the Ministry of

Environment (MoE). Nevertheless, there remains a need to localize these concepts as per the ground realities for Cambodia's urban areas.

In collaboration with the Global Green Growth Institute (GGGI), the NCSD, MoE, and relevant local governments have developed Green City Strategic Plans. In 2017, these included the Phnom Penh Green City Strategic Plan 2017-2026 and the Sustainable City Strategic Plan 2018-2030, covering seven cities (GGGI, 2016; GGGI 2019). The strategic plans aim to develop sustainable urban infrastructure, improve local economies, promote social inclusiveness, access to services, job opportunities for all, and improve cities' governance. They address various urban service delivery challenges through an environmental sustainability and green growth focus, proposing a range of potential green projects across various sectors. Such strategic plans may also be indicative for other secondary and tertiary cities (krong) in Cambodia. Here again, the challenge will be how to translate these plans into effective action given the existing financial and institutional capacities and the largely unregulated urban development.

Kratié Province in the Context of Cambodia's Socio-Economic Transformation



Key Messages of Section

1. The population of Kratié Province is predominantly rural, with over 70% of the population living in rural areas.
2. For almost one hundred years, the rubber industry has been important for the economy of Kratié Province.
3. Key indicators such as infant mortality and access to electricity show the structural socio-economic vulnerability of the province of Kratié.
4. Kratié Province can gain a significant boost in economic growth from infrastructure development driven by the Greater Mekong Subregion (GMS) program.
5. Analysts attribute a very high economic growth potential to Krong Kratié, yet low or a very low growth potential to the other districts of Kratié Province. However, more research is needed to substantiate these assessments.

Key Characteristics and Key Trends for Kratié Province

Located in northeastern Cambodia, Kratié Province has seen a steady increase in population over the years.

The province can be reached from the capital, Phnom Penh, via National Highway No. 7 passing through Snoul District (250 km), Chhlong District (200 km), and via the Mekong River (220 km). The river flows through Krong Kratié and four of the other five districts at a total length of 140 km within the province.

The province, spanning 12,250 km^2, shares borders with Mondolkiri Province to the east, Kompong Thom Province to the west, Kampong Cham Province to the south, and Stung Treng to the north (141 km) (CIB, 2014).

Within the province, there are a total of 258 villages in 42 communes and five sangkats across five districts and one krong (ADB, 2017) (See Figure 8).

Krong Kratié is located on the eastern side of the Mekong River, serving as the administrative center for Kratié Province. According to the National Institute of Statistics (NIS) (2020), the population of Kratié Province grew by 1.5% annually between 2008 and 2019 (National population growth 1.2% during the same period). In 2020, the population was 429,908, up from 318,813 in 2008.

The population density of Kratié Province is relatively low compared to other provinces in Cambodia. Whereas Cambodia has a population density of 82 people per square kilometer, the population density for Province Kratié is recorded at 33 people per square kilometer (National Institute of Statistics, 2021). The population of Kratié Province is predominantly rural, with the majority (over 70%) of the population living in rural areas.

The population density further varies between the Kratié Province's five districts and one krong. The area with the highest population density is "Krong Kratié", with 48 people per square kilometer. The district with the lowest population density is Prek Prasap, with only 10 people per square kilometer. The population density also varies within the districts themselves, with some areas being more densely populated than others, for example the urban areas of Krong Kratié and Sambor have a higher population density than the rural areas surrounding them. This might be due to the fact that these areas are centers of commerce

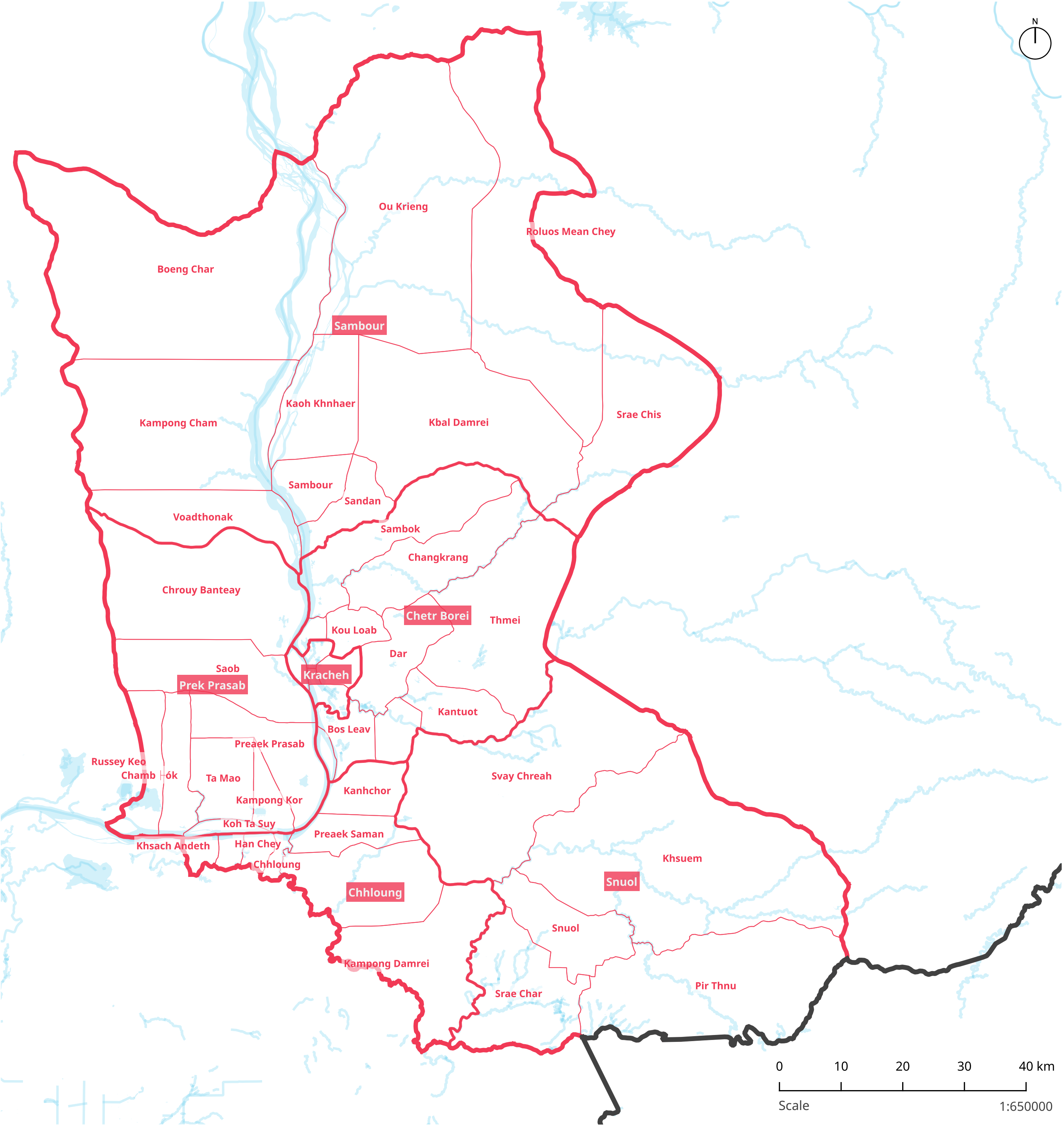


Figure 8. Administrative map showing Kratié Province with surrounding districts and communes
(Source: Own Compilation based on National Institute of Statistics (NIS), & Ministry of Planning (MoP), 2013)

and industry, attracting people from surrounding areas.

The population size varies among districts: Snoul District has the highest population of 100,016 people, while Krong Kratié has the lowest population of 31,843 people. The other districts - Chhlong, Chit Borey, Prek Prasap and Sambor - have between 65,075 and 80,035 people. Indigenous ethnic minority populations, such as Pnong, Koy, Stiang and Khanh, live in these districts. The vast majority of the population (81.42%) are farmers.

Located on the border with Vietnam, Kratié Province plays an active role in bilateral trade with its neighboring country and has significant potential for further expansion.

The landscape of Kratié Province, with a total area of 11,094 km^2, can be divided into northeast and the southwest region. The natural characteristics have a strong influence on the economic activities and potentials. The northeastern region is characterized by a plateau of dense forests, abundant grasses, and fertile red soils that provide favorable conditions for livestock production and agro-industrial plantations, such as rubber, pepper, and cashew nuts.

The southwestern region, on the other hand, consists mainly of humid plains that are synonymous with the Cambodian countryside. These plains have fertile soils, especially along the Mekong River, making them well suited for the cultivation of rice, corn, and beans. In addition, these plains are home to a group of Irrawaddy dolphins and other fish species, which are a major tourist attraction for the province and the city of Kratié.

The Indicator Framework of the Mekong River Commission intends to measure the social development and the well-being of all riparian States. For the Province of Kratié, indicators like access to electricity and rates of infant mortality show a higher degree of socio-economic vulnerability. This is also indicative of a limited resilience to the effects of climate change (See Info Box 1).

The World Bank in its Economic Potential Index (EPI) for Cambodia (market accessibility, transport connectivity, economic density, level of urbanization, and human capital) attributes very high economic growth to Krong Kratié, this perhaps can be explained by the existence and growth of economic land concessions in favor of agriculture plantations and agro-industrial processing (See Info Box 2).

Info Box 1. Under-5 Child Mortality and Childhood Stunting

Nationally, the 2022 Demographic and Health Survey reports that during the preceding 5 years, the under-5 mortality rate was 16 deaths per 1,000 live births. This is a decline from 35 deaths per 1,000 live births. Under-5 mortality is highest in Ratanakiri and lowest in Phnom Penh and rates of mortality for under-5s are considerably higher in rural areas than in urban areas. Moreover, Nationally 22% of children under-5 are stunted, 10% are wasted, 16% are underweight, and 4% are overweight. The prevalence of stunting and underweight is higher among boys (25% and 18%, respectively) than girls (19% and 15%, respectively). Wasting indicates acute weight loss and can impair the functioning of the immune system increasing the risk of death, and stunting contributes to impaired growth and development. Both can be linked to poor nutrition and repeated infections, especially diarrhoea (WHO, 2015 'Stunting in a nutshell', UNICEF, 2020). For drinking water as of 2020, urban areas had 57% access while rural areas were below 50%. For sanitation, urban rates of access reach 93.1% but are considerably lower at just over 60% in rural areas. For hygiene, urban access to basic handwashing services was 83.3% while rural areas were slightly over 70% (JMP Cambodia, 2020).

While specific data for Krong Kratié is not detailed in the survey, for Kratié Province under-5 mortality is 14 deaths per 1,000 live births, compared to 43 in Ratanakiri Province, 12 in Siem Reap Province and 5 in Phnom Penh as of 2022. (DHS, 2022). These obstacles to ensuring improved childhood health and nutrition indicate a need for substantial continued investment in both infrastructure and social change.

From the authors' point of view, however, such a categorization would have to be reviewed in detail, since growth indicators such as the development of land prices do not yet justify such a forecast. The other districts of the province of Kratié are attributed a low growth potential according to the EPI.

Kratié Province can gain a significant boost in economic growth from infrastructure development driven by the Greater Mekong Subregion (GMS) program. Initiated by the Asian Development Bank (ADB), the GMS program is aimed at contributing significantly to both Cambodia's urban development and the broader regional economic landscape, respectively the enhancement of the regional economic integration across Cambodia, Lao PDR, Myanmar, Thailand, Vietnam, and certain Chinese provinces.

The Province of Kratié is positioned on the Central Corridor along the Mekong River, which runs through Thailand and Vientiane in Laos onward to Phnom Penh and to Sihanoukville in Cambodia. The corridor links 13 cities with a total urban population of about 3 million and a

Transport Corridors of the Greater Mekong Subregion corridor population of about 20 million generating regional economic outputs of over $20 billion (ADB, 2018a).

The focus of the program is on reducing transport costs, bolstering trade and investment, and developing cross-border infrastructure, such as highways, bridges and power transmission lines. The GMS program may be particularly impactful for Cambodia's krong (secondary or tertiary cities) by fostering connectivity, urban growth, and economic development. Moreover, within the GMS Economic Corridors, Cambodia's strategic position, especially in the southern region, enables it to link key corridors, boost regional economic cooperation, and serve as a potential engine for regional economic growth (See Figure 9).

However, it is not yet possible to accurately predict what growth impulses can be expected for Kratié Province.

Info Box 2. Cambodia's Rubber Industry

How important is the rubber industry for Cambodia's economy?

Rubber is a significant export industry for Cambodia, which earned $206.728 million from rubber and related items between January and April 2023 alone. Cambodian exports recorded $541.661 million in 2022, an increase of 28.34% from $422.062 million in 2021. This is an increase of 230.28% from $164.002 million in 2015. Major buyers of Cambodian latex are: Vietnam, China, South Korea, Malaysia, Singapore, Japan and the EU (Hin, 2023).

In 2022, Cambodia recorded 404,578 ha of cultivated rubber land, with 315,322 ha or 77.94% being tapped for latex. Currently, 168 rubber processing factories operate in Cambodia across 11 provinces. They can produce 370,000 tons of rubber goods, earning more than $610 million and more than $1.5 million from the export of rubber wood (Chhum 2023).

As of 2022, the Vietnam Rubber Group (VRG) operated in Cambodia through 16 subsidiaries and had been investing in rubber plantations in Cambodia since 2007. In 2022, it had over 74,000 ha of a total of nearly 90,000 ha across Kratié, Ratanakkiri, Kampong Thom, Mondulkiri, Siem Reap, Oddar Meanchey and Preah Vihear provinces. VRG operates six latex processing plants: four in Kampong Thom and one each in Kratié and Ratanakkiri provinces (Vietnam Rubber Group, 2022).

Figure 9. Overview map of GMS Transport Corridor showing Kratié Province and Krong Kratié on Central Corridor
(Source: Greater Mekong Subregion (GMS), 2017).

Info Box 2. Cambodia's Rubber Industry

How important is the rubber industry for Kratié's economy? What impact will the rubber industry have on Kratié Province?

For Kratié Province the rubber industry has been important for the economy for almost one hundred years. Such agro-industrial production, as the rubber industry, contributes to local GDP and justifies the improvements in transportation infrastructure across the region, such as the Kratié-Kampong Thom Bridge across the Mekong River currently under construction south of Krong Kratié and the earlier construction of the Stung Trang Bridge.

When did the rubber industry start in Cambodia? Why is the rubber industry in Kratié Province?

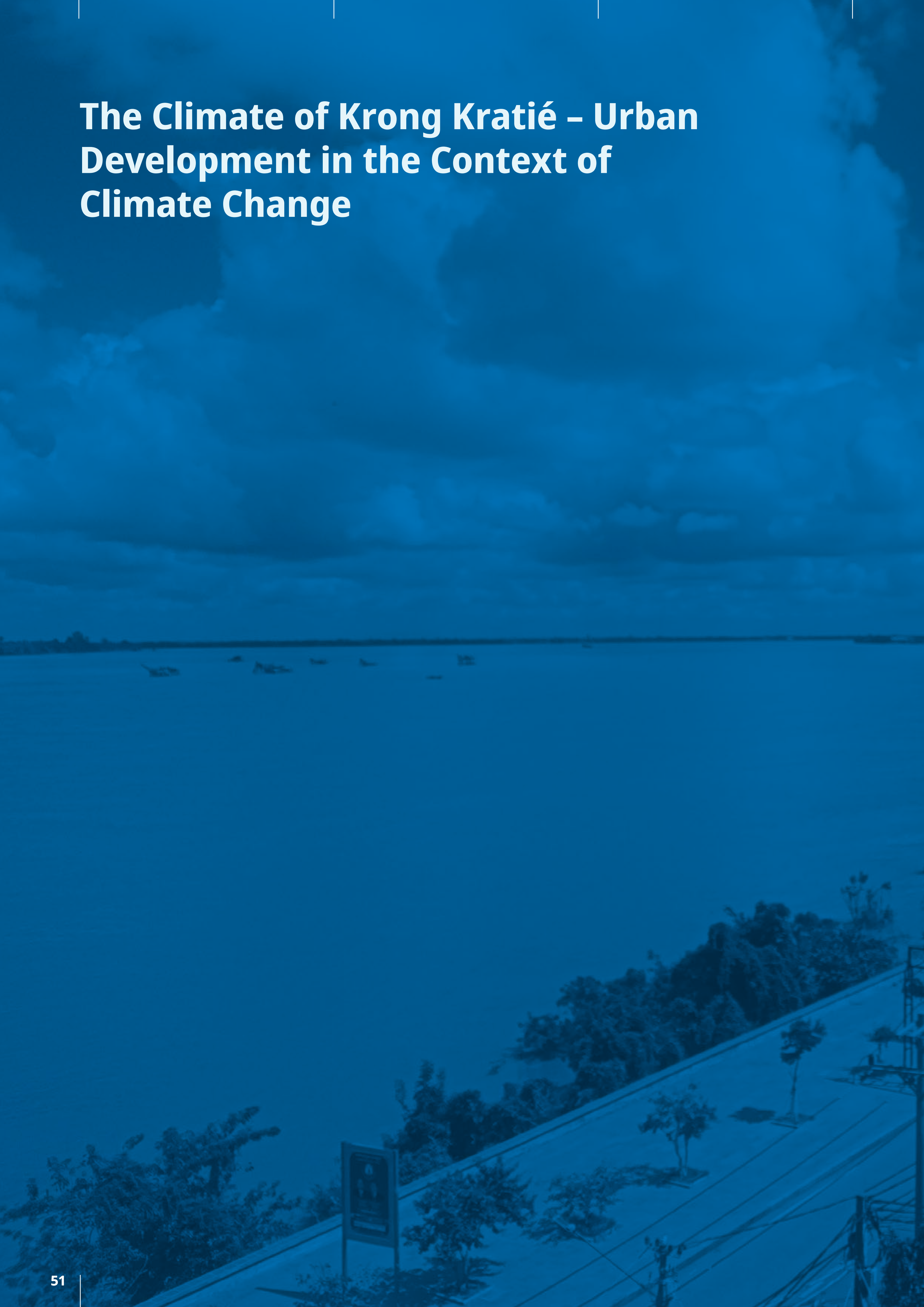
The basaltic red soils native to Kratié Province are suitable for rubber production due to their water-storage capacities producing high yields despite long dry seasons. Snoul District in Kratié Province was the location for one of Cambodia's first large-scale rubber plantations promoted by the French colonial administration in the early 20th century. This plantation owned by the Société des Plantations de Kratié, or Kratié Plantation Company, Snoul was established in 1927 close to the Cambodia and Vietnam border. Cambodia's first rubber plantation was established in Kampot in 1911 with a significant expansion of plantations in the mid-1920s during the 'second rubber boom' (Aso, 2010-2011; Ross, 2016).

The total plantation area grew to 27,000 ha during the "rubber boom" and by 1937 an estimate of 13,000 metric tons of rubber was being produced (Ross, 2016). In the 1990s peace and stability returned to Cambodia and the government enacted a range of government reforms to attract foreign investment in the rubber industry, such as the introduction of Economic Land Concessions (ELC). ELCs are a form of special economic zone that give long-term leases to domestic and foreign companies to use their land for agro-industrial purposes, such as sugar, cassava, acacia, and rubber production. By 2007, approximately 1 million ha had been granted (Ross, 2016).

Which rubber companies operate in Kratié Province?

In Kratié Province, VRG operates six companies: Dong Phu Rubber Joint Stock Company - Kratié, Dong Nai - Kratié, Dau Tieng Cambodia, Dau Tieng - Kratié, Vketi (oc Ninh), Binh Phuoc 1 (Chu Prong). These companies cultivate 21,598.14 ha of rubber, of which the rubber exploitation area is over 21,000 ha. Revenue is estimated at over 428 trillion dongs (over 18 billion USD), the total profit is over 55 trillion dongs (over 2 billion USD). This company employs just under 4,000 workers at an average wage of 7.2 million VND (over 300 USD)/person/month) in 2022 (Vietnam Rubber Group. (2022). The VRG also provides social initiatives in terms of constructing worker houses with electricity, building health clinics and schools, and providing worker health check-ups (Vietnam Rubber Group. (n.d.).

The Climate of Krong Kratié – Urban Development in the Context of Climate Change



Key Messages of Section

1. With its tropical climate, Krong Kratié already experiences significant dry season temperatures and rates of precipitation, and in recent years there has been a slight increase in annual temperatures and precipitation.
2. Such changes might be interpreted as manifestations of the effects of climate change. However, predictions of how the climate will develop in the coming years and decades are still subject to significant uncertainties.
3. Nevertheless, despite this uncertainty, it is likely that climate change will affect ecosystems, livelihoods, public health, and other elements that contribute to urban livability in a tropical context.
4. Overall, there is a high vulnerability of large areas of Kratié Province to climate change, and negative impacts for the Krong are also to be expected.
5. Stakeholders and the governance structures of Krong Kratié are challenged to significantly enhance local adaptation capacities and disaster preparedness to respond effectively to climate change.

Climate

Situated within the Lower Mekong Basin and the Cambodian Floodplains, the climate of Krong Kratié is greatly influenced by the south-west monsoon's regional weather system. This exhibits two main phases: From May to October, the rainy season brings cooler temperatures and high rainfall, while November to March experience minimal rainfall during the dry season.

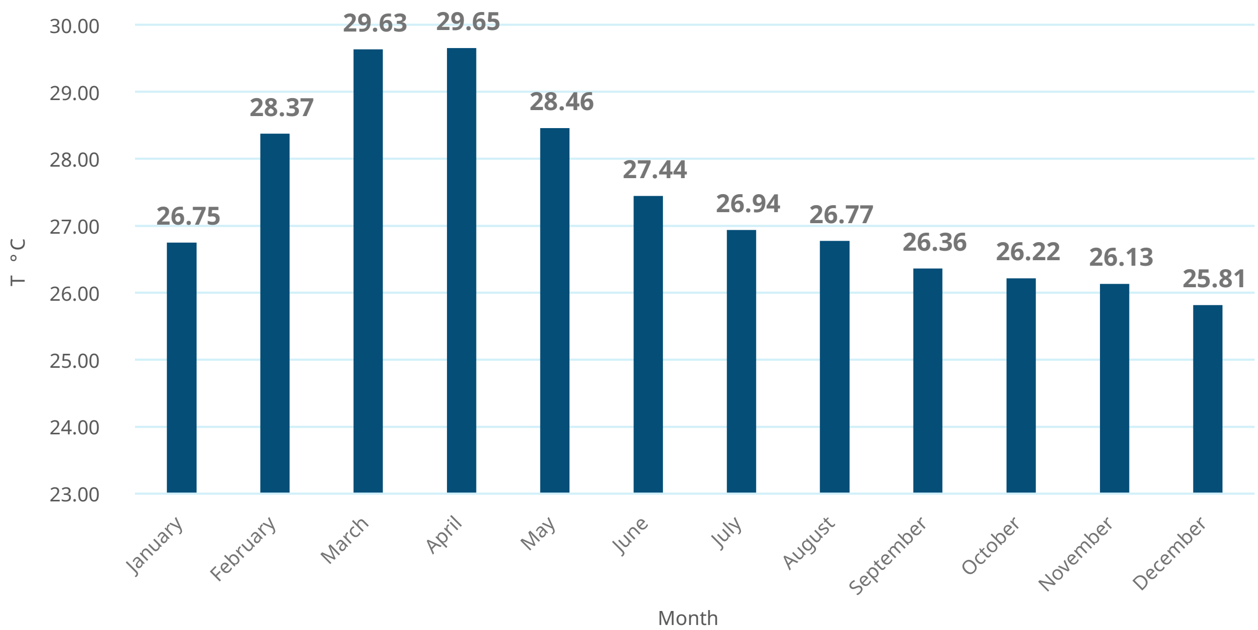
In April, the region undergoes a transitional period marked by a peak in hot, dry temperatures just before the Monsoon's arrival (Mekong River Commission, 2005). The onset of the wet season and this transition period are influenced by El-Niño events, which cause changes in the Walker and Hadley circulations and result in alterations to Intra-seasonal Oscillations (Zhang et al., 2002).

Kong Kratié has a tropical savannah climate (Aw) according to the Köppen-Geiger climate classification scheme.

Temperature

The temporal distribution of the mean monthly temperature in Kratié Province means the warmest months are between February and May, with a monthly average that approaches 30°C in March and April. However, the coldest months are November and December with a monthly average of 26°C approximately (See Figure 10).

Figure 10. Temporal distribution of the mean monthly temperature in Krong Kratié in °C between 1981-2021.
(Source: Own Work based on Muñoz Sabater, 2019)



In Kratié Province, a discernible increase in temperatures has been observed over the years. An analysis of the mean annual temperature distribution, measured in degrees Celsius, between 1981 and 2021 as seen in Figure 11, suggests evidence of this trend.

Observations from Kong Kratié appear to corroborate an assessment of annual temperatures in Cambodia, which shows a subtle increase from 27°C in 1985 to 27.5°C in 2020. Analysis of temperature anomalies and changes indicate fluctuations within a range of -1.7°C to 0.8°C. Over the course of four decades since 1980, a distinct upward trend has become apparent, with temperatures rising between 0.1°C and 0.5°C. This trend suggests an overall temperature increase across Cambodia.

Figure 12 illustrates the documented and anticipated patterns of shifts in the mean annual temperature up to the year 2100 based on two climate change scenarios, RCP4.5 and RCP8.5. These are compared against the reference period from 1981 to 2005. Both scenarios project an upward trend in the average annual temperature, with a more pronounced escalation anticipated under the RCP8.5 scenario (National Council for Sustainable Development, 2022).

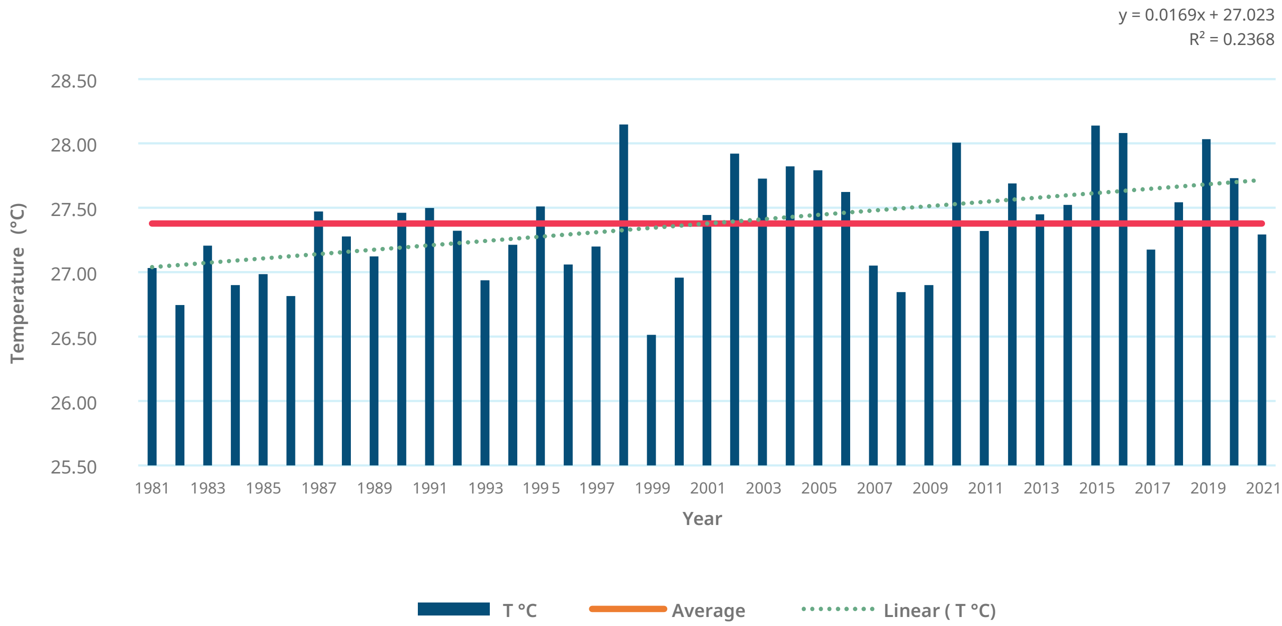
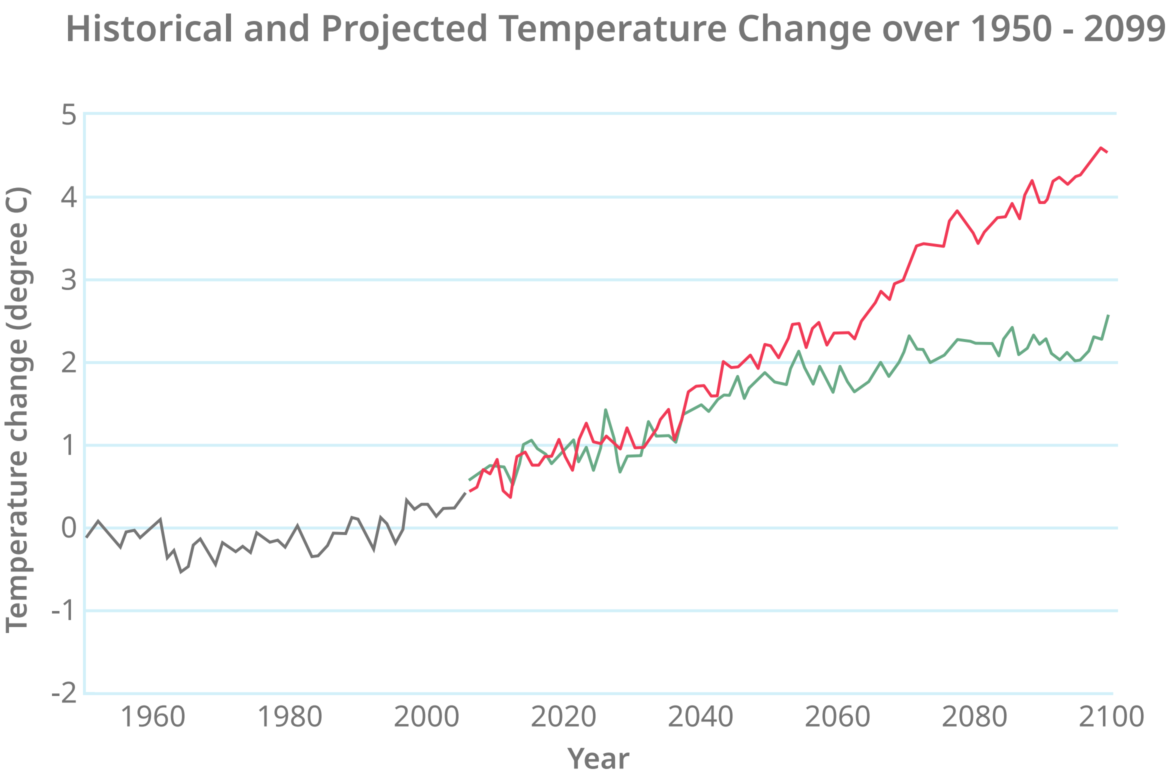


Figure 11. Temporal distribution of the mean annual temperature in Krong Kratié in °C between 1981-2021
(Source: Own Work based on Muñoz Sabater, 2019)

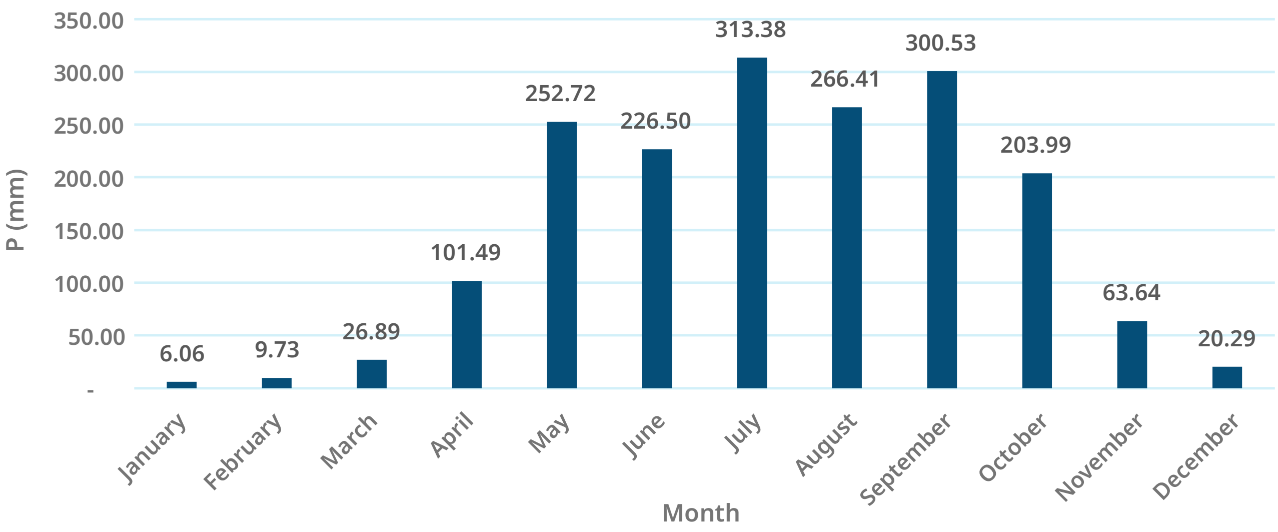


Precipitation

A review of the temporal distribution of mean monthly precipitation in Kratié Province from 1981 to 2021 reveals a pattern typical of the region's tropical climate (See Figure 13). Rainfall distribution is uneven throughout the year, with a marked dry season and a pronounced wet season. The wet season, influenced by the south-west monsoon, is characterized by high rainfall and typically occurs from May to October, aligning with cooler temperatures towards the end of the year. In contrast, the dry season, spanning from November to April, experiences significantly less rainfall as temperatures increase.

It is important to emphasize that the evolution of climate in urban and adjacent areas is influenced by various factors beyond large-scale climate change. Significant changes in land use, such as conversion of wetlands, sealing of surfaces, and the use of heat-absorbing building materials, such as concrete, can contribute significantly to the warming of Krong Kratié, affecting the quality of life for residents and visitors. While the effects of climate change undoubtedly play a role in altering the local climate or microclimate, these additional anthropogenic activities exacerbate the warming effect and should not be ignored when considering strategies to improve the quality of life in the region.

Figure 12. Observed and projected temperature changes up to 2100: two climate change scenarios (RCPA4.5 and RCP8.5)
Note: Based on CRU TS4.02 dataset and different ensembled climate models. (Source: National Council for Sustainable Development, the Ministry of Environment, 2022, p.100).



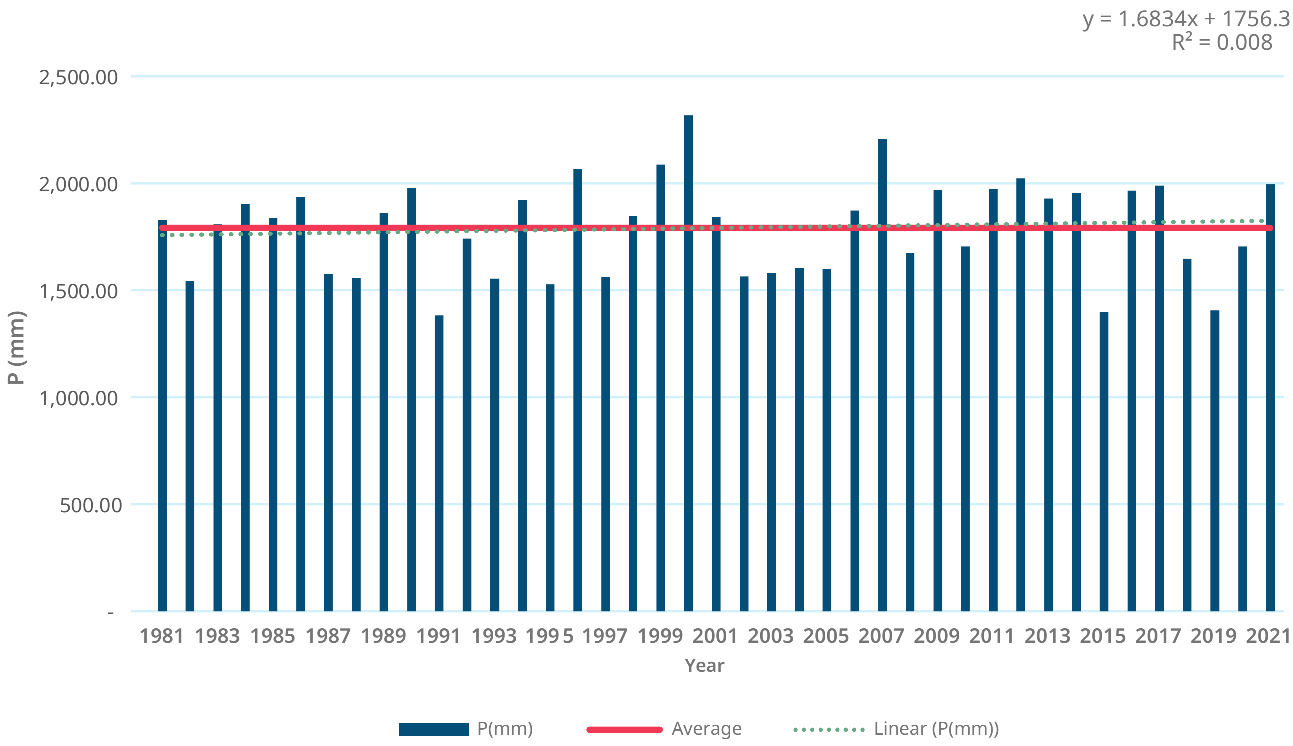


Figure 13. [top] Temporal distribution of the mean monthly precipitation in Krong Kratié in °C between 1981-2021.
(Source: Own Work based on Funk et al., 2015)

Figure 14. [bottom] Temporal distribution of the mean annual precipitation in Krong Kratié in °C between 1981-2021.
(Source: Own Work based on Funk et al., 2015)

From 1981 to 2021, Krong Kratié experienced a slight increase in annual rainfall, as seen in Figure 14. The temporal distribution of mean annual precipitation in this region, when assessed in relation to historical data, indicates a rising trend. While variability from year to year is a natural aspect of climatic patterns, the overall trend points towards an increase in total annual rainfall.

The projected trends for average annual rainfall across Cambodia to 2100 are based on two distinct climate change scenarios: RCP4.5 and RCP8.5 (IPCC, 2014) (See Figure 15). Both scenarios suggest varied outcomes for the region's rainfall patterns. Under RCP4.5, considered a moderate scenario, changes to the average annual rainfall are anticipated, yet they are expected to remain within certain bounds. Conversely, RCP8.5, often referred to as a more severe or 'worst-case' scenario, predicts a much more drastic fluctuation in rainfall levels[4].

Climate Change Impacts

These projections play a crucial role in understanding and preparing for the potential impacts on Cambodia's environment, agriculture, public health and water resources (MoE, 2022). For instance, the occurrence and duration of droughts might change based on future climate conditions and their interplay with local contexts. Some regions might experience longer and more frequent droughts, while others may face shorter and less frequent droughts. Either scenario could have significant effects on local livelihoods.

These climate shifts could have wide-ranging and significant impacts. They could alter river flows and water levels, change the duration and intensity of wet seasons, affect biodiversity, and threaten water-dependent livelihoods. Changes in flood patterns could either amplify or reduce the affected areas. Increased flooding could severely impact larger populations and result in elevated economic losses due to extreme weather events (MRC, 2018).

The climate in the catchment area of the lower Mekong is changing visibly:

- Average annual basin-wide temperatures have increased over the historical record.
- Sea levels near the Mekong Delta are trending upward.
- Annual precipitation appears to be increasing in central-eastern Thailand, while decreasing in other parts of the Lower Mekong Basin (LMB).
- To date, there is no evidence of an increase in the

4 RCP2.6, RCP4.5, and RCP8.5 are Representative Concentration Pathways (RCPs), which are four greenhouse gas concentration trajectories used in the Intergovernmental Panel on Climate Change's (IPCC) fifth Assessment Report (AR5)(add source). They describe different climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. RCP2.6: Often referred to as the "peak scenario", it assumes that global annual greenhouse gas emissions will peak between 2010-2020, with significant decline afterwards. It is considered the most optimistic scenario and aims to limit global warming to 2°C above pre-industrial levels by the end of the century. RCP4.5: This is a "stabilization scenario" where total greenhouse gas emissions peak around 2040, then decline. This scenario is consistent with a world in which some climate change mitigation policies have been implemented, but not as aggressively as in RCP2.6. RCP8.5: This scenario is often referred to as the "worst-case" or "business-as-usual scenario" as it assumes that greenhouse gas emissions will continue to rise throughout the 21st century. This leads to a much higher concentration of greenhouse gases in the atmosphere by 2100, resulting in more severe climate change impacts.

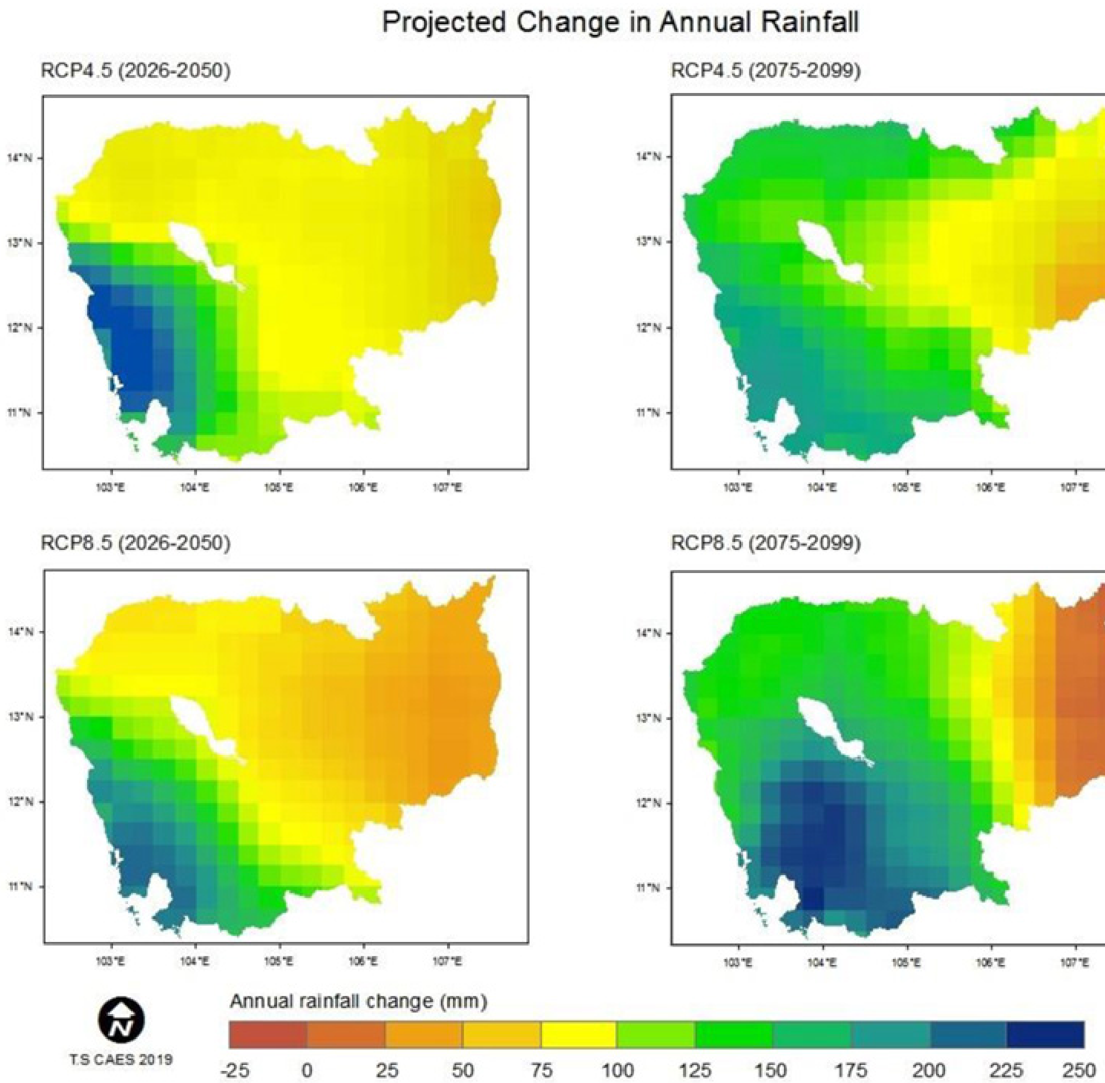


Figure 15. Projected annual rainfall changes by 2100: two climate change scenarios (RCP 4.5 and RCP8.5).
(Source: National Council for Sustainable Development the Ministry of Environment, 2022, p.102).

frequency or intensity of rainfall or tropical storms in the basin (MRC, 2018)[5].

According to the Mekong River Commission (MRC) (2018), over recent decades, the Lower Mekong Basin (LMB) has borne the brunt of intense drought hazards, causing serious economic fallout due to agricultural crop damage, environmental harm, and disruption to livelihoods. These impacts have rippled out, affecting not just farming but also industrial and residential water usage. When comparing successive drought events over the last twenty years, there's a marked increase in the duration and severity of their effects. This stark trend signifies that the Lower Mekong region is currently highly susceptible to droughts, with the situation gradually escalating (Ibid). Moreover, various climate models predict that the LMB could face even more extreme droughts in the forthcoming 30, 60, and 90

5 Annual precipitation appears to be increasing in central-eastern Thailand, while decreasing in other parts of the Lower Mekong Basin (LMB) (MRC, 2018).

years (Ibid). Factors such as decreased rainfall, elevated air temperature, and increased evapotranspiration contribute to this prediction (MRC, 2019).

The MRC (2021), therefore, classifies the 2019 hydrology, flood, and drought events as part of a general trend:

- Characterized by a pronounced climate variability, a tendency for extreme events to occur within short periods of time, and a significant departure from historical observations.
- Unprecedented discharge conditions were observed in the mainstream Mekong River. Base flows of tributaries were exceptionally low.
- Unpredictable climate variations ranged from extreme drought to wetness within short periods of time (MRC, 2021).

Climate change scenarios for the Lower Mekong Basin (LMB), that are based on three potential emission levels (low, medium, and high) and three potential patterns (primarily drier, primarily wetter, and significant seasonal fluctuations) show (MRC, 2017):

- In terms of ecosystems, substantial changes in bioclimatic conditions are projected across the LMB's ecoregions). By 2060, up to 100% of some ecoregions may experience completely novel bioclimatic conditions.
- There is broad consensus on a basin-wide temperature increase across all seasons. The main uncertainties concern the magnitude and rate of this increase.
- By 2060, average annual temperature increases could range from a modest 0.4°C to a substantial 3.3°C, depending on global emissions and the resulting patterns of change.
- Precipitation patterns could increase or decrease, and the magnitude of changes and location of impacts could vary widely. By 2060, average precipitation across the basin could decrease by 16% under a high emissions and drought scenario or increase by 17% under a high emissions and rain scenario.

Although there is evidence that climate change has already had an impact on the LMB region, the precise medium- and long-term impacts of climate change on the LMB, and thus on Kratié Province, remain subject to a high degree of uncertainty. Any prediction of change in the climate must include changes in natural resource use and management, changes in land use patterns, or urbanization trends. Thus, trends such as the current pressures on ecosystems, on fish stocks, and ultimately on the livelihoods of communities and public health might be amplified or take on a whole new quality.

Vulnerability to Climate Change

It is important to acknowledge that the province of Kratié is confronted with a significant challenge to strengthen its resilience to the impacts of climate change and formulate an effective climate change adaptation strategy. The province is classified as being highly vulnerable to climate change, a conclusion drawn from an assessment conducted in line with a vulnerability framework considering sensitivity, exposure, and adaptive capacity (MoE, 2022).

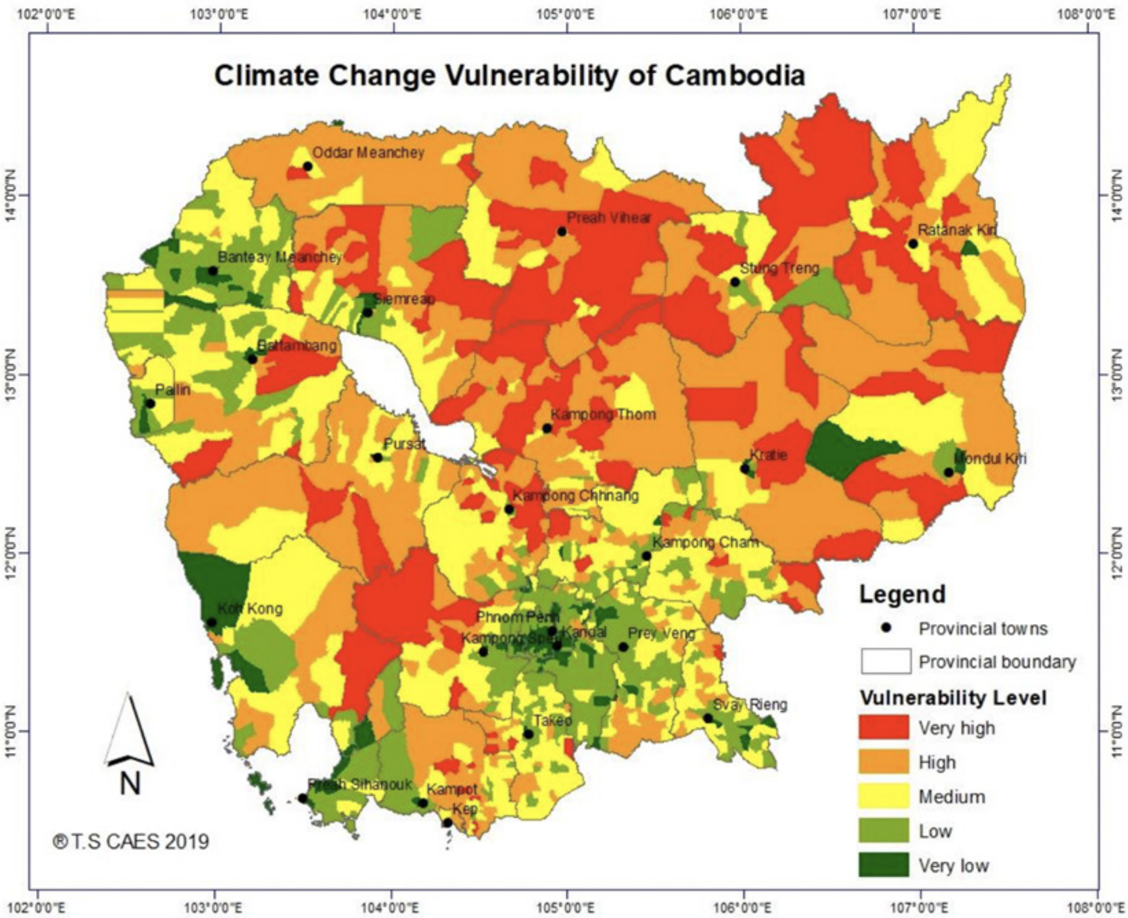
This assessment of vulnerability at the commune level incorporated the nationwide 2017 commune statistics, a comprehensive review of pertinent documents, and expert judgment, abiding by the methodological approaches and guidelines recommended by the United Nations Framework Convention on Climate Change (UNFCCC).

Eight key indicators were consolidated in the assessment, encompassing (i) education level across age groups, (ii) primary occupation types, (iii) household assets and facilities, (iv) degree of remoteness, (v) source of drinking water, (vi) sanitation facilities, (vii) dependency ratio, and (viii) frequency of occurrence of extreme climate events (Ibid).

For Krong Kratié, the municipality, the vulnerability to climate change may be different to Kratié Province as a whole (See Figure 16). Supporting the Ministry of Public Works and Transport (MPWT), under technical guidance of the Cities Development Initiative for Asia (CDIA) a “Climate Vulnerability and Adaptation Assessment for Kratié” was carried out (NIRAS, 2020).

Under the RCP2.6 scenario, the climate of Krong Kratié is not expected to undergo any significant change from 2019 to 2050 (Ibid). Consequently, the incidence and severity of natural hazards, such as floods and droughts are not anticipated to worsen notably from their current levels.

However, the RCP8.5 scenario presents a different situation (See Figure 15). In this case, the average minimum



Hazard	Δ Impact		Vulnerability	Risk	
	RCP2.6	RCP8.5		RCP2.6	RCP8.5
Primary Hazards					
Floods	Medium	High	Medium	**Medium**	**High**
Typhoons	Low	Medium	Medium	**Low**	**Medium**
Storm surge	Nil	Nil	Nil	**Nil**	**Nil**
Sea level rise	Nil	Nil	Nil	**Nil**	**Nil**
Droughts	Low	High	Low	**Low**	**Medium**
Fires	Low	Low	Medium	**Low**	**Low**
Secondary Hazards					
Water shortages	Low	Medium	Medium	**Low**	**Medium**
Food shortages	Low	Low	Medium	**Low**	**Low**
Health problems	Low	Medium	Medium	**Low**	**Medium**
Riverbank erosion	Medium	High	Medium	**Medium**	**High**

temperature is projected to rise by about 1.5°C, from 23.5°C to 25.0°C. Additionally, the average maximum temperature is also expected to increase by roughly 1.7°C, from 33.2°C to 34.9°C. The average annual rainfall is anticipated to increase from the 1684 mm recorded in 2019 to about 1884 mm in 2050. These climatic changes will likely result in more frequent and intense occurrences of floods and droughts.

The hazard-vulnerability-risk assessment reveals that the primary hazards in Kratié, which are most likely to be affected by climate change, include floods and riverbank erosion (Ibid) (See Table 1).

Figure 16. Spatial distribution of climate change vulnerability at the commune level.
Note: There are five vulnerability levels: The color scale ranges from very low (dark green) to very high (red). (Source: National Council for Sustainable Development, the Ministry of Environment, 2022, p.103).

However, in contrast to the results of the study, given the urban transformation process in Krong Kratié in the face of rising temperatures, the authors of this baseline assessment anticipate medium or high vulnerabilities to public health if appropriate adaptation measures are not implemented in the urban area. At the same time, it is also uncertain how the inflow to and thus the water regime in the Lake Area in Krong Kratié will change in the course of the urban development process. Depending on the climate change scenario, this may have considerable effects on securing the livelihoods of local communities.

Table 1. Hazard Vulnerability Risk Assessment.
Note: Example of risk results for an inland riverside city from "Climate Vulnerability and Risk Assessment. (Source: NIRAS, 2020, p.8).

The Mekong River - The Changing Life Flow of Krong Kratié

Key Messages of Section

1. The Mekong River is a socio-economic artery for the economic and social development of the Mekong Basin region. A comprehensive understanding of the characteristics of the river and its catchment is crucial to the development of Kratié Province and Krong Kratié itself.
2. Any urban planning for Krong Kratié that aims to ensure water protection and livelihoods and to develop tourism should make strong reference to the characteristics of the Mekong River and its eco-systems.
3. The predictable nature of the River's hydrological regime is now uncertain as it has been undergoing increasingly dynamic development, especially since the 1980s.
4. Changes in land-use patterns due to urbanization, large-scale conversion of the River's wetlands and forests, the use of river water, especially for hydrological infrastructure and climate change are significantly altering the ecosystems and flow regime of the Mekong River.
5. Without safeguards, these changes may have a significant impact on the primary livelihoods of already vulnerable populations living in the Lower Mekong Basin, such as those in and around Krong Kratié.

Natural Characteristics

Spanning roughly 4,800 km in length and draining a catchment area of 795,000 km^2, the Mekong River is a vital resource for over 60 million people residing within its basin (See Figure 17). The river greatly influences their daily lives and significantly contributes to the economies of the six countries it flows through. Ecologically significant areas encompass a range of different ecosystem types, including rivers, wetlands, forests and grasslands.

The Greater Mekong region can essentially be segmented into two sections:

- The Upper Basin, located in Tibet and China (where the river is referred to as the Lancang Jiang), and
- The Lower Mekong Basin encompassing the part of the river that flows downstream towards the South China Sea, traversing Myanmar, Thailand, Laos, Cambodia, and Vietnam.

Since the 1980s, the Mekong River Basin has been undergoing increasingly dynamic socioeconomic and ecological changes. A growing population and rising wealth lead to a higher demand for water, energy, and food, which in turn drives land-use changes. Rapid urbanization results in a swift conversion of river zones and wetlands: forests being transformed into agricultural areas, and river valleys being used for the development of hydroelectric capacities are the most obvious changes.

The scale and impact of this transformation vary significantly across the Basin. Despite the momentum of urbanization, a majority of the 60 million inhabitants in the Lower Mekong Basin still reside in rural locales, primarily near rivers, lakes, and wetlands. For these communities, the gathering of fish and other wetland resources remains a vital component of their livelihoods (Meynell, et al, 2017).

Overall, it's worth noting that the Mekong River Basin's water resources are less comprehensively understood and developed compared to other major river basins globally, such as the Danube, Nile, and Amazon. Consequently, it presents a significant challenge to depict the various interdependencies and the specific impacts of the widespread changes, including the effects of climate change. Nevertheless, clear trends of changes can be discerned (Evers & Pahtirana, 2018; Campbell, 2023).

Figure 17. Main reporting hydrological stations along the Mekong River (Source: MRC, 2021).


N
Chiang Saen
Luang Prabang
Paksane
Chiang Khan
Vientiane
Nong Khai
Thakhek
Nakhon Phanom
Savannakhet
Mukdahan
Khong Chiam
Pakse
Stung Streng
Kompong Luong
Kratie
Prek Kdam
Kompong Cham
Bassac Chaktomouk
Neak Luong
Koh Khel
Tan Chau
Chau Doc
0 100 200 300 400 500 km

Hydrology and Flow Regime of the Mekong River

The Mekong River has an average annual discharge of approximately 475 cubic kilometers (km^3) (MRC, 2009). By the time the Mekong reaches Cambodia, over 95% of its flows have already merged with the River. From this point downstream, the landscape flattens, and water levels, rather than flow volumes, dictate the distribution of water across the terrain. This results in a unique "flow reversal" into and out of the Tonle Sap or Great Lake via the Sap River. This is driven by the seasonal cycle of fluctuating water levels at Phnom Penh (MRC 2005) where three rivers converge: the Mekong, Bassac and Sap rivers.

Encompassing an area of approximately 795,000 km2, the Mekong Basin spans six countries but the water input from these countries is not equal. The accepted estimates of water runoff contribution from each country are as follows: China contributes 16%, Myanmar 2%, Laos 35%, Thailand and Vietnam each add 18%, while Cambodia supplies 11% (Osborne, 2004).

For many centuries, the Mekong River's flow regime has been predictable and had stable flow patterns. This consistency in river flow is one of the factors that have made the Mekong River a crucial resource for those relying on it for their livelihoods, including fishers, floodplain farmers, and river bank gardeners (Campbell, 2023).

However, the hydrology of the Mekong River is currently changing, principally attributed to up-stream flow modifications through the construction of dams in the Upper Mekong Basin and by land-use changes. Reservoir developments in the Basin have caused a significant change in the flow regime of the Mekong River and are contributing to the observed substantial decrease in sediment concentrations.

Dry season flows have become more substantial while wet season flows have diminished (See Figure 18). These shifts are more apparent in the river's upper reaches and lessen downstream, yet these changes are unlikely to be due to climate change at this time. Also, there have been very significant changes in vegetation cover, forests, biodiversity, and ecosystems across the Lower Mekong Basin (MRC, 2018).

In future, alterations in rainfall patterns could have enduring effects on river flow levels. Projections for the medium- and long-term impacts of climate change depend on the climate models used with the assumptions associated with them. At the same time, projections of changes in the River's flow regime must include, among other things, different scenarios that consider infrastructure development and changes in land-use patterns.

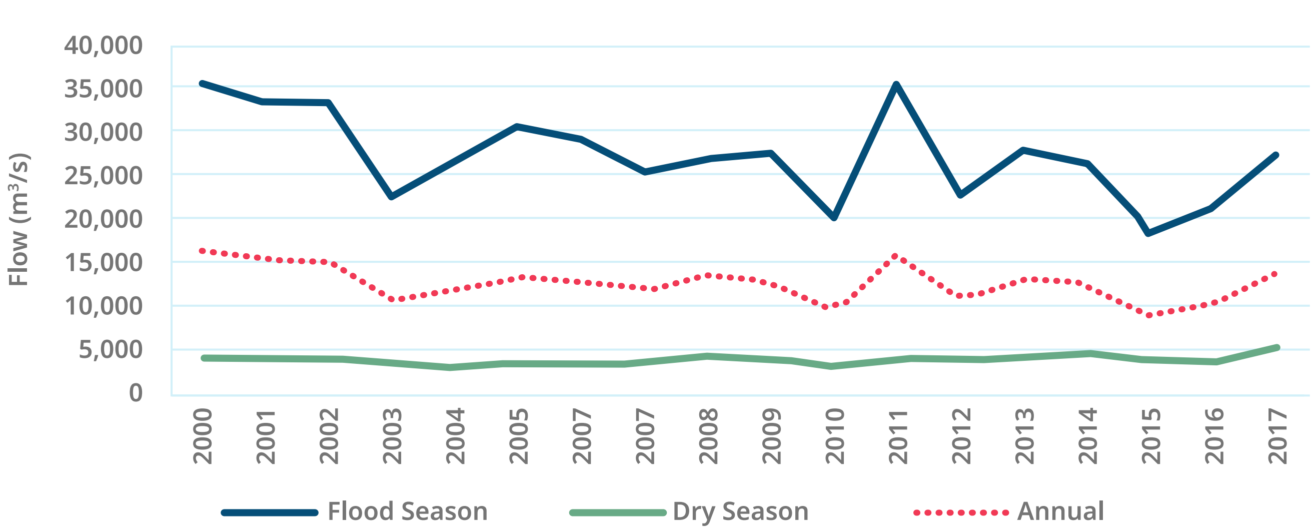
Wetlands Associated with the Mekong River

The Mekong River Basin's wetland system—consisting of diverse swamps, marshes, lakes, floodplains, and peatlands—is a beacon of biodiversity (See Figure 19). These wetlands not only serve critical ecological functions, such as water purification, flood regulation, and carbon storage, but they also play a pivotal role in supporting local economies and providing for the region's food security, with those in close proximity to the urban area assisting in mitigating floods and heat island effects.

Of the LMB's total land area, approximately 42% is classified as wetland, with natural wetlands accounting for 56,000 km^2 of this area (MRC, 2018). The rest primarily comprises man-made rice paddy fields. As of 2010, the LMB retained just over 100,000 km^2 of wetlands, and the Mekong River Commission estimated that less than 2% of the Mekong Delta's original wetland area remained intact (MRC, 2019).

Human activities and climate change are exerting considerable pressures on the Mekong River Basin's wetlands. Expansive deforestation, wetland conversion into agricultural and urban lands, unsustainable fishing practices, and the construction of hydroelectric dams all contribute to these ecosystems' degradation and loss. These changes disturb the river's natural flood cycle, adversely impacting the wetlands' biodiversity and the livelihoods of communities

Figure 18. Stream Flow at Krong Kratié
(Source: MRC, 2019)



dependent on them. Furthermore, wetland loss can heighten the impacts of climate change by diminishing the region's carbon absorption and flood regulation capabilities.

MRC expects a further decline in wetlands unless there is a concerted effort to better manage the basin’s landscape and preserve key habitats (Ibid).

Biodiversity

The biodiversity of the Mekong and its wetlands is second only to the Amazon and Congo rivers (Meynel, 2017). It is believed that the Greater Mekong Region harbors an astounding 1,148 fish species, alongside 20,000 plant species, 430 mammals, 1,200 bird species, and 800 reptile and amphibian species (Campbell 2013).

Home to the world's most significant inland fishery, the Mekong Basin yields 2.8 Mt of fish annually, with 1.9 Mt sourced from the capture fisheries within the wetlands (MRC, 2007). These fisheries are vital for regional food security, providing the primary source of protein for 65 million people. With annual freshwater fish catches exceeding 2.2 Mt, the fisheries’ first sale value ranges from USD 3.6 to 6.5 billion (2009), with retail markets approximately doubling this value (Null et al., 2021).

The loss of wetland areas combined with infrastructure development, habitat degradation and the introduction of exotic species, overexploitation and an illegal wildlife trade has likely contributed to a considerable loss of species and an increase in the number of threatened species. Currently, 14 species are listed as critically endangered (including the Irrawaddy dolphin and Mekong giant catfish), 21 species are listed as endangered and a further 29 species are considered vulnerable (MRC, 2019). There are increasing reports that dwindling fish stocks are posing a threat to the livelihoods of fishing communities in north-eastern Cambodia, encompassing the region of Krong Kratié (Try, 2023). The net preserve value of the fisheries sector is expected to have declined by 16.5 million by 2020 and 22.6 million by 2040 in all lower Mekong countries: Cambodia, Lao PDR, Thailand and Viet Nam (MRC, 2018).

Hydropower

Hydropower developments contribute significantly to the changing flow regimes of the Mekong River. Hydropower development is a crucial backbone for energy security and the economic and social development of the region.

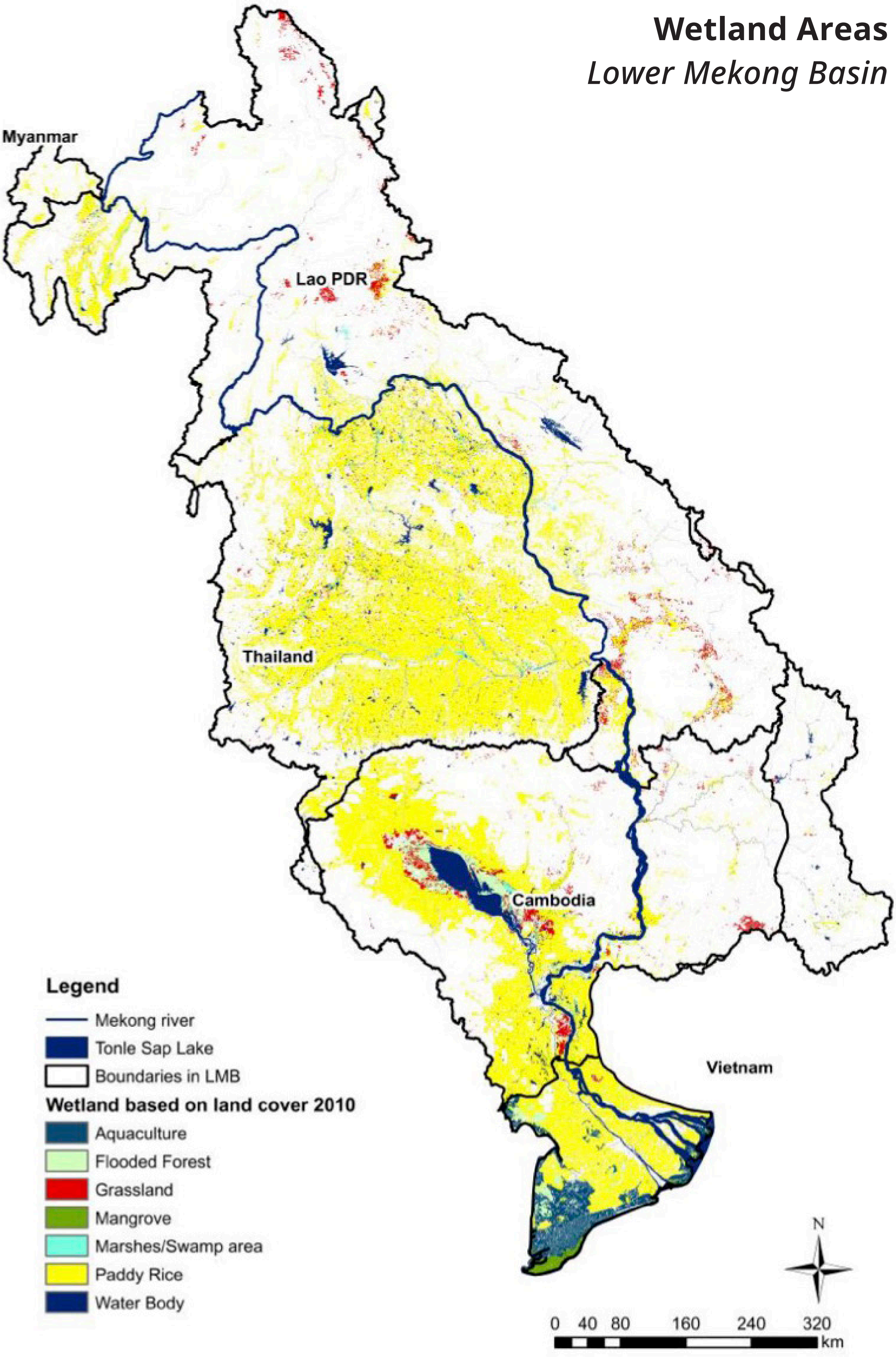


Figure 19. Wetland areas of the LMB (Source: MRC, 2019, p.56).

The Mekong's powerful flow and elevation changes make it ideal for generating hydroelectric power. The estimated potential for hydropower in the Mekong Basin's range between 53,000 and 59,000 megawatts (Null et al., 2021). As per the CGIAR on Water, Land and Ecosystems (WLE) project in 2020, there are already 241 large dams in the Mekong Basin, with an additional 29 under construction and another 91 planned (Ibid).

Hydropower development in the so called 3S Basin with its Sekong, Sesan, and Srepok rivers exemplifies these challenges and the alterations to river flow downstream towards Krong Kratié. The Basin drains vast regions of southern Laos, Vietnam's Central Highlands, and northeastern Cambodia and is a main tributary of the Mekong River. Despite accounting for just 10% of the Mekong River's watershed area, it contributes up to 25% of the streamflow and sediment load (Null et al., 2021). This illustrates its exceptional significance to the ecology and fisheries of the Mekong River.

However, the development of hydropower is not without unintended impacts, such as substantial alterations to the River's natural flow regime. Higher dry season flows and lower wet season flows, most evident in the Mekong's upper reaches, are attributed mainly to upstream flow modifications due to the construction of these dams in respect of the management of the dams' water flows. This has significant impacts on the River's ecology and the livelihoods of communities that depend on its resources. The disruption to the habitats of migratory fishes and other aquatic life that affect local fisheries and biodiversity is widely observed (Osborne, 2022; MRC, 2019).

Figure 20. [below] Water level in metres at Krong Kratié from 2014-2019.
(Source: MRC, 2023 accessed June 12)

Figure 21. [right] Living with floods - detached stilt house in residential area of Krong Kratié (Source: Own Work, 2019)

Floods and Adaptation to Floods

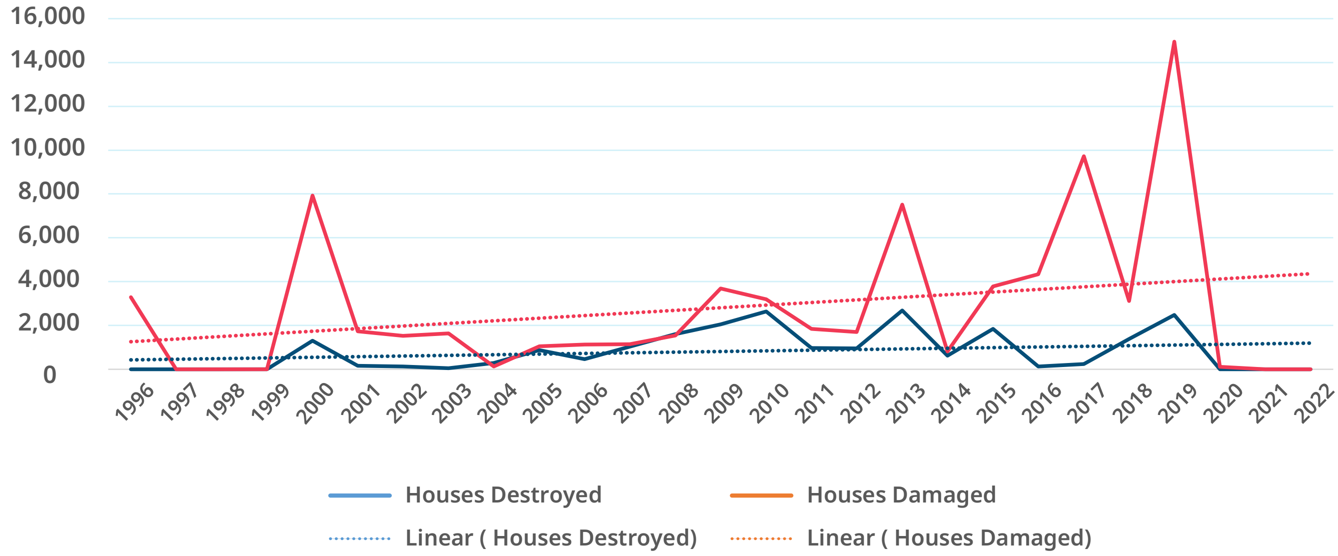
Flooding is part of the annual pulse of the Mekong River and is a lifeline for its ecosystems and its inhabitants. Figure 20 indicates the regularity of flood pulses experienced by Krong Kratié from 2014 to 2019, generally peaking in September of each year. The functions and benefits of floods are manifold: they create the basis for a rich diversity of plant and animal species, they enable important habitats and migration opportunities for fish, they provide sediment to fertilize land, they are the basis for water-intensive agriculture, and they contribute to the recharge of groundwater bodies.

Traditional flood management strategies along the Mekong River have been continuously developed over generations. "Living with floods" was the more or less unspoken philosophy for individuals, communities and institutions that sought to strengthen their resilience and adaptability to flood events (See Figure 21).

Though flood induced hazards and disasters have been inherent to living conditions in the Mekong River Basin for centuries, factors such as inadequate infrastructure development, construction activities in flood-prone areas, land use changes that disturb river flow regimes, inappropriate land development, and climate change may result in an increased vulnerability of the population, public and private assets, and the environment. There has been a general increase in the numbers of houses destroyed or damaged by flooding in Cambodia over the past 25 years (See Figure 22).

Figure 22. [left] Houses destroyed and houses damaged by flooding in Cambodia. (Source: CamDi, 2023)

Figure 23. [right] Location of Krong Kratié within different watersheds and its elevation profile
(Source: Own Work based on Global Administrative Areas (GADM), 2012; Digital Chart of the World (DCW), n.d.; CNES Airbus, n.d.; Maxar Technologies, 2023; NASA Shuttle Radar Topography Mission (SRTM), 2013; & Shuttle Radar Topography Mission (SRTM) Global, n.d.)



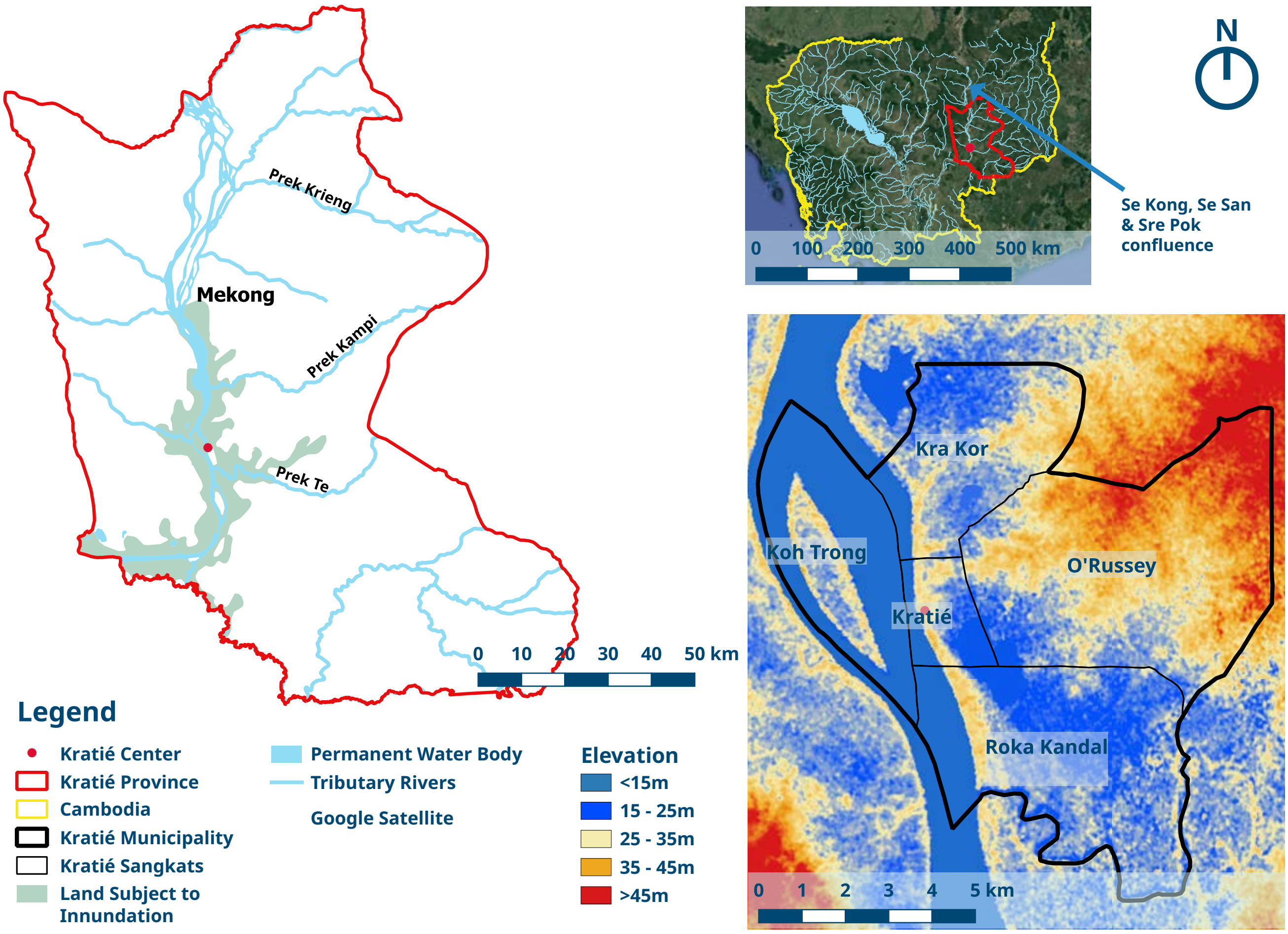
The Mekong at Krong Kratié

Hydrology, Water Resources and Topography

The landscape surrounding Krong Kratié is part of the river valley that is 12 km wide and features only minor elevation changes, except for some secluded places, which are elevated due to the underlying geology (Campbell, 2009) (See Figure 23).

Krong Kratié is located quite far downstream on the Mekong River, and downstream of the tributary Se Kong, Se San, and Se Pok rivers. In addition to the Mekong River, Kratié is also largely influenced by the river catchment of the Prek Te to the south of the municipal area.

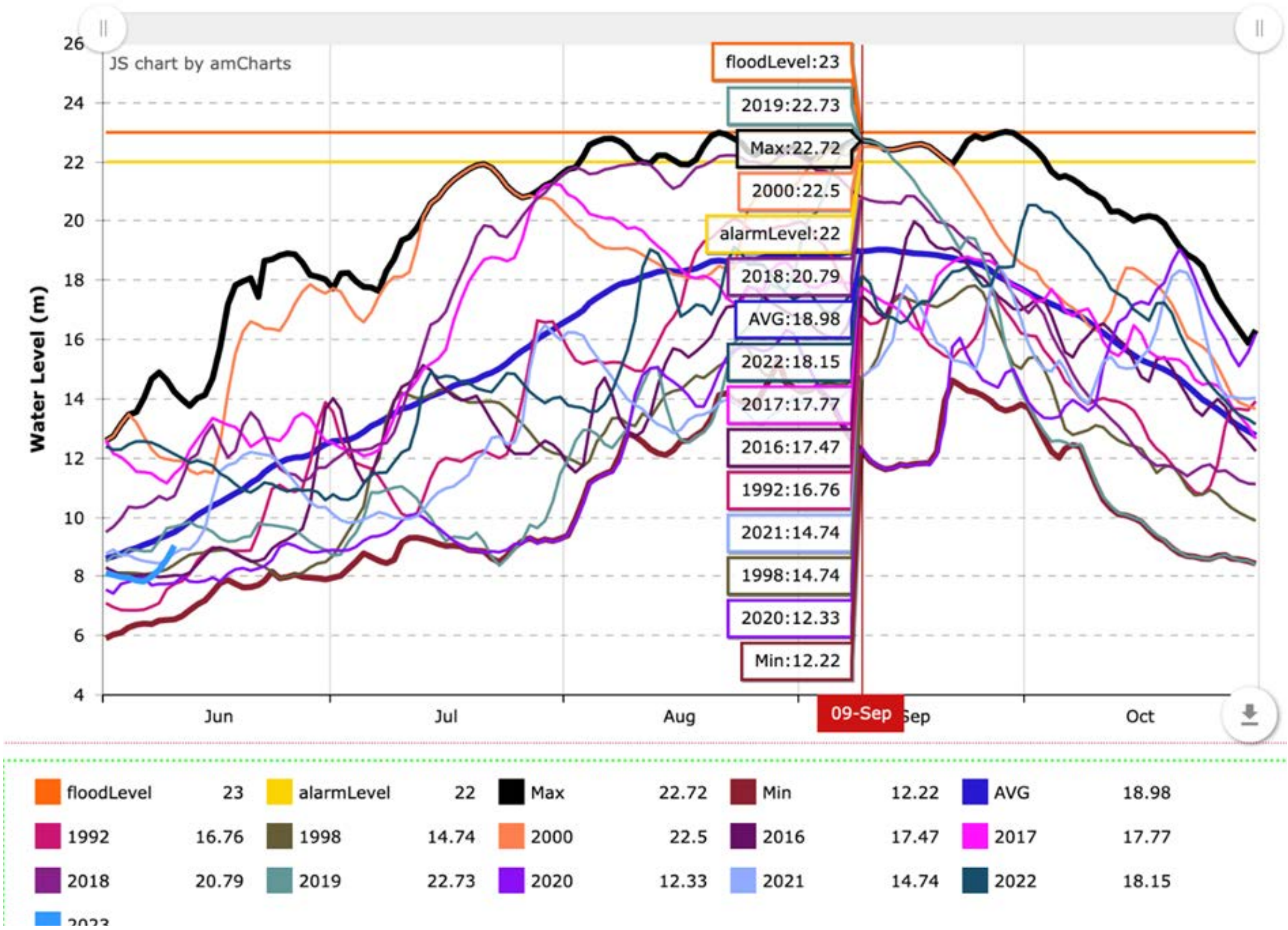
Krong Kratié itself is situated at 19m above sea-level (Climate Data for Cities Worldwide, 2023). South of Strung Treng, the river features alluvial accumulation from the quaternary with about 4-5 km width and only slight elevation changes. The underlying sediments are between 10-20m thick (Own Work, 2023). At Krong Kratié, the riverbed widens to around 12km. Spread around the city are elevated areas which are sandstone blocks or basalt fragments (Campbell, 2009).



By the time the Mekong River reaches the municipality, it carries with it 91% of its average streamflow volume (MRC, 2005). Downstream flow in the Mekong River at Krong Kratié is about five times larger compared to the flow at the Chinese border, indicating more rainfall than consumption and evaporation in the catchment areas of Cambodia, Lao PDR, Thailand, and Viet Nam (Ibid).

From 2005 to 2015, the recorded flood peak flow rates at Krong Kratié ranged from 30.421 cubic meters per second in 2015 to 57,025 cubic meters per second in 2011. Over the span of 2000 to 2017, the mean annual flow rate was noted to be 12,756 cubic meters per second. During the dry season, this rate decreased to 3,874 cubic meters per second, while during the flood season, it increased significantly to 27,319 cubic meters per second (MRC, 2019) (See Table 3).

Records of water levels at Krong Kratié from 1992 to 2022 indicate peaks in the month of September with the average being just under 19m with the 'alarm level' exceeded in 2019 and 2000 at over 22m with the maximum height being 22.72m. Nevertheless, flood levels at Krong Kratié have not



been exceeded within this time range although this does not mean that parts of Krong Kratié are not flooded for periods of the year (See Figure 24).

The streamflow station at Kratié indicates a trend of marginally decreasing annual flows, a minor increase in dry season flow, and a decrease in flood season flow (See Table 2 & Table 3). These trends, observed over a relatively short period, are likely a result of human activities.

A report depicts the average annual flood "pulse" estimates for Krong Kratié under the baseline (2013) and future climate change conditions. As illustrated in Figure 25, an increase of about 20% is projected. This escalation could result in an increase in the annual exceedance probability of a "major" flood level from 0.05 (1 in 20 year flood event) to roughly 0.75 (a flood event occurring three out of four years on average) (USAID, 2013).

Most likely, in addition to the effects of climate change, the extensive land use transformations in the Basin will significantly influence the flow regime of the Mekong at Krong Kratié. As a result, there is considerable variation in predictions of the flow regime of the Mekong River at Krong Kratié. For example, peak flows may increase or decrease within a range of up to 3 meters each, and the total river flow may decrease by up to 38% or increase by up to 28%. At first, these range of projections may not allow for clear conclusions regarding the long-term changes in the river flow of the Mekong River and, in particular, in Krong Kratié (See Table 4).

Nevertheless, an analysis of this data highlights the need to prepare today for profound changes in river flow and the associated impacts on water security in the future. This includes, most importantly, strengthening infrastructural and urban measures to build resilience to flooding events..

Figure 24. Observed water level at Krong Kratié
Note: Observed water level for selected years between June and October, with an exemplary indication for September 9th.

(Source: MRC Monitoring Portal, 2023 June 23)[6].

6 Flood level is defined as a situation where the water level reaches a full river- bank and overland flow of the low-lying area.

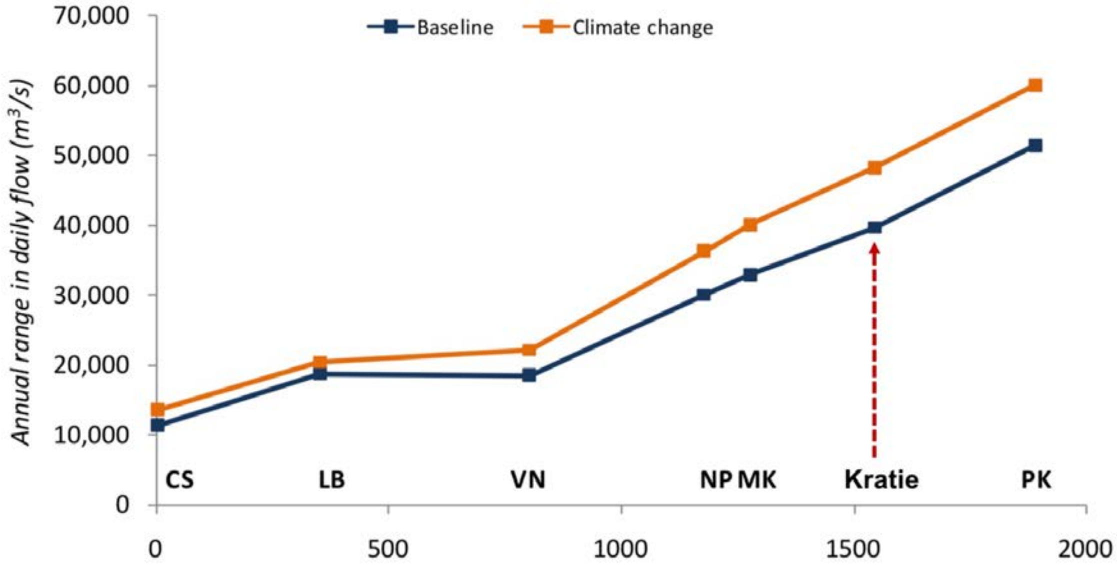


Figure 25. Average annual flood pulse of the Mekong River under baseline and climate change conditions
(Source: ICEM, 2013, p. 97)

Station	Trend (% per year)		
	Annual	Dry Season	Flood Season
Krong Kratié	-15%	7%	19%

Table 2. Changes in observed flows and trends for the main streamflow stations over the period 2000-2017 in percentages (%)
(Source: MRC Flow Monitoring Records, n.d. as cited in MRC, 2019, p.30).

Station	Trend (% per year)			Average flow (m^3/s) Trend (m^3/s per year)		
	Annual	Dry Season	Flood Season	Annual	Dry Season	Flood Season
Krong Kratié	12,756	3,874	27,319	-186	28	-511

Table 3. Observed flows and trends for the Mekong River mainstream stations over the period 2000-2017
(Source: MRC Flow Monitoring Records, n.d. as cited in MRC, 2019, p.30).

Station	Trend (% per year)
River flow	-38% and +28%
Water level	-1.95m and +1.29m
Flood peak season flow	-30% and +43%
Flood season peak	-2.83m and +2.96m
Minimum 1 day water level	-0.18m and +0.90m
Minimum 1 day flow	-21% and 79%

Table 4. Projected changes in the river flow regime of the Mekong River at Krong Kratié for the year 2060
Note: The hydrological impact range indicates projected changes resulting from both cli- mate change and devel- opment scenarios

(Source: Own Compilation based on MRC, 2017, p.9)

Krong Kratié – Urban Transformation within a Changing Economic, Social and Ecological Landscape

Key Messages of Section

1. Krong Kratié faces the challenge of redefining its role, functions and responsibilities amidst policy reforms, economic growth, and population expansion. A problem that is faced by many secondary and tertiary cities across the region.
2. Ongoing urbanization is transforming Krong Kratié's landscape, presenting new challenges and opportunities as it leads to housing densification, surface sealing through new developments, and expanded infrastructure, most notably in its four mainland sangkats.
3. The widespread use of concrete, asphalt, and masonry provides benefits that include durability and safety, but also results in environmental impacts, potential heat island effects and significant changes in the town's hydrology, including increased runoff and the contributing to the pollution of water bodies.
4. Current urban growth scarcely adheres to urban development guidelines as implementing Prakas (official proclamation) are not available. The existing urban masterplan for 2030 only partially addresses the water challenges faced by the city.
5. To fully capitalize on Krong Kratié's charm as a relaxing place to live, do business, and attract tourists while guaranteeing thriving livelihoods for its residents, it must interweave strategic management of urban water resources into its development blueprint as a crucial component for fostering a vibrant and livable city.

General Features

Located roughly 240 km to the northeast of the Cambodian capital, Phnom Penh, lies Krong (municipality) Kratié (See Figure 1). Encompassing an area of 88.6 km^2, the city has a strategic position along the banks and floodplain of the Mekong River.

In terms of demographic composition, Krong Kratié presents a stark contrast to its larger counterparts, such as Phnom Penh or Battambang. It maintains the characteristics of a mid-sized town with a significantly smaller population size.

Kratié's function as a "Krong" is derived from its role as the host of the provincial capital and administration. This endows the Krong with a key administrative function within the regional governance structure, serving as a hub for the administration of province-wide policies and directives.

The overall Krong Kratié features all necessary “Urban Criteria” established by the Ministry of Planning, although Sangkat Koh Trong does not fulfil all social and economic requirements to be considered “urban” and very little urbanization processes concern the island.[7]

From an administrative perspective, Krong Kratié is sub-divided into five "Sangkats" or communes, which collectively comprise a total of 16 villages (CIUS, 2019). This hierarchical structure of governance allows for efficient administration at both the city and local levels.

Given its geographical characteristics and environmental challenges described in previous sections, Krong Kratié can be viewed as a case study for water sensitive urban planning across Cambodia. It's important to note that out of the current 29 urban municipalities or cities in Cambodia, 16 are situated on riverine floodplains linked with the Mekong catchment. The lessons learned from Krong Kratié can potentially be applied to other municipalities in the country, offering valuable insights on how to integrate water sensitive strategies within the broader context of urban planning and development.

7 MoP Criteria for Urban Designation: (2nd Reclassification of Urban Areas 2011)

- The 27 krongs/cities statutorily declared in the 2008 Sub-Decree 1st Mandate;
- Any communes/sangkats meeting 3 criteria:
  - » Population density exceeding 200/sq.km;
  - » The % of population (both sexes) employed in agriculture is less than 50%; and
  - » Total population exceeding 2,000.

Drivers for Economic and Social Development in Krong Kratié

Agriculture: As a predominantly rural province, a substantial portion of Krong Kratié's population depends on agriculture for their livelihoods either for cash economy or subsistence. Krong Kratié, as a provincial center, serves as a key marketplace for local produce and commercial goods. Furthermore, the presence of agrobusinesses in the province play a major role in the Krong's overall development (See Annex II, Figure 1).

Fisheries: The Mekong River, teeming with diverse freshwater fish species, provides a critical source of income and nutrition for local communities, energizing the local economy. However, sustainable fishing practices are essential to safeguard this resource (See Annex II, Table 2).

Tourism: Kratié Province is known for its population of Irrawaddy dolphins, a primary tourist attraction. The local government is advocating for ecotourism in the region to attract more tourists and stimulate economic growth. Nevertheless, it's evident that a more comprehensive approach, one that leverages the region's rich biodiversity, is needed to extend beyond just being a 'one-stop' location. The Krong's relaxing environment, local eco-tourism attractions and examples of Khmer and colonial architecture elevate its status as a regional hub, drawing tourists and encouraging cultural exchange (See Info Box 3). Data from the Ministry of Tourism for 2011 to 2018 shows a doubling of domestic tourists and an increase of approximately a third for international tourists (CIUS, 2019). Prior to the COVID-19 pandemic closing borders, visitor numbers for 2019 indicate a continued increase. As of 2020, Krong Kratié had 16 restaurants, eight markets, 15 hotels and 30 guesthouses employing slightly more than 300 people of whom 208 were female (See Annex II, Figure 3) (CDB, 2020).

Infrastructure Development: In Krong Kratié synergies with the Greater Mekong Subregion (GMS) program aim to stimulate local and national economic development. Infrastructure projects, such as an improved drainage system, wastewater treatment facilities and solid waste management, as well as city beautification measures, are currently underway or under-consideration in order to enhance the city's livability and attractiveness for both residents and visitors. However, as this baseline study indicates, sustainable infrastructure development must not only ensure the provision of basic services but also protect private and public investments and livelihoods.

Resource Extraction: Although Kratié Province appears to possess considerable untapped mineral resources, their future exploration and extraction could significantly impact the province's economic development. However, the environmental and social implications of resource exploitation will be a critical consideration for the province's and krong's development trajectory.

Foreign Direct Investment (FDI): Kratié Province has successfully attracted FDI, especially in the agriculture and manufacturing sectors with its implications for local economic development and job creation. The Krong's overall attractiveness and sustainable infrastructure development will undoubtedly contribute to making it an attractive investment location and a thriving business hub.

Population

Administratively, the Krong is divided into five "Sangkats", which are themselves made up of a total 16 villages. With the number of villages in a sangkat varying between two and five. One of the Sangkats (Koh Trong) with two villages (Kbal Koh, and Chong Koh) is located on an island in the Mekong River and this Sangkat is the least developed and has the most deficient water related infrastructure.

As per the 2020 Commune Database (CDB), the population of Krong Kratié reached 31,843 (15,521 males and 16,322 females) with a total of 7701 families (See Figure 27). With 37% of the population under the age of 18 years and a further 8% considered as >61 years of age. 895 of the total 7,701 families are headed by women (12%).

The CDB (2008 to 2020) shows that the average size of a family has decreased over the last decade in both Kratié Province and Krong Kratié. While the average family size in Krong Kratié was still five persons in 2008, the average size of a family in 2020 decreased to only just over four persons. Overall, 17% of all families in Krong Kratié are reported as being poor as per the official Identification of Poor Households (ID Poor) mechanism. The highest percentage of poor families are found in Sangkat Koh Trong (20%) and only 14% of families are considered poor in Sangkat Kratié, marking the lowest number of poor families in comparison to all the sangkats (RGC, 2022).

Info Box 3. Tourism in Krong Kratié

Today, Kratié is still a relaxing destination with remaining examples of colonial architecture although some of these are disappearing. Generally, Krong Kratié is famous as the 'jumping-off' point for visiting the endangered Irrawaddy dolphins in Kampi 20 km to the north of the town and up to the Laos border. Some cycle tours visit the surrounding area. For many travelers, the town is a convenient stop en-route to and from Lao PDR and the thousand islands.

Within the town, the quay area is an attractive location for both visitors and locals, who use the riverside area for exercise and socializing in the mornings and evenings. Only a small number of boats operate on the Mekong River itself and besides sand dredging, the main traffic is between the quay and Koh Trong Island, a popular laid back site for tourists enjoying homestays, cycling and a car-free experience. River cruises from further south once plied the Mekong River in the 1950s and 1960s and this business could become popular again with tourists and travelers eager to avoid road travel if a port is established in Kampong Cham (Simon-Barouh, 2004; ADB, 2017).

Krong Kratié is not currently a mass tourist destination and is more widely visited by independent travelers, business people and Cambodians from elsewhere in the country during particular festivals, such as Khmer New Year.

While dolphin watching is popular, the endangered nature of these animals, and, therefore, the attraction's sustainability should be considered and opportunities to diversify should be identified. For example, greater promotion of Boeung Romleach and Koh Trong might offer popular eco-tourism experiences. This will require urban planning and infrastructure development be provided in a way that enhances the visitor experience as well as the livability of the Krong for the residents (ADB, 2017).

In recent years, the Krong has seen a steady growth in population and current data predicts an ongoing population increase. Koh Trong shows the smallest change in population in the period from 2008 to 2020 (+ 0.5%). Sangkat Kra Kor, on the other hand, shows the largest rise in population in the same period, with an increase of 16.3%. While the population in O'Russey and Roka Kandal increased almost identically by 10.2% and 10.8%, respectively, Sangkat Kratié shows a growth of 4.6%. This growth can be attributed to several factors, including increased economic opportunities and improved healthcare.

Sangkat O'Russey as of 2020 had the highest population with 13,111, followed by Sangkat Kratié with 6,475 people. Third and fourth most populated are Sangkat Roka Kandal

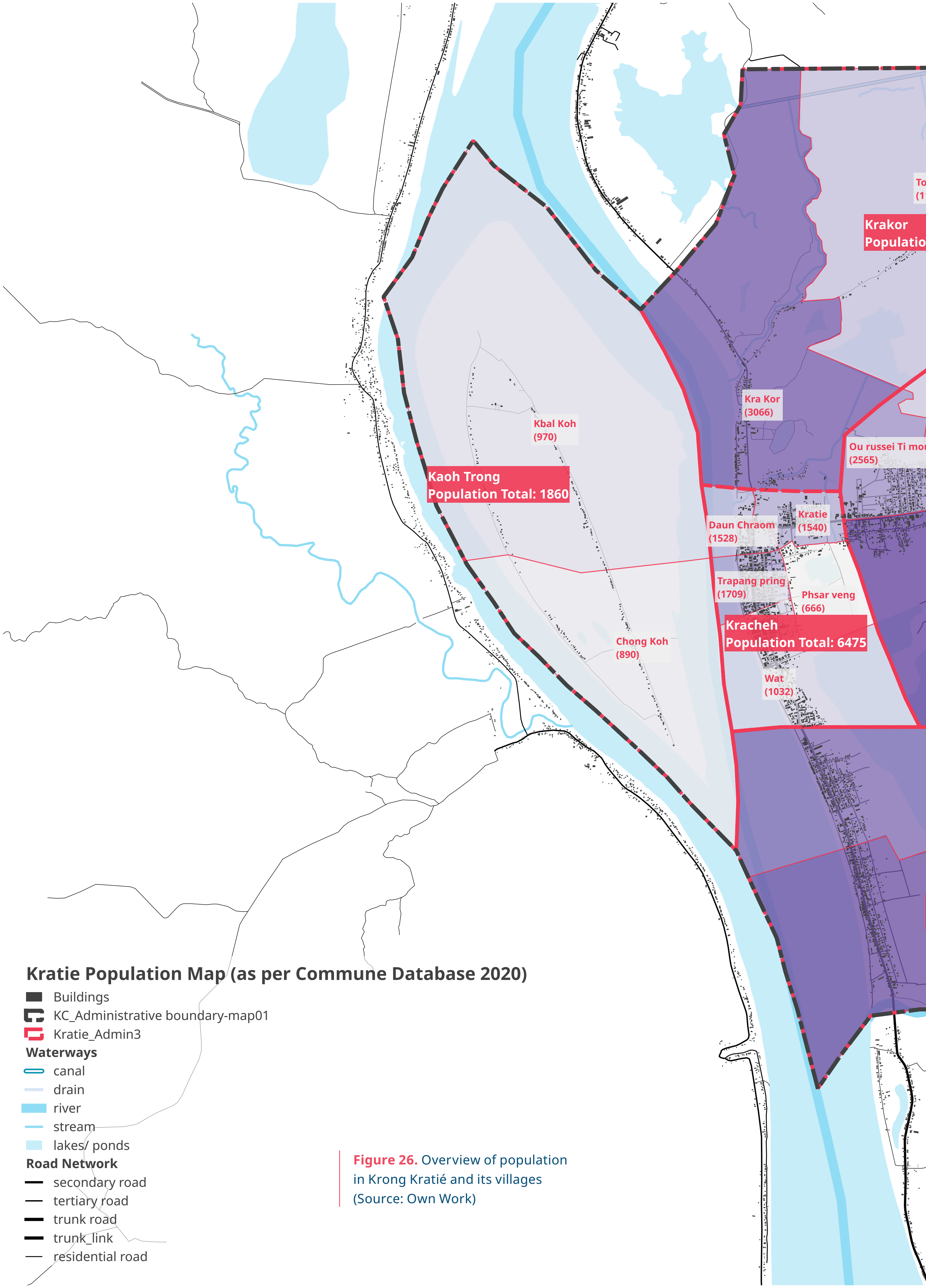
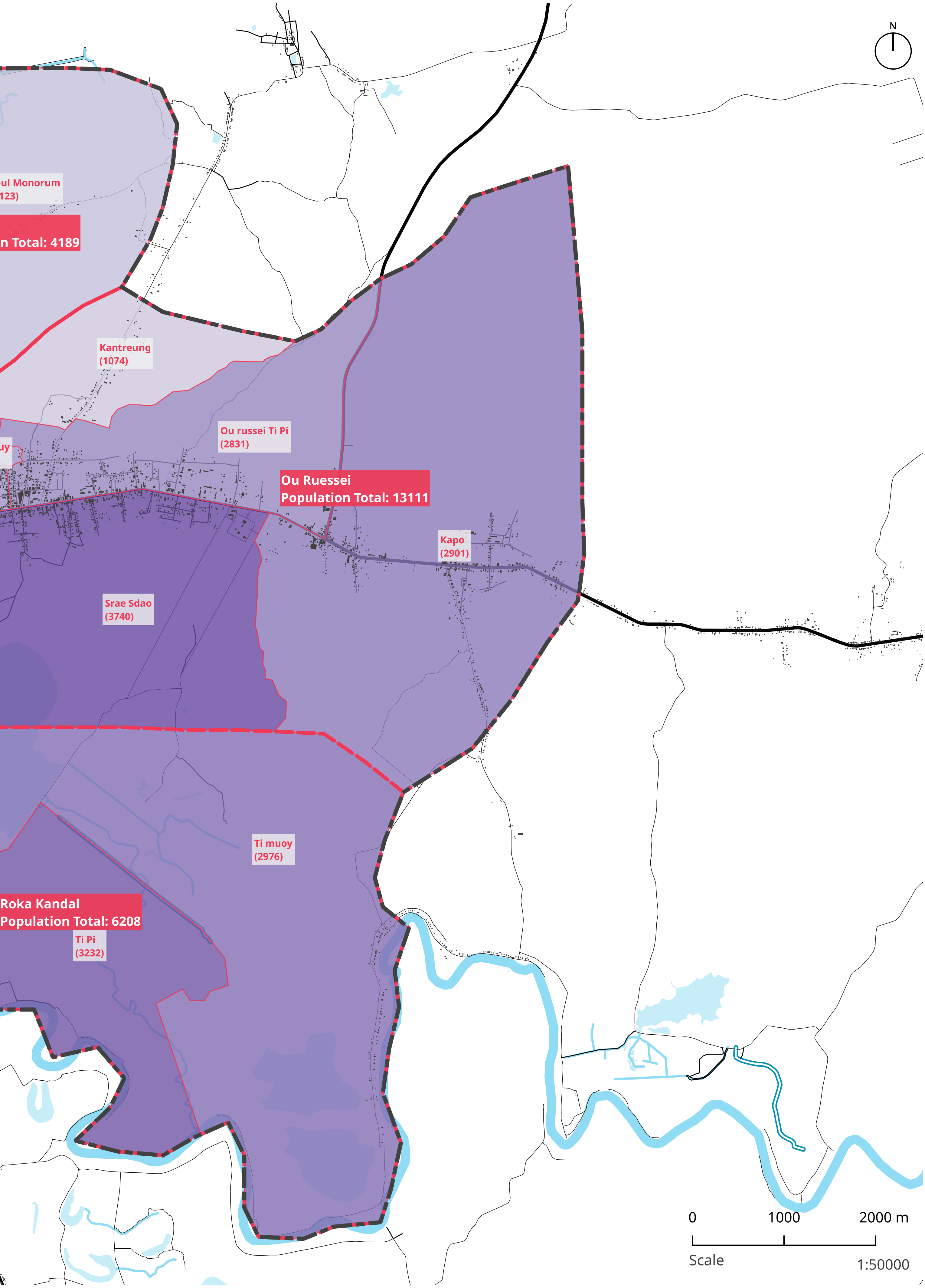


Figure 26. Overview of population in Krong Kratié and its villages (Source: Own Work)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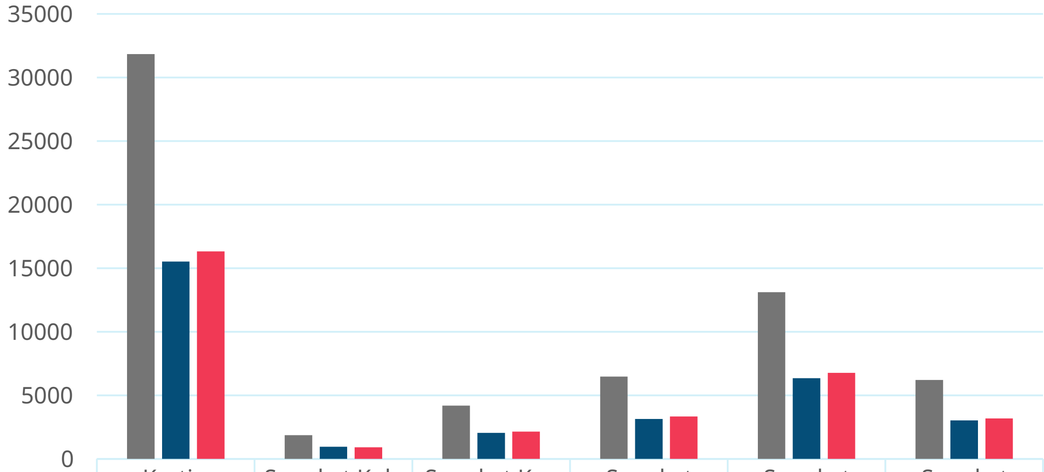


	Kratie Municipality	Sangkat Koh Trong	Sangkat Kra Kor	Sangkat Kratié	Sangkat O'Russey	Sangkat Roka Kandal
Total	31843	1860	4189	6475	13111	6208
Male	15521	949	2052	3142	6350	3028
Female	16322	911	2137	3333	6761	3180

■ Total ■ Male ■ Female

Figure 27. [top] Total population, total males, and total female for Krong Kratié 2020 (Source: Own Work based on CDB 2020)

At a Glance Municipal Area (Krong Kratié)		
AREA	:	Approximately 88.6 km² (land area 72 km²)
SANGKAT	:	5 Sangkats (Kra Kor, Kratié, Roka Kandal, O'Russey, Koh Trong)
VILLAGES	:	16 Villages

(total population of 6,208 people) and Sangkat Kra Kor with a population of 4,189 people. With a total population of just below 2000 people, Koh Trong is the least populated Sangkat (See Figure 26 & Figure 27).

The History of Urban Development in Kratié

Krong Kratié's urbanization has evolved gradually through spatial expansion and densification. Originally, it started as a small settlement along the Mekong River in the 19th Century. During the French colonial period, it transformed into an administrative and trading center with the construction of government offices, a market, and residential structures. In the early 20th century, the town experienced significant urban development, replacing wooden houses with durable masonry constructions. Post-colonial influences introduced innovative architecture and urban planning, blending modern techniques with traditional Khmer elements, using materials like reinforced concrete. However, progress was disrupted during the civil unrest of the 1970s. After stability was restored, Krong Kratié witnessed repopulation and the emergence of contemporary residences, prioritizing aesthetics and durable materials rather than climate responsiveness. In the modern period, there is a tendency towards haphazard development that often neglects environmental considerations (See Info Box 4).

Info Box 4. Evolution of Settlement Area – Small Village to Modern Town

Early Settlement

The area that is now Krong Kratié started as a small cluster of local villages along the Mekong River with no administrative significance

French Colonial Period

By the end of the 19th century, this area was a small village characterized by a path intersected by ravines (deep, narrow valleys or gorges formed by the erosive action of water), making it difficult for travelers to navigate. With the arrival of French colonial administration, Krong Kratié began to take shape as an administrative and trading centre. In 1885 Telegraph office and opium warehouse were constructed, and by 1895 the village consisted of 2 streets. Chinese traders were allocated land on the first street, while non-traders occupied the second street and Krong Kratié market was inaugurated.

1900-1930 Expansion and growth as a colonial city

As Krong Kratié developed under French rule, the town's built-up area expanded. New buildings, including government offices, shops, and residential structures, were constructed to accommodate the growing population and increased commercial activities.

During the early 20th century, Krong Kratié underwent significant urban development. Wooden houses were replaced with sturdy masonry constructions, attracting impoverished residents from surrounding forest villages who settled in the outskirts[8]. In 1922, Krong Kratié was officially recognized as an urban centre, marking the town's growing importance. Subsequent renovations took place

8 After Cambodia came under French authority in the mid-19th century, the construction of a new masonry Royal Palace marked the beginning of a shift in Khmer architecture. Modern materials introduced through the palace gradually influ- enced urban residential buildings by the end of the 19th century. Following the devastating Great Fire of Phnom Penh in 1894, grounded masonry houses became popular among city dwellers. This led to the emergence of two new residential archetypes: European-style villas and Chinese-style shophouses. The shophouse, characterized by shared walls and homogeneity, became the most successful and dominant residential type in Cambodia's urban landscape. Factors such as cost and layout efficiency contributed to its widespread adoption (Housing Evolution in Cambodia, n.d.).

Info Box 4. Evolution of Settlement Area – Small Village to Modern Town

between 1924 and 1925, focusing on improving existing buildings and infrastructure, such as public works, Posts and Telegraph Offices, the water network, prison, and market. 1937 brought further enhancements, including the inauguration of a new prison, the construction of a maternity hospital, police officer base, teachers' residences, and a concrete town hall, solidifying Krong Kratié's development (Forest, 2005).

Independence Period (Sangkum Reastr Niyum) influences on Krong Kratié

For Cambodia, emergence from the French colonial past was marked by innovative architecture, urban planning, and Khmer monuments through New Khmer Architecture (Ross & Collins, 2006). This new architecture quickly spread throughout the country and can be found in both public and residential buildings (Ibid). At this time, the country experienced an "extraordinary blossoming of construction after independence”. As New Khmer Architecture evolved in public buildings, modern techniques blended more with Cambodian traditions. A prominent feature was the use of reinforced concrete as a fundamental design element (Housing Evolution in Cambodia, n.d.). Additionally, concrete as a building material started to become widespread with the introduction of a new cement plant in Kampot (Ibid). However, the progress and advancement were abruptly halted in the 1970s as Cambodia plunged into a prolonged period of violent civil unrest.

Post-war & Modern Period influences on Krong Kratié

With the restoration of stability in Cambodia, people regained the confidence to construct houses, and cities began to witness a repopulation trend after the evacuation efforts imposed by the Khmer Rouge. Contemporary residences often prioritize aesthetics over practicality, disregarding the climate-responsive elements that were once central to architectural traditions (Housing Evolution in Cambodia, n.d.). Cambodian provincial urban centers witnessed a transition from pedestrian-friendly spaces to congested traffic environments, favoring four-wheeled vehicles (Forest, 2005). By the mid-2000s, Phnom Penh had embraced a khmerized, post-modern architectural style characterized by cement and glass, leading to the emergence of high-rise buildings that exceeded the previous unwritten height regulations from the French Protectorate era. The modern period is characterized by hastily constructed condominiums that often lack consideration for the local environment and the well-being of the residents, exemplified by the quick filling in of lakes in the countries urban areas as prime real estate. (See Figure 28, Figure 29 & Figure 30)

Figure 28. [top] Traditional Cambodia wooden stilt house with concrete stilts, inside urban core abutting large apartment block at boundary. (Source: Own Photo taken in 2019)

Figure 29. [bottom] Office of Provincial Government in French colonial villa (built 1907) (Source: Own Photo taken in 2022)


1998

Figure 30. Various multi-story attached residential buildings (shop houses) in central area and dense clustering of buildings in urban core area
(Source: Own Photo taken in 2023)

Urban Layout and Form

As other major cities in Cambodia, Krong Kratié has been constructed on elevated land, either naturally or artificially, situated close to rivers and lakes, as well as areas with high water tables. The prevailing trend in urban development is to fill residential areas with soil to elevate buildings, while leaving other regions susceptible to flooding.

The urban area of Krong Kratié exhibits a general T-shaped layout. The vertical part of the T extends for 8 km in a north-south direction along the banks of the Mekong River. The horizontal part of the T spans 8.5 km and connects to the redirected National Highway No. 7 at a distance of approximately 5.8 km, continuing towards the municipal boundary (See Annex III, Figure 10 & Figure 11). The town also includes the large island called Koh Trong in the Mekong River.

The municipality contains approximately 7,240 houses and over 900 business establishments, including six markets (comprising two regular markets and six smaller markets), 16 restaurants, 15 hotels, and 30 guesthouses. Additionally, there are three health centres, one referral hospital, 13 public primary schools, seven lower secondary schools, and three high schools (CIUS, 2019).

Figure 31. Main settlement areas of Krong Kratié showing general town layout with dense urban clusters characterized by a higher concentration of buildings adjacent to agricultural fields.
(Source: Google Earth Pro 7.3.4.8573 (06/2021). Krong Kratié, Cambodia, Coordinates 12°29'23.30"N 106° 1'46.48"E Elev. 2.84km)

The expansive riverfront of Krong Kratié influences the town's overall orientation and north and south growth trajectories with connections to the national road network, which provides accessibility and links to other areas (See Figure 31)

Central areas adjacent to the Mekong River exhibit dense urban clusters characterized by a higher concentration of buildings, whereas the lakes and wetlands feature comparatively fewer constructions. This disparity can be attributed to the lakes being utilized as outlets for wastewater discharge, and being areas of land that are comparatively cheaper to construct homes (Own Work, 2022) (See Figure 32).

The town proper and historical core of the urban area has a relatively compact layout, dominated by a central marketplace, with a mix of residential, commercial, and administrative areas. The town's urban fabric is characterized by a grid-like street pattern, which facilitates ease of movement throughout the area. In core areas, streets are typically lined with buildings, creating a continuous street wall and a sense of urban enclosure (See Figure 31 & Figure 33).

Krong Kratié has a distinctive urban form that combines elements of traditional and modern influences, including pre-colonial/traditional Khmer architecture, French colonial, post-colonial / modern Khmer and Chinese architecture (See Figure 32 & Figure 33).

Similar to other urban areas in Cambodia, the building types exhibit considerable heterogeneity. The three types of cover include:

- Detached: Buildings have setbacks on both lateral/side plot boundaries.
- Semi-detached: Buildings have a setback on one lateral/side plot boundary.
- Attached (linked): Buildings have no lateral/side setbacks, creating a continuous row of structures.

Particularly in Krong Kratié´s urban core areas, (such as the commercial center), buildings are constructed with an attached or linked building coverage type. This is notably evident along main arterial roads and around the market area, where the prevalent architectural style comprises rows of shop houses known as "Pteah Luwen." These interconnected structures contribute to the unique urban

Figure 32. Sense of urban enclosure in central urban area (Source: Own Photo taken in 2022)

fabric of Krong Kratié, creating a distinctive streetscape characterized by rows of shop houses.

Approximately 4% (279 residences) of the local housing supply may be classified as being in poor living conditions resembling informal housing. When disregarding matters related to land ownership, which is a common practice by many governments worldwide, a significant proportion of households are likely not to possess formal land titles. However, when taking land tenure into account, the overall percentage of households residing in informal settlements rises to 16% of the total. These figures stand considerably lower compared to the United Nations' reported rates of urban poor housing across Cambodia, where 55% of the urban population is said to be living in such conditions (See Figure 34).[9]

9 UN-HABITAT defines a slum household as "a group of individuals living under the same roof in an urban area who lack one or more of the following: (i.) Durable housing of a permanent nature that protects against extreme climate conditions. (ii.) Sufficient living space which means not more than three people sharing the same room. (iii.) Easy access to safe water in sufficient amounts at an affordable price. (iv.) Access to adequate sanitation in the form of a private or public toilet shared by a reasonable number of people. (v.) Security of tenure that prevents forced evictions", https://mirror.unhabitat.org/documents/media_centre/sowcr2006/SOWCR%205.pdf

Figure 33. Central urban area shop houses
(Source: Own Photo taken in 2022)

Modernisation and Transition to Impermeable Building Materials

Cambodian towns and cities have adopted concrete, asphalt and masonry (building with bricks, stones, or concrete blocks held together by mortar) as key construction materials for many types of buildings and infrastructure (Housing Evolution in Cambodia, n.d.). Post-independence Cambodia saw “New Khmer Architecture” swiftly gain popularity nationwide (See Info Box 4), in which reinforced concrete is a key design element. At the same time, the opening of a national cement plant made concrete a more accessible material in rural areas (Ibid). In Krong Kratié, these materials are typically used in core areas characterised by higher levels of human activity, extensive infrastructure development, and a high density of commercial and residential structures and are marked by a notable concentration of concrete buildings, paved streets, sidewalks and parking areas, and include (See Figure 35, Figure 36 & Figure 37)

Figure 34. Informal housing area behind Department of Culture and Fine Arts and near the riverside and riverside market
(Source: Google Earth Pro 7.3.4.8573 (06/2021). Krong Kratié, Cambodia, Coordinates 12°29'23.30"N 106° 1'46.48"E Elev. 2.84km)

- Roads;
- Sidewalks;
- Plazas and public spaces;
- Parking lots;
- Public transportation areas;
- Building facades;
- Vertical surfaces.

The analysis (See Figure 38) of a sample block in Sangkat Kratié revealed that the built-up area, which includes building structures, and the sealed area consisting of surfaces comprising compacted soil and concrete flooring, represented 82% of the block compared to 18% allocated for vegetation. If these findings were extrapolated to similar central built-up urban areas, it implies that a substantial portion of that urban area is also characterized by extensive built-up and sealed surfaces.

The significant presence of concrete, asphalt, and masonry that absorb and retain heat and prevent urban run- off and infiltration in Krong Kratié reflects the town's general adoption of the evolving architectural practices adopted throughout Southeast Asia and globally. While the introduction of these materials has brought numerous benefits, including enhanced durability, improved resistance to natural elements, and increased safety, drawbacks include higher costs, considerable environmental impacts, limited structural flexibility, the potential for contributing to the heat island effect, and perceived aesthetic monotony. Additionally, there can be significant implications for a town´s hydrology, such as increased surface water run-off, reduced groundwater recharge, altered natural drainage patterns, and the transportation of pollutants to local water bodies (EPA, 2003).[10]

10 7% of total global CO2 emissions come from concrete according to PBL Netherlands Environmental Assessment Agency (2016).

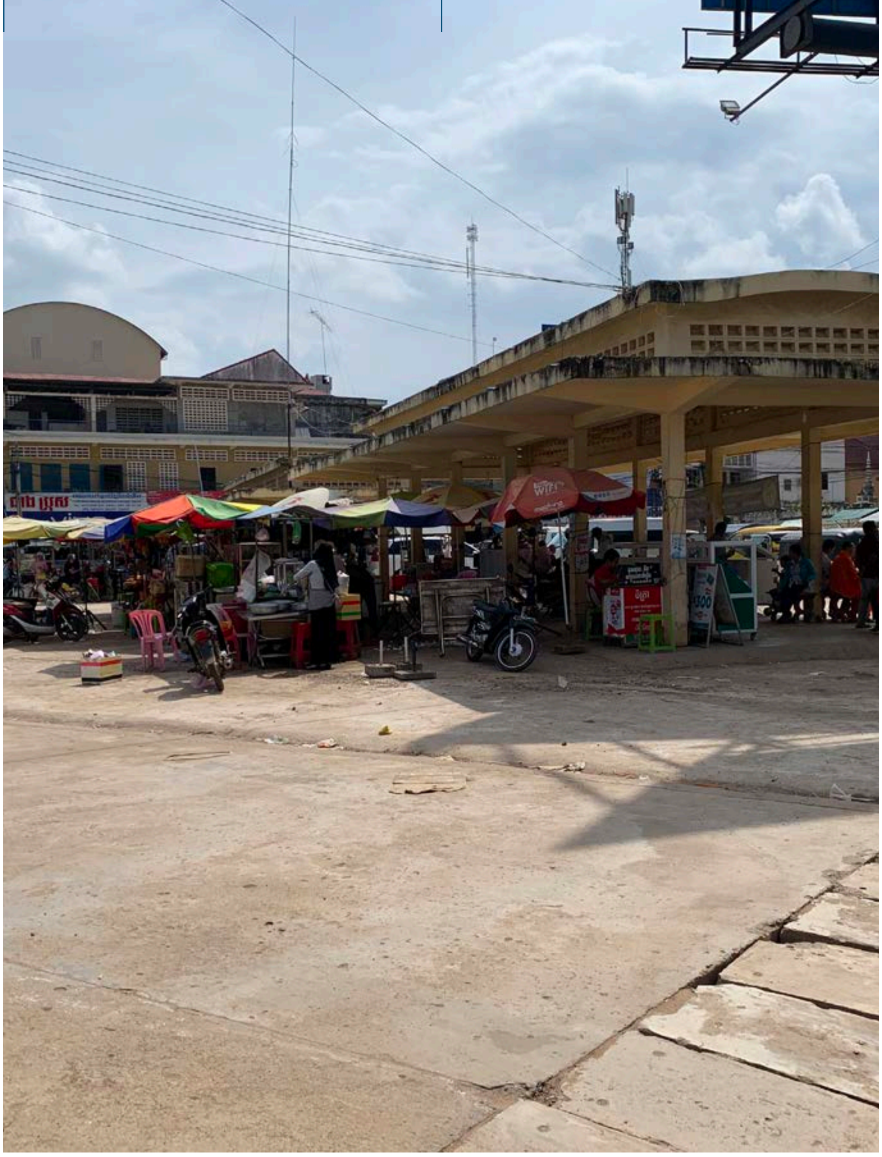
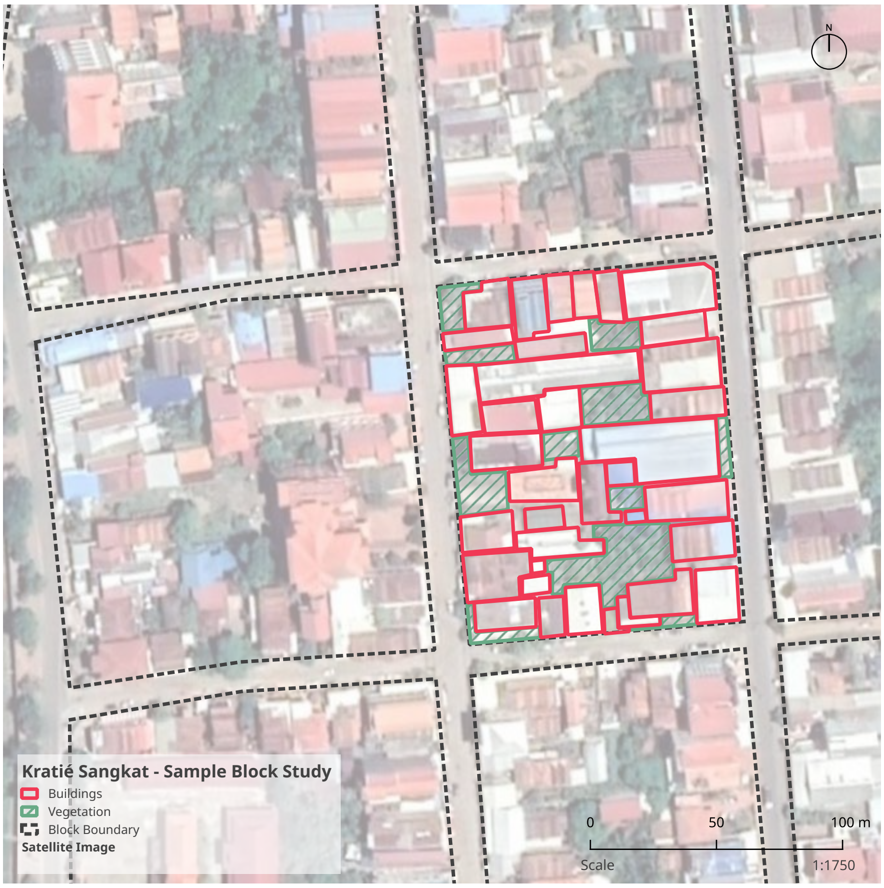


Figure 35. [top] Example of concrete sealing at Krong Kratié Bus Station
(Source: Own Photo taken in 2023)

Figure 36. [bottom] Examples of concrete surfaces completely covering grounds of roads and a property in central area
(Source: Smith, 2014)

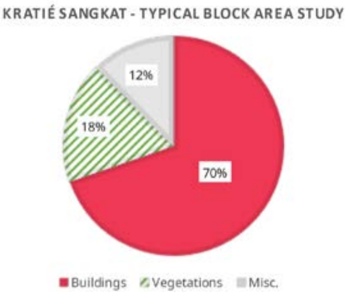
Figure 37. [top] Example of concrete sealing at Krong Kratié Market
(Source: Own Photo taken in 2023)

Figure 38. [bottom] Composition and proportions of elements in the Sangkat Kratié Sample Block Study
(Source: Own Work)



	Area (m2)
Block Total	15004
Buildings	10460
Vegetations	2696
Misc.*	1848

*Misc. = mostly sealed surfaces such as compacted soil, concrete flooring, etc.
(TUB Field Observations, 2023)



Urbanization Trends in Krong Kratié

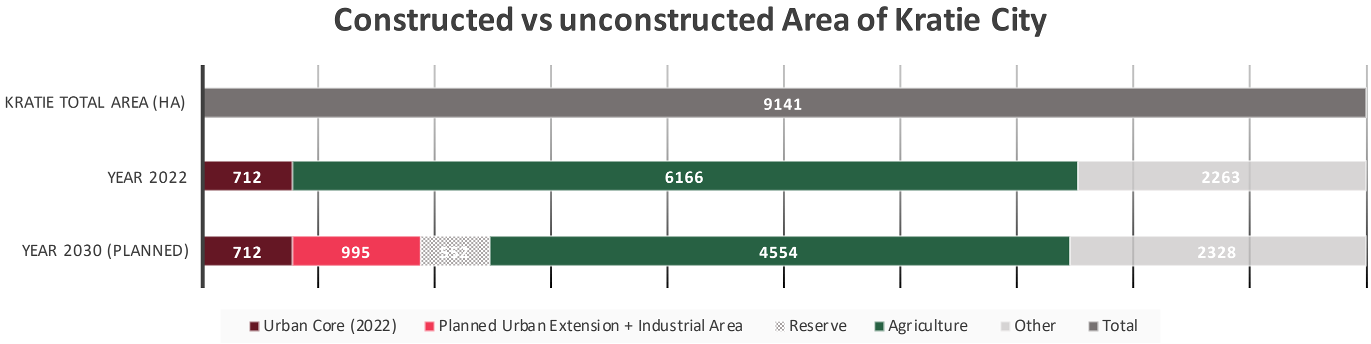
Currently, ongoing urbanization processes are (re-) shaping the urban conditions of Krong Kratié (See Figure 40). Besides Sangkat Koh Trong, the other four sangkats are affected by urbanization processes in various forms, which feature densification of housing, sealing of (natural) surfaces through new developments and expansions of infrastructures as part of urban renewal.

The Land Use Master Plan for 2030 aims to guide urban development, proposing a significant expansion of the urban area (See Figure 41). Under this plan, out of 6,166 ha of agricultural land, 1,612 ha would be allocated for urban use (See Figure 39).

From the perspective of water-sensitive urban development, several challenges arise:

- **Basic Needs Services:** Providing these newly urbanized areas with essential services, such as drainage, water supply, septage management, and solid waste management will be a primary challenge.
- **Green Infrastructure Development:** Given the climate change-induced rise in temperatures, ensuring the livability of these neighborhoods through the development of green infrastructure becomes crucial.
- **Urban Flood Management:** Proposed development needs to occur within the framework of comprehensive urban flood management. A closer examination of the Master Plan reveals that large portions of the planned urban areas lie within the 'Lake Area' that are regularly flooded. There is not only a significant risk of flood exposure to these locations, but these areas also play a vital role in flood mitigation, the Krong's climate, and the livelihoods of communities. In addition to effective

Figure 39. Constructed vs. unconstructed area in Krong Kratié 9141
(Source: Own Work)



flood-resilient infrastructure planning, a more evolved urban planning approach should comprehensively consider the environmental and social impacts of these developments not only for the residents but for the overall Krong.

Currently, urbanization in Krong Kratié is evidenced by several notable transformations in different areas (See Figure 42 & Figure 43):

- The emergence of new developments on greenfield sites and vacant plots within the existing built-up area, particularly in the central residential zone.
- Densification is occurring through ongoing development and the filling of existing built-up plots across residential and commercial areas, resulting in plot coverage ratios of 1.0 or more.[11]
- The urbanization process has also led to the establishment of new extension areas and the further development of main roads, strategically accommodating potential future housing needs. Krong Kratié has expanded eastwards, reaching National Highway No. 7, as well as expanding northward and southward along the former national road.
- This expansion is accompanied by infilling of wetlands behind the urban core and as part of the new development area.

11 The building plot ratio, also known as the floor area ratio (FAR) or plot coverage ratio, is a planning and zoning term that represents the ratio of a building's total floor area to the total area of the plot of land on which it is situated. It is a numerical value that determines the density or intensity of development allowed on a particular site.

For example, a plot ratio of 1.0 means that the total floor area of a building can be equal to the total area of the plot. A plot ratio of 2.0 would allow for a building with a floor area twice the size of the plot area.

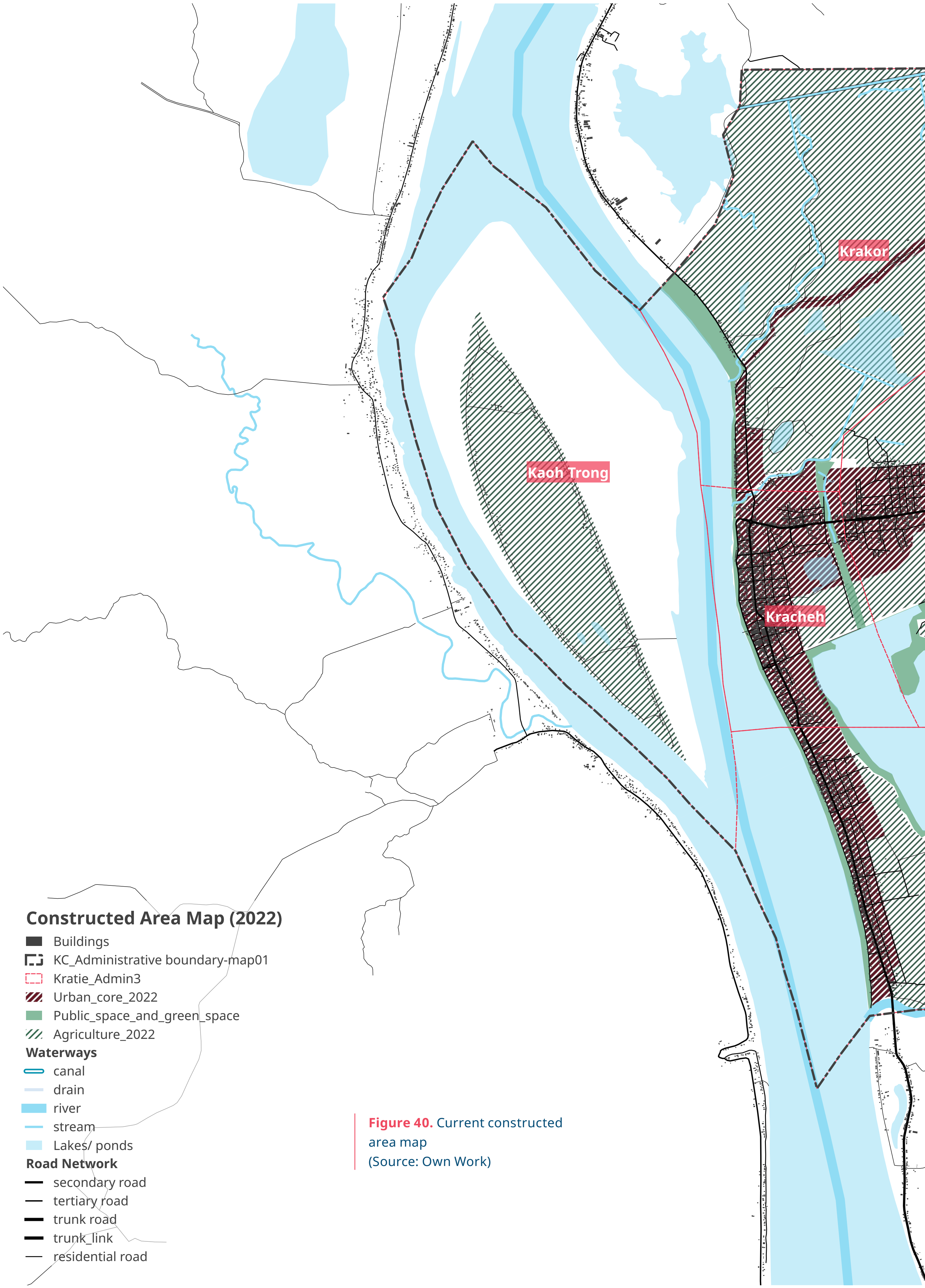
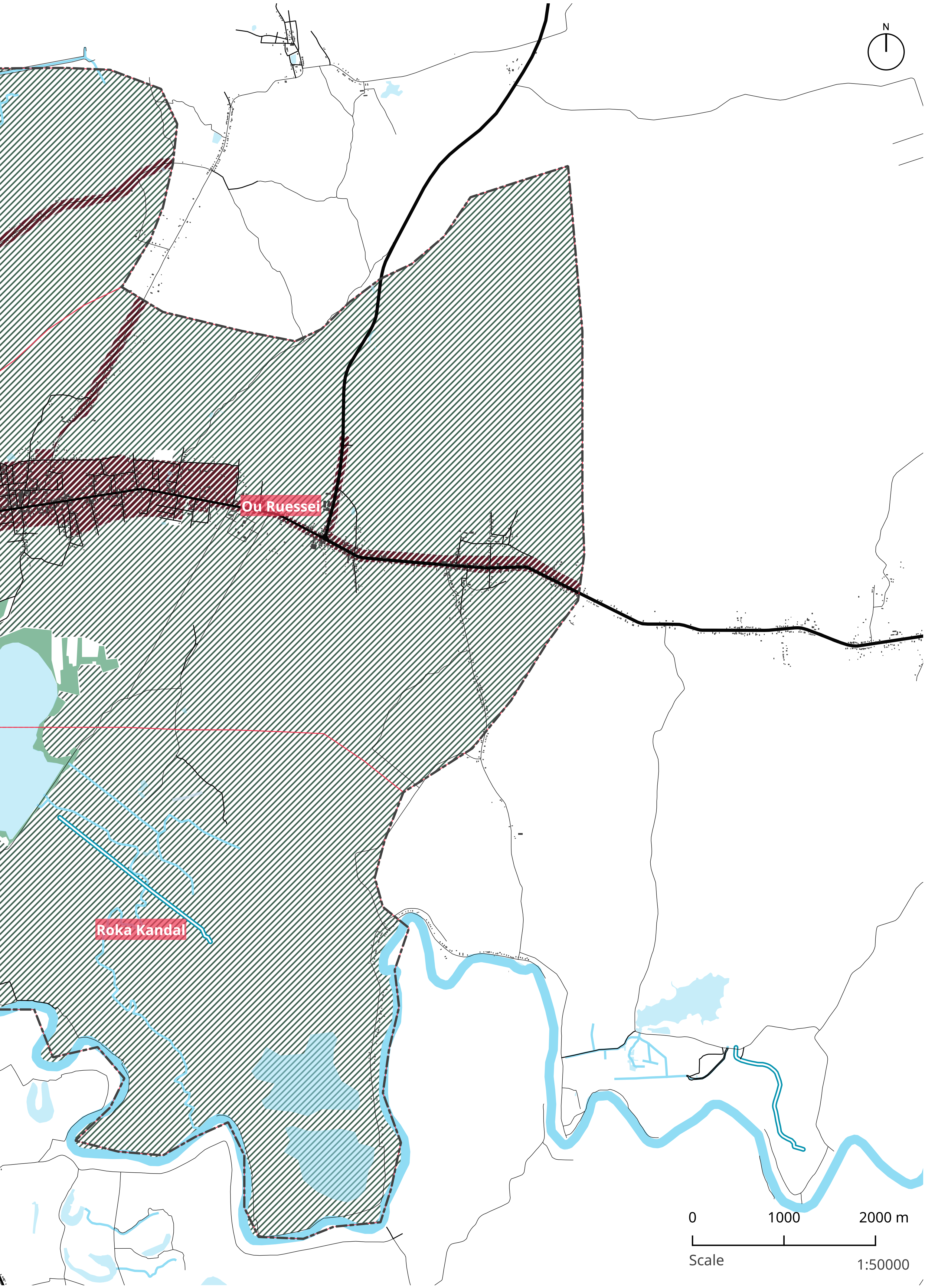


Figure 40. Current constructed area map
(Source: Own Work)


N
Ou Ruessei
Roka Kandal
0
1000
2000 m
Scale
1:50000

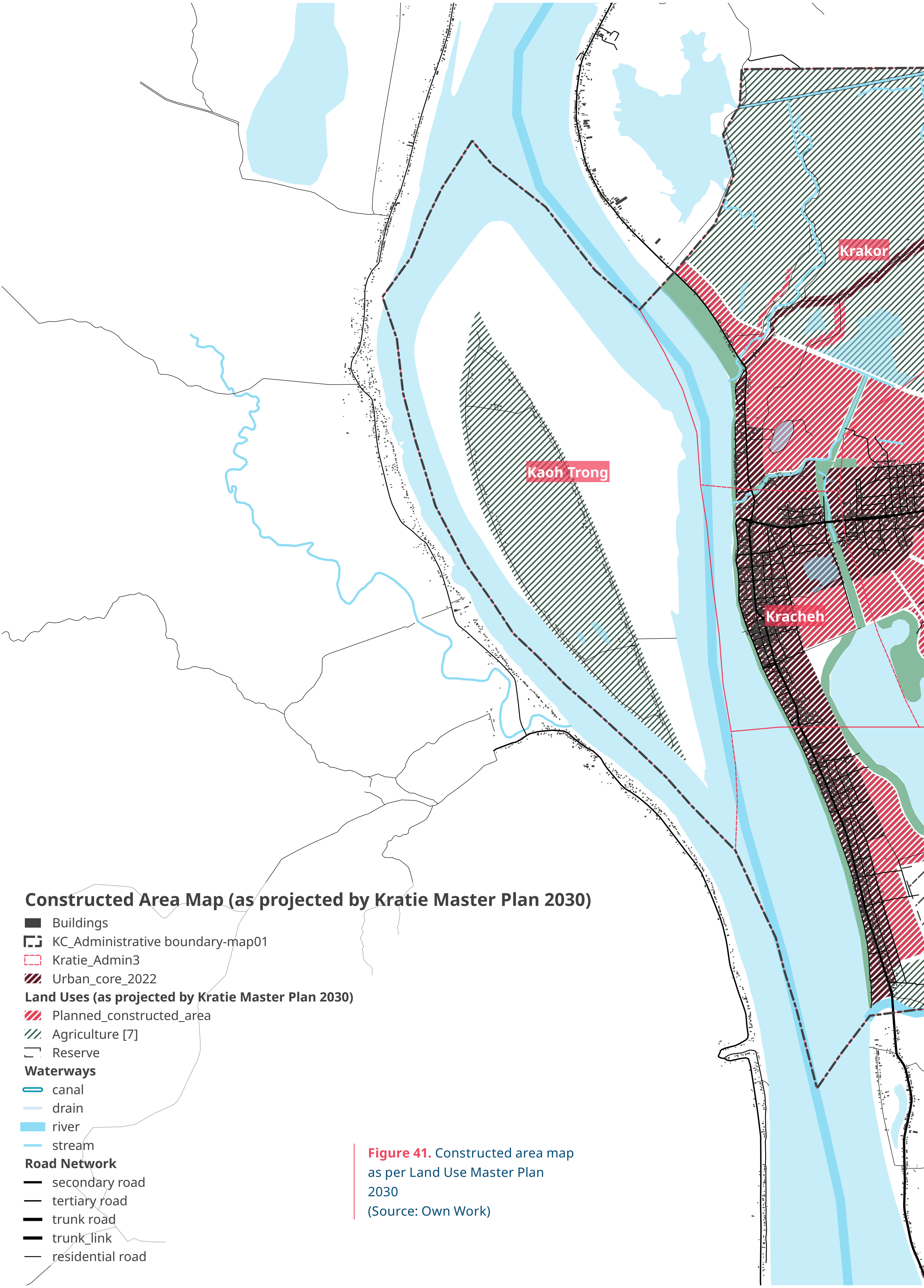


Figure 41. Constructed area map as per Land Use Master Plan 2030 (Source: Own Work)

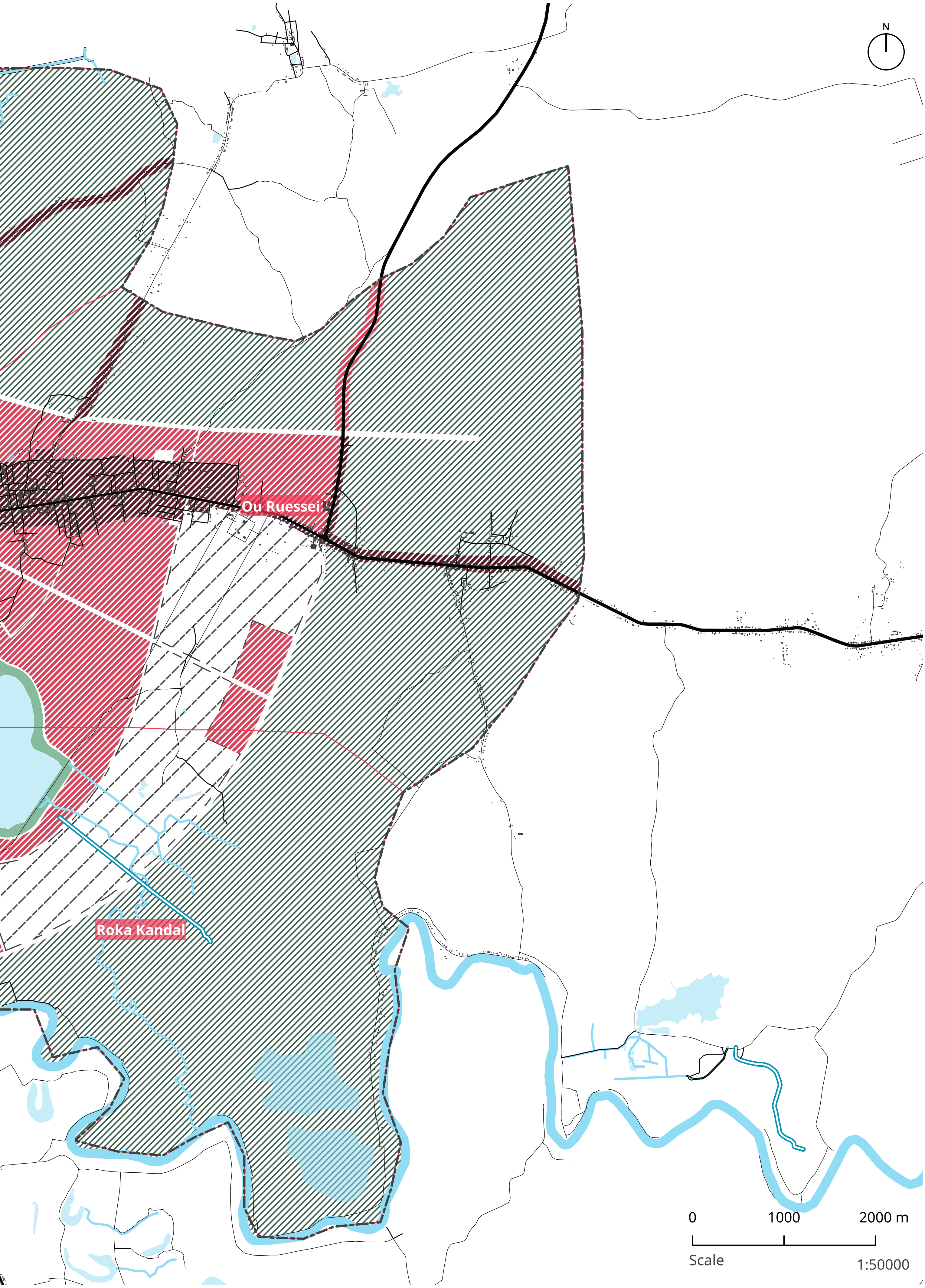

N
Ou Ruessei
Roka Kandal
0
1000
2000 m
Scale
1:50000

Figure 42. Indication of development and infilling between 2013 and 2021
Source: Top: Google Earth Pro 7.3.4.8573 (12/2013). Krong Kratié, Cambodia, Coordinates 12°29'20.85"N 106° 1'21.68"E Elev. 1.26km; Bottom: Google Earth Pro 7.3.4.8573 (06/2021). Krong Kratié, Cambodia, Coordinates 12°29'20.85"N 106° 1'21.68"E Elev 1.26km

Figure 43. Indication of development of plots on eastern fringe or urban area between core and lake between 2013 and 2021
(Source: Top: Google Earth Pro 7.3.4.8573 (12/2013). Krong Kratié, Cambodia. Coordinates 12°29'18.11"N 106° 1'11.60"E Elev. 582m; Bottom: Google Earth Pro 7.3.4.8573 (06/2021) Krong Kratié, Cambodia. Coordinates 12°29'18.11"N 106° 1'11.60"E Elev. 582m)

Densification of Existing Areas and Urban Expansion

(1) Urban Centre Densification

In the central areas of Sangkats Kratié and Roka Kandal a notable phenomenon of vertical densification can be observed (See Figure 44 & Figure 46). Currently, Kratié defines the urban core and is the densest sangkat. Houses are incrementally being renovated, improved and rebuilt. Densification entails the construction of new multistory buildings and the incremental renovation or reconstruction of existing houses. A prominent characteristic of these new structures is the strategic allocation of the ground floor level for commercial purposes. Additionally, recent construction activities have improved green infrastructure, storm water drainage and public space design along the riverside promenade and around the central market, Phsar Sammaki.

Figure 44. Example of urban center densification (Source: Own Photo taken in 2019)

(2) Progressive Extension Towards the 'Lake Area'

In the eastern section of Sangkats Kratié and Roka Kandal, a notable expansion of the existing high-density residential zone is observable, particularly towards the 'Lake Area' (See Figure 45). In general, Sangkat Roka Kandal features an urbanized axis along National Road No. 73 going southwards and agricultural land towards the east. Currently, there is a discernible trend of partial development occurring in proximity to the wetlands and Boeung Romleach. Construction sites in close proximity to the Lake Area are frequently encountered, often situated on land that is precarious in nature, susceptible to temporary flooding, or even already exhibiting standing water on the plots. This expansion of development activities towards the Lake Area indicates a cost-effective option for developers and prospective property owners due to less desirable, potentially risk prone locations.

Figure 45. Example of extension towards the lake area (Source: Own Photo taken in 2022)

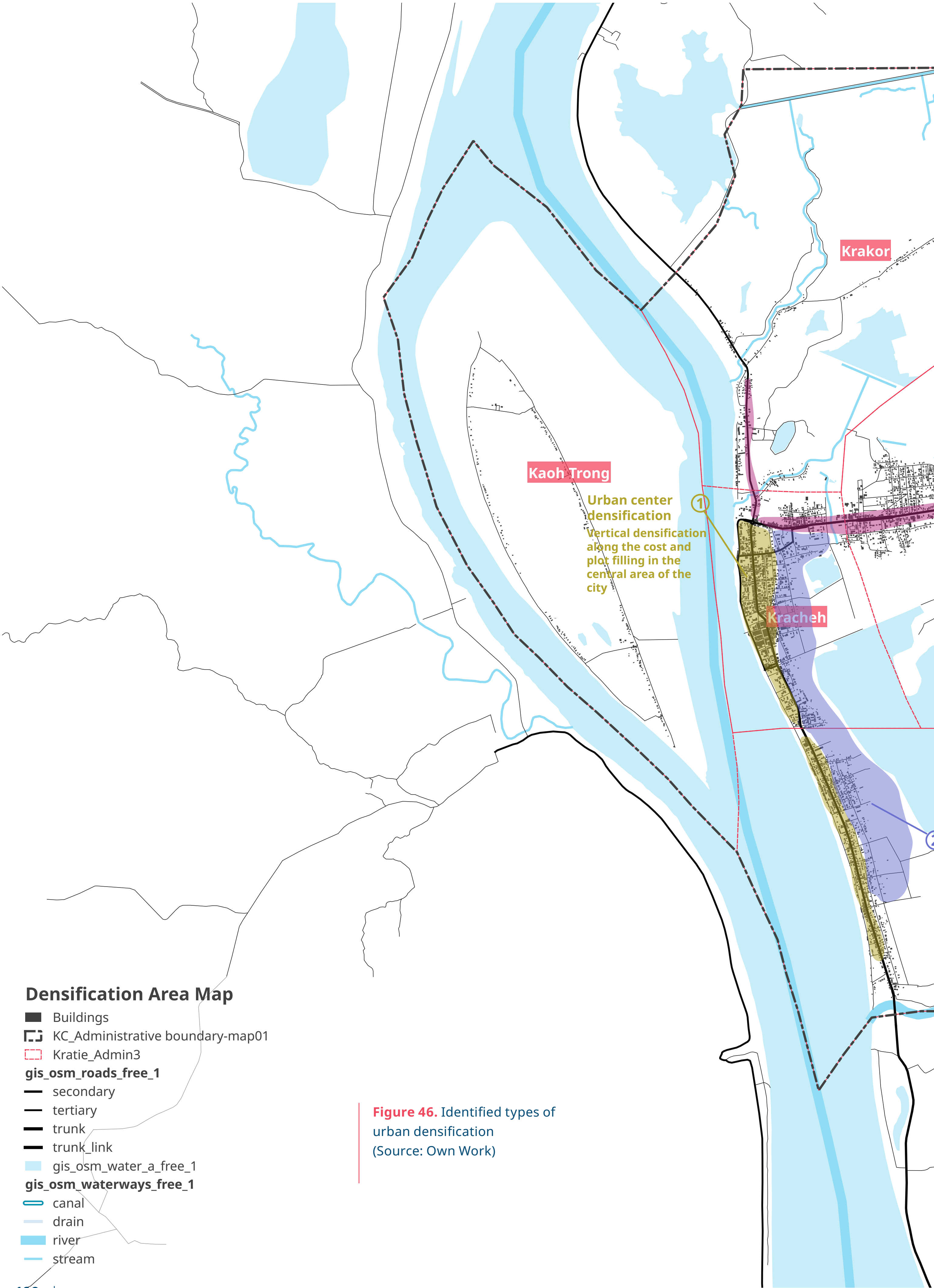
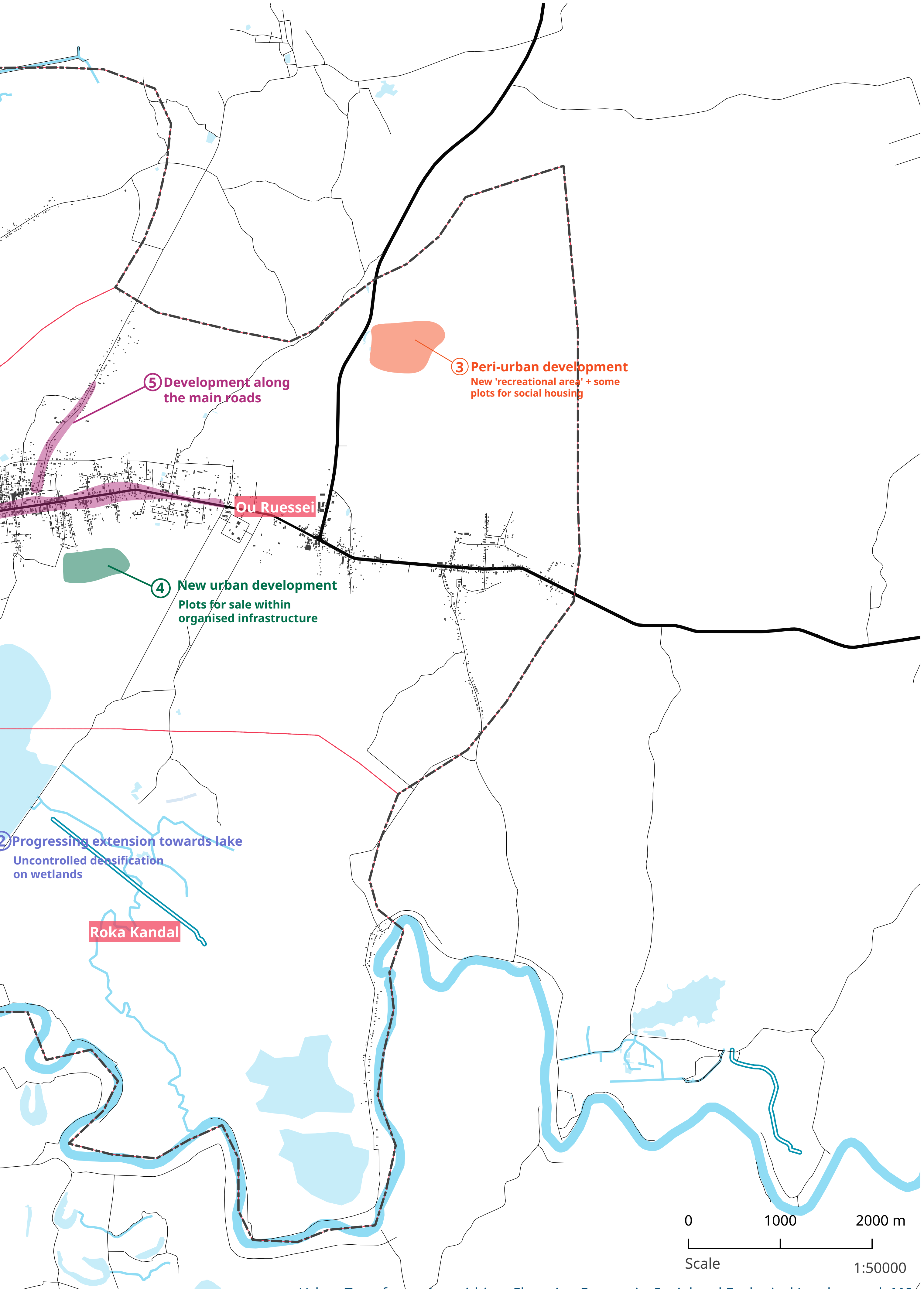


Figure 46. Identified types of urban densification (Source: Own Work)



③ Peri-urban development
New 'recreational area' + some plots for social housing
⑤ Development along the main roads
Ou Ruessei
④ New urban development
Plots for sale within organised infrastructure
② Progressing extension towards lake
Uncontrolled densification on wetlands
Roka Kandal
0
1000
2000 m
Scale
1:50000

(3) New Peri-Urban Development

In the north-eastern part of Krong Kratié in Sangkat O'Russey, a new "residential area" with more than 40 ha of land can be identified, which includes certain plots allocated for housing and commercial use (See Figure 47, Figure 48 & Figure 49). Sangkat O'Russey mainly consists of an urban/peri-urban landscape along National Highway No. 7 to the east. It is an important road linking Krong Kratié with four other provinces. The new development site is roughly five km from Krong Kratié's urban center. Within close proximity of the new development is a food processing factory. Currently, higher end "urban villas" are being constructed. Additionally, small and uncomplicated modular housing is being built, described by the local stakeholders as social housing. There are numerous already subdivided plots that remain vacant as of March 2022, indicating potential investments made by residents or their families. Marketing of properties started in 2022.

Figure 47. [bottom-left] Marketing of land for sale of new peri-urban development
(Source: Own Photo taken in 2022)

Figure 48. [top-right] Newly built urban villa in new peri-urban development
(Source: Own Photo taken in 2023)

Figure 49. [bottom-right] Development of road infrastructure for the new residential area
(Source: Own Photo taken in 2023)

(4) New urban development

In the northern fringes of Boeung Romleach in Sangkat O'Russey, a notable phenomenon of new urban development is observed in low and medium density zoned areas (See Figure 50). Plots of land are actively advertised for sale, comprising the primary choices for prospective developments. The prevailing trend in this zone is the construction of low-rise housing of 1 to 2 storeys. It is worth noting that the commencement of construction on these new dwellings occurs at an elevated level, typically around 50-80cm above ground level. This deliberate elevation suggests an awareness of potential temporary flooding in the area, implying a proactive approach to mitigate flood-related risks.

Figure 50. New urban development
(Source: Own Photos taken in 2022)

Development Along the Main Roads

There is a discernible pattern of gradual urban development spanning from Sangkat Kratié along Kra Kor and O'Russey, characterized by the development of building plots, observed along the main road leading to National Highway No. 7 and its associated road networks fanning out to the north and south (See Figure 51). Going north in Sangkat Kra Kor, peri-urban settlements blend with rural areas. The main roads and settlements in these areas have been longstanding, are gradually being modernized, feature many services and are the main connection for tourists to visit the Mekong dolphins. The urban expansion signifies a progressive transformation of the surrounding area into an urban landscape, with increasing human settlements and infrastructure. The developmental process unfolds in a step-by-step manner, with the initial growth observed near the main road and subsequently spreading to the interconnected road networks. The additional building activities are being extended on existing settlement structures and are moderate in terms of the number of new houses. (See Annex III for additional maps and figures on urban transformation)

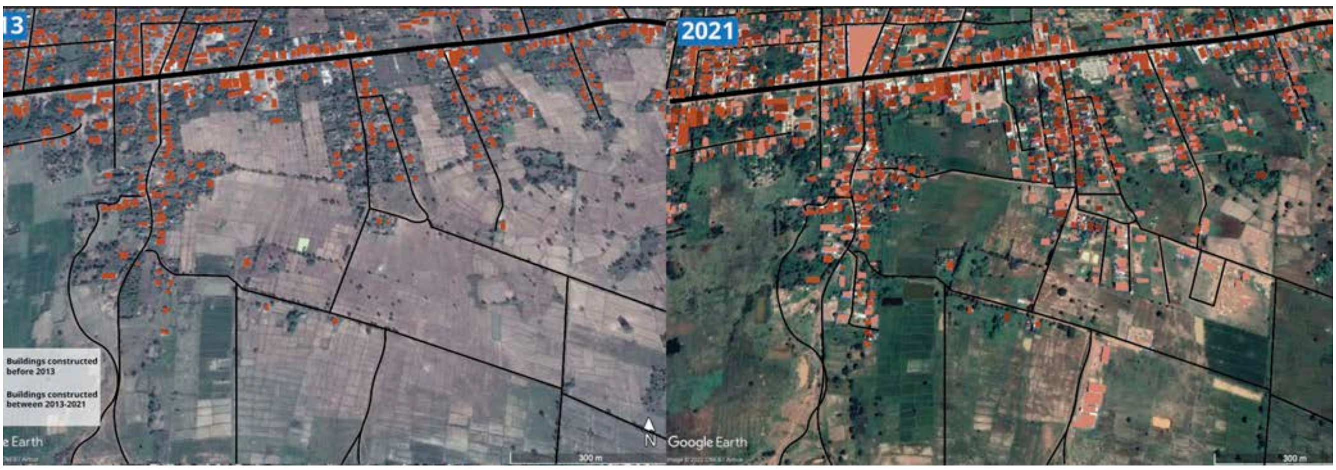


Figure 51. Development along the main roads
Note: The two aerial photos depict the development that occurred between 2013 and 2021

(Source: Left Photo, Own Compilation based on Google Earth Pro 7.3.4.8573. (n.d.). [Google Map of Kratié urban block]. Retrieved July 17, 2023, from http://www.earth.google.com and Right Photo, Own Drone Captured Image taken in 2022)

The Key Function of Green Infrastructure Development for the Livability and Modernization of Krong Kratié

Key Messages of Section

1. Urban green infrastructure in Krong Kratié is of strategic importance to the Krong as it can strengthen water security, enhance the well-being of residents and communities, and drive socio-economic development.
2. The amount of public green space in Krong Kratié is currently limited, leading to a lack of accessible and well-maintained public green areas within the urban core.
3. The lack of urban green space and the current pattern of urban development can contribute to increased urban temperatures, greater flood exposure, and deterioration of water resources, impacts that may be exacerbated by climate change.
4. Incorporating green spaces and natural vegetation into the urban fabric can manage stormwater, reduce flooding risks, improve water quality, and significantly enhance urban aesthetics and function. This incorporation is also crucial for tourism development.
5. A strategic approach to urban green development should include the 'Lake Area', given its important functions for the Krong and potential for eco-tourism development.

Existing Urban Green in Krong Kratié

Traditionally, Cambodian krongs (cities and towns) have enjoyed a wealth of green and natural spaces that were used by urban and peri-urban residents for (informal) farming to supplement diets and incomes. Through ongoing urbanization processes with a growing demand for building and infrastructure development, these green spaces have diminished over the years and have not yet been replaced by appropriate green spaces. Such a process can be observed in Krong Kratié (See Figure 52 & Figure 53).

Time Series (2013 – 2021): Decline of Green in the Urban Core

Although Krong Kratié is acclaimed for its scenic Mekong riverfront and promenade and its profound link to the natural world, it has a noticeable scarcity of parks and green spaces throughout the built-up areas of the town.

The urban core is mainly devoid of green public spaces. Most of the existing green space is situated on semi-public courtyards, such as around the Pa Chha Pagoda or Krong Kratié Pagoda. Other landscaped green spaces with limited access and use are also located on land owned by public institutions, such as the Kratié Provincial Office. Moreover, road-side greening, which involves planting trees along streets and sidewalks, is not as prevalent in the urban core. Numerous trees and other vegetation grows on undeveloped plots of land and thrive within inner courtyards, nestled between the surrounding buildings (See Figure 54).

Whereas Krong Kratié provides more green areas in its peri-urban sangkats, such as O'Russey or Roka Kandal, the provision of green spaces in the core urban area in and around Sangkat Kratié is somewhat patchy. Moreover, specific green spaces are largely lacking in the new extension areas. In the course of urban construction and infrastructure development, green areas are increasingly sealed.

There are very limited well-maintained urban recreational areas, apart from inner block areas with partial greening from bushes, lawns and trees, roadside greenery in the form of trees and bushes and free-standing plots with vegetation. While numerous green spaces are designated

Figure 52. Greened court yards and block areas with trees in urban core of Sangkat Kratié in 2013 (Source: Google Earth Pro 7.3.4.8573. (n.d.). [Google Map of Kratié urban core in 2013 and 2021]. Retrieved July 17, 2023, from http://www.earth.google.com)

Figure 53. Partially diminished green court yards and trees in urban core of Sangkat Kratié in 2021
(Source: Google Earth Pro 7.3.4.8573. (n.d.). [Google Map of Kratié urban core in 2013 and 2021]. Retrieved July 17, 2023, from http://www.earth.google.com)

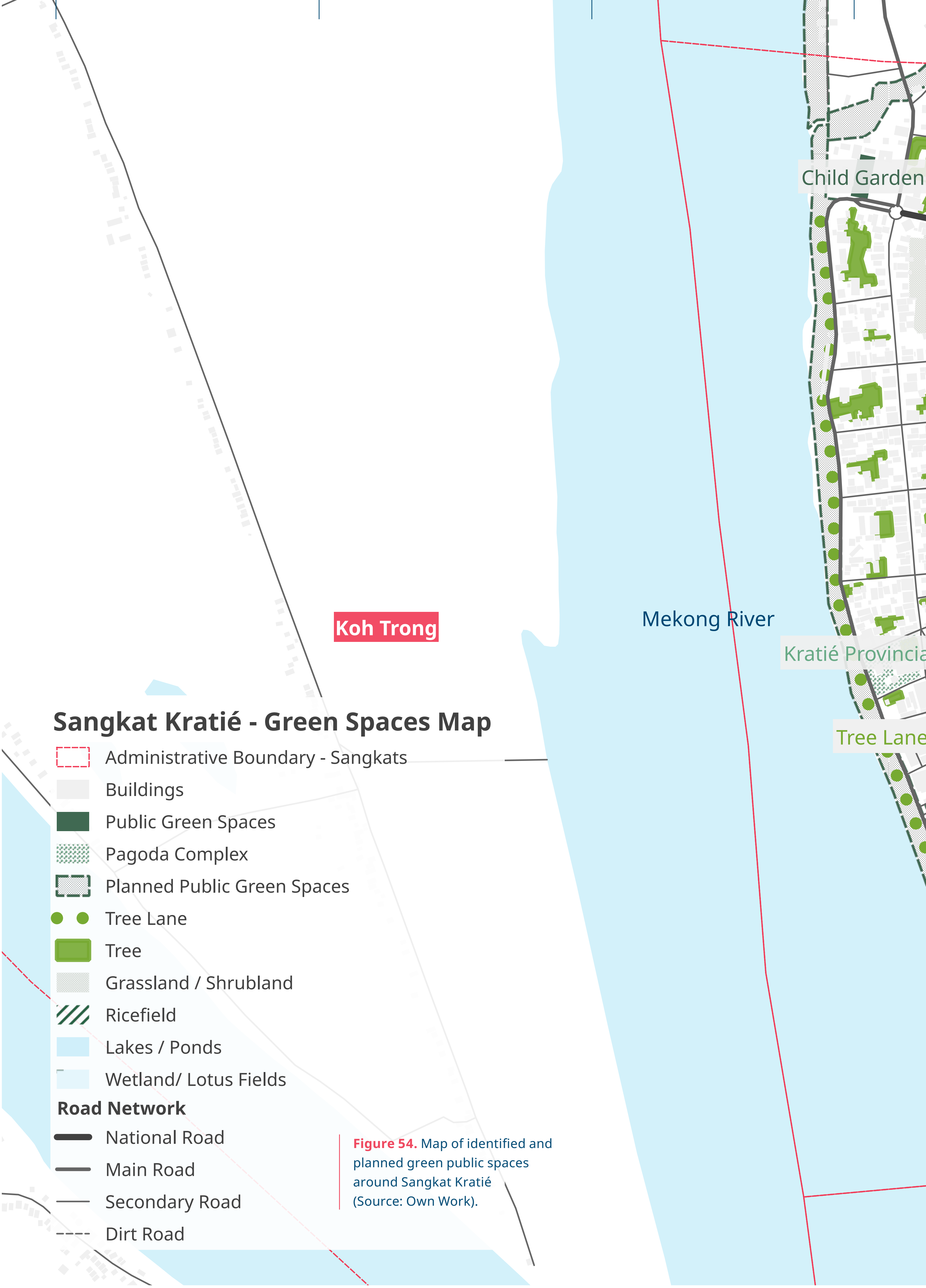
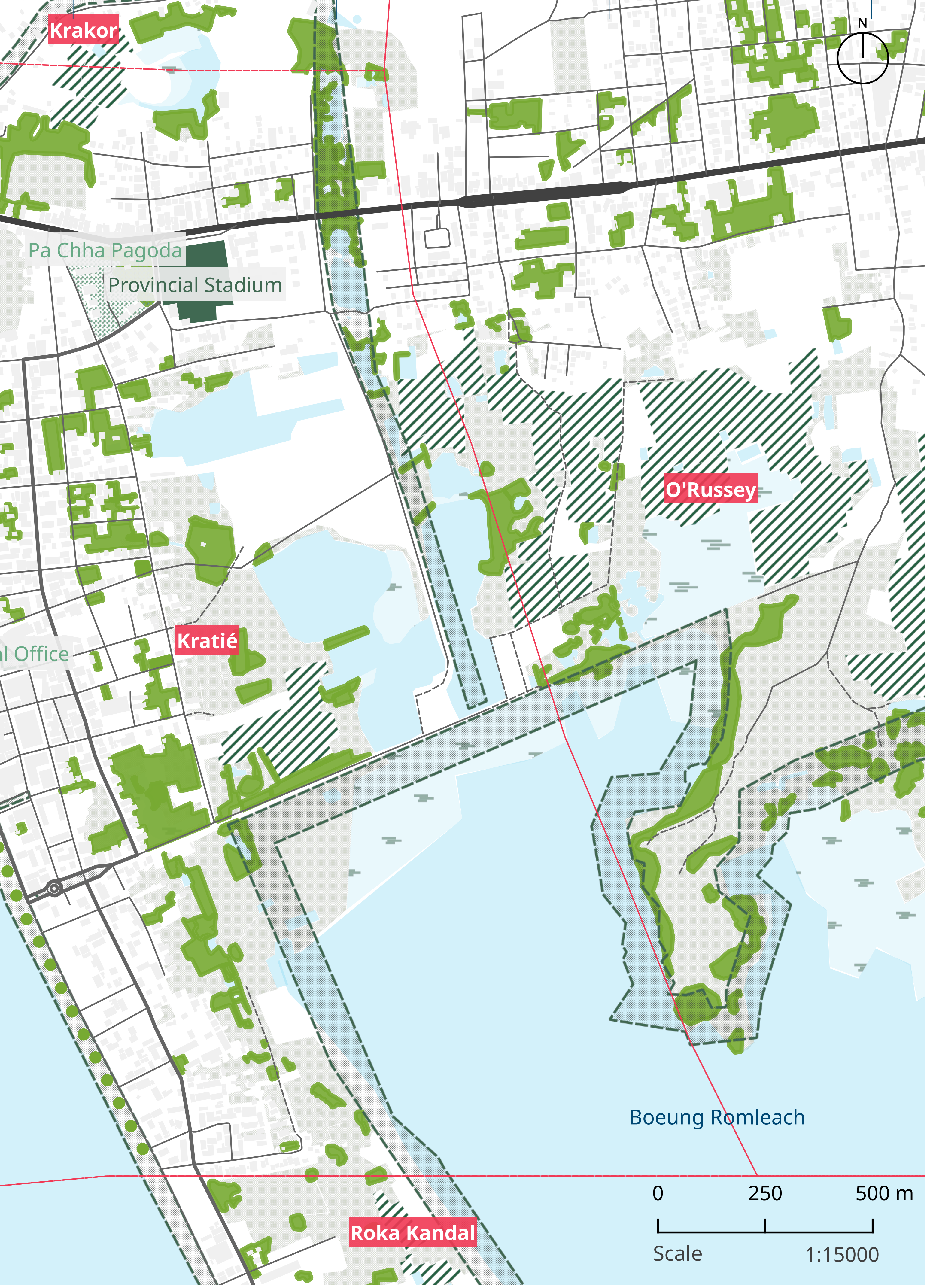


Figure 54. Map of identified and planned green public spaces around Sangkat Kratié (Source: Own Work).


Krakor
N
Pa Chha Pagoda
Provincial Stadium
O'Russey
Kratié
l Office
Boeung Romleach
Roka Kandal
0
250
500 m
Scale
1:15000

on private land, the availability of formal urban parks and public green space is severely limited to a small number of locations, such as the Provincial Stadium and Child Garden.

The existing green areas often consist of small plots where trees are individually planted, rather than being part of a larger, interconnected green system. While there are isolated green spaces in the core area and larger connected green spaces on the periphery of the settlement area, there is a lack of connectivity between the individual green spaces, such as a 'green corridor' or connected network through the Krong.

The green spaces of inner Krong Kratié consist of a very small number of public areas with different functions and characteristics spread throughout. The most prominent recreational and leisure areas with green components are the promenade along the Mekong River (See Figure 55) and the green areas around Boeung Romleach (See Figure 57), as well as very few public squares within the krong's centre. These range from sports and play areas, such as the Provincial Stadium, representational places, such as the Independence Monument, or exercise and recreation spaces, such as the Mekong Promenade. Most of those green spaces are equipped with a basic number of street furniture, closed paving, and trees.

Figure 55. Aerial view of Krong Kratié with the Mekong River Promenade (left), green courtyards and Boeung Romleach (right).
(Source: Smith, 2014)

A Strategic Approach for Sustainable Development of Krong Kratié.

Urban modernization and the development of green infrastructure in Krong Kratié should be intrinsically linked, particularly in the context of climate change. The systematic management and the development of green infrastructure that incorporates existing and new natural systems into the urban fabric is not only desirable, but vital for sustainable and resilient urban development of Krong Kratié:

- The systematic development of urban green may bring multiple positive effects for people and their environments and contribute significantly to improved livability of Krong Kratié. Incorporating parks, green private and public plots and buildings, and bodies of water generate multiple economic and ecological benefits. The significance of a greener city that provides a livable environment for its citizens and visitors and a healthier mental and physical wellbeing will increase with the incremental impacts of climate change, such as rising temperatures (Asian Development Bank, 2012; Asian Development Bank, 2016; Jabbar et al., 2021; WHO Regional Office for Europe, 2021).
- Green spaces and natural vegetation can help to manage stormwater by absorbing rainfall, reducing flooding risks, preventing soil erosion and sedimentation in water bodies, acting as a natural filter, and improving water quality by removing pollutants and excess nutrients. Incorporating and preserving green spaces in urban planning promotes sustainable water management, enhancing hydrological processes and overall ecological resilience (Coutts & Tapper, 2017).
- Natural vegetation, such as local trees and bushes, should be used to mitigate the urban heat island effect. Trees and bushes provide shade, reduce surface temperatures through evapotranspiration, and promote airflow and cooling through their canopies. Additionally, green areas act as buffers against heat by absorbing and dissipating solar radiation (Coutts & Tapper, 2017).
- Urban development in Krong Kratié should aim to protect, rehabilitate, and mimic its natural systems, ensuring the preservation of green spaces and their integration into a wider network. Here especially the overall existing green infrastructure of Krong Kratié, including the Lake Area, should be integrated into a green urban development approach (ADB, 2016).

The development and implementation of a comprehensive Green Infrastructure Plan will be a key component to ensure a strategic development of Green Urban Development in Krong Kratié:

1. **Assess Existing Green Assets:** As already begun in this base-line assessment, further identification of existing natural assets and green spaces within Krong Kratié. This could include parks, community gardens, private and public premises, street trees, wetlands and other vegetation. Utilization of Geographic Information System (GIS) technology to map these assets may take place to help visualize the current green networks.

2. **Identify Areas of Improvement:** Identify areas that are of strategic importance for green and socio-economic urban development, that have valuable green infrastructure to be protected, areas that are particularly vulnerable to climate-related risks, and sites where the introduction of green spaces could bring maximum benefits to local residents.

3. **Develop a Strategy:** In cooperation with communities, businesses and investors, formulate a vision for a strategic plan for green infrastructure development in Krong Kratié.

4. **Green Infrastructure Interventions:** Propose specific interventions, such as public spaces, green yards and gardens, tree planting and related management initiatives, and wetland management systems, that are prioritized and that are feasible with the given capacities. It is noteworthy that any vision is of little value if it is not translated in the near future into specific activities. In addition to substantial commitment from stakeholders, financing should be ensured. Initially, small-scale, pilot initiatives can be implemented that can serve as proof-of-concept for these interventions. Their success can garner further support and open avenues for larger, comprehensive green urban development projects.

5. **Regulation, Management and Financing:** Update local planning and zoning regulations to incorporate green infrastructure requirements and incentives. Clear leadership and project management under participation of all relevant stakeholders has to be present. Identify and secure diverse funding sources, which could include municipal funds, grants from environmental or urban development agencies, and public-private partnerships.

6. **Stakeholder Engagement:** Engaging local stakeholders – communities, households, businesses, and investors – will be a cornerstone of successful green infrastructure planning in Krong Kratié. These stakeholders not only have a vital role to play in the implementation of green infrastructure interventions, but also in their long-term maintenance.

7. **Implementation:** Establish a clear implementation plan, including timelines, responsibilities, and cost estimates. The plan should be flexible, allowing for adaptation and revision as necessary.

8. **Establishing an Implementation Plan for Green Infrastructure in Krong Kratié:** A well-structured implementation plan should clearly lay out what will be done, who will do it, when it will be done, and what it will cost. Given the complex and changing nature of urban development and environmental conditions, it should also allow for necessary ongoing adjustments as part of monitoring.

Valuing the Lake Area as a Strategic Asset for Sustainable Development of Krong Kratié

Key Messages of Section

1. The Lake Area presently serves multiple key roles and features, including acting as a critical resource for community livelihoods, a flood-buffer zone, a recipient for wastewater, an urban climate regulator, and a vital biodiversity habitat.
2. However, the Lake Area is facing increasing threats due to landfill activities, escalating water body pollution from sewage, agriculture run-off, habitat loss, and subsequently, a weakening of the basis for livelihoods.
3. In light of sustainable and water-sensitive urban development, the significance of the Lake Area is expected to grow. Such areas will serve as mitigators against escalating urban temperatures driven by urbanization and climate change, function as recreational spaces, provide protection as premium quality natural habitats for the growth of eco-tourism, and be considered strategic areas for comprehensive flood protection development.
4. While the strategic importance of lakes and wetlands for sustainable urban growth has increasingly been acknowledged, a coherent plan for their utilization and development has been absent. For Krong Kratié, this gap should be addressed through strategic planning, involving the relevant stakeholders, aimed at the sustainable utilization and appreciation of the Lake Area. The implementation of such a plan will be integral to future urban and spatial development.

A New Perception of the Lake Area: The Shift from Underdeveloped Area to a Strategic Asset for Increased Resilience and Livability of Krong Kratié

As a component of urban infrastructure, the Lake Area plays a vital role in improving the livability and resilience of Krong Kratié in the following ways:

- Through their ecosystem services, they perform indispensable functions, such as water purification, flood control, and climate regulation, all of which are critical for maintaining urban sustainability.
- The biodiversity found in the lake and wetlands is a livelihood source for local communities.
- They can potentially act as a strategic asset for boosting eco-tourism development.
- Smart urban design can incorporate parts of the Lake Area to create recreational and green spaces that fulfil the increasing expectations of residents and tourists for a modern, attractive city.

Urban planning must shift away from the view that the Lake Area is undeveloped land and instead acknowledge its significant role in sustainable urban development.

The Lake Area should be perceived as an integral component of the urban fabric. The functionality of these nature-based solutions to develop an urban area characterized by a high quality of life should be acknowledged. However, at present the public mandates for managing these Lake Areas and their urban surroundings may currently be somewhat fragmented or ambiguous.

Urban planning for Krong Kratié should adhere to the following guidelines:

1) Ensure the preservation of the flow regime within the Lake Area. In particular, the obstruction of floodwater drainage by inappropriate development should be avoided at minimum, resorting to necessary infrastructure development if needed.

2) Substantially decrease the inflow of untreated waste waters. Discussions are ongoing for effective and long-term operational system solutions. In the short-term, particularly for some parts of the sangkats on the periphery of the municipal area, centralized solutions may not be feasible, and thus, decentralized solutions should be explored.

3) Prevent unregulated development in areas crucial for biodiversity. Protection zones could be designated in suitable areas to balance between utilization needs (housing, commercial use) and nature conservation.

4) Develop high-quality infrastructure in the Lake Area to cater to the recreational needs and nature observation interests of residents and tourists. This could include hiking trails, viewpoints, and nature-adapted recreation sites.

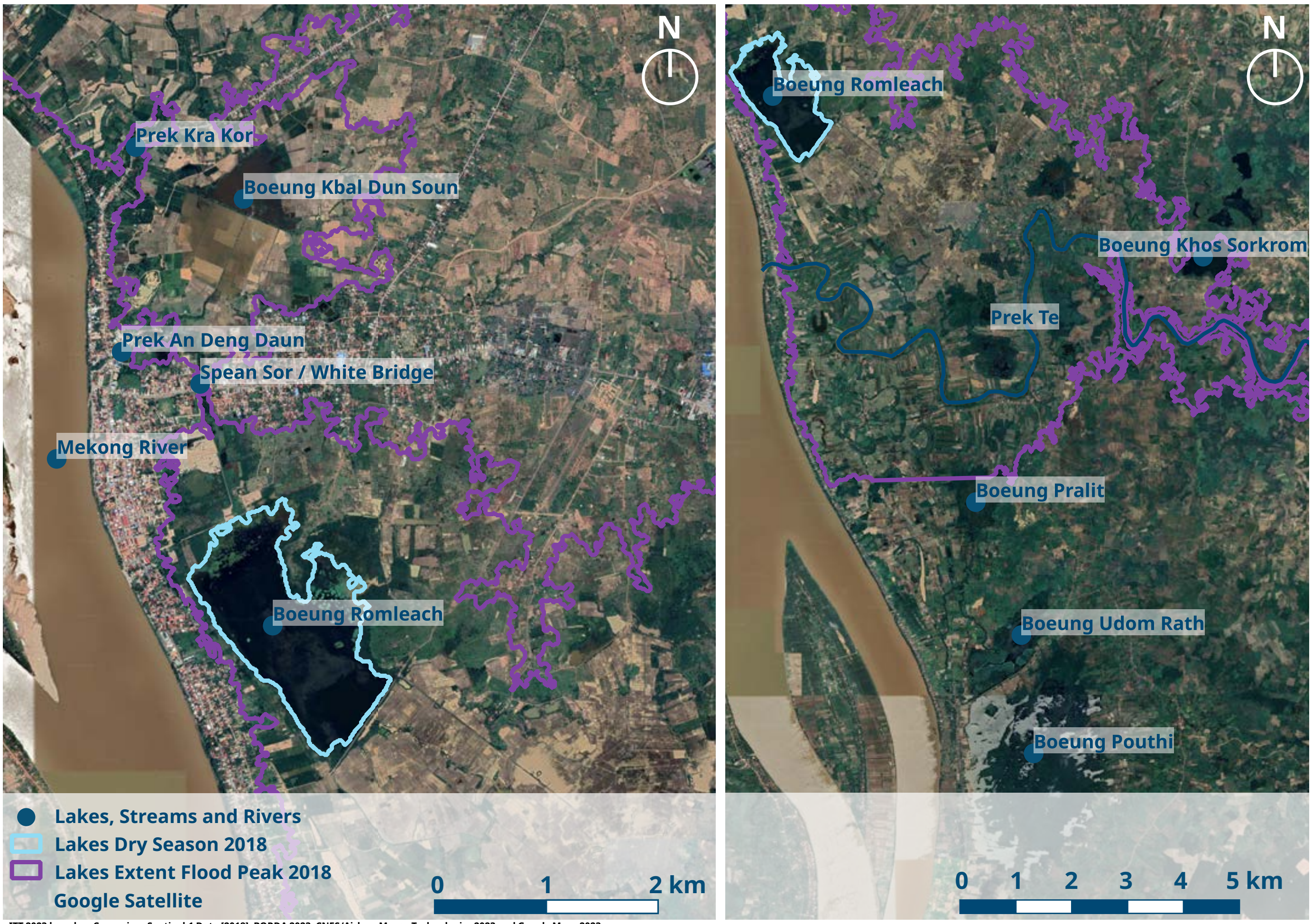
Krong Kratié's Lake Area as Natural Flood Control System

Krong Kratié is home to several wetland ecosystems, including marshes, swamps, and floodplains. The lake and wetland area South-East and South of the built-up municipal core, referred to here as the "Lake Area", encompasses a variety of water bodies, such as Boeung Romleach in close proximity to the urban area, and Khos Sorkrom, Boeung Pralit, Udom Rath, and Boeung Pouthi outside of the municipality (See Figure 56).

More specifically, estimates of the water coverage of Boeung Romleach for the years 2015 and 2022 show:

- During the dry season, the length of Boeung Romleach was 2.26 km, while in the wet season, it ranged from a minimum of 6.26 km to a maximum of 10.63 km, with an average of 8.57 km. The width of the lake during the dry season fluctuated between 0.67 km and 1.25 km. During the wet season, it ranged from a minimum of 0.71 km to a maximum of 8.67 km, with an average of 3.72 km.
- Boeung Romleach's water volumes for the wet season have been computed across the period from 2015 to 2022, with an average volume estimated at around 75,945,000m^3. The minimum volume recorded was approximately 15,300,000m^3 in 2021, while the maximum volume reached a staggering 180,000,000m^3 in 2019 (See Figure 57).[12]

12 Leveraging open source elevation models (SRTM) and C-Band SAR water extend analyses from the European Space Agency's Sentinel 1 (ITT, 2023).



The Lake Area in Krong Kratié performs a crucial role in the local ecosystem as a natural flood control system. Owing to their unique geographical and biological characteristics, they help manage water levels and reduce the risk of flooding, serving as a protective barrier for the surrounding communities and ecosystems. Furthermore, the Lake Area's wetlands, due to their high content of organic matter, play a crucial role in greenhouse gas mitigation, acting as carbon sinks.

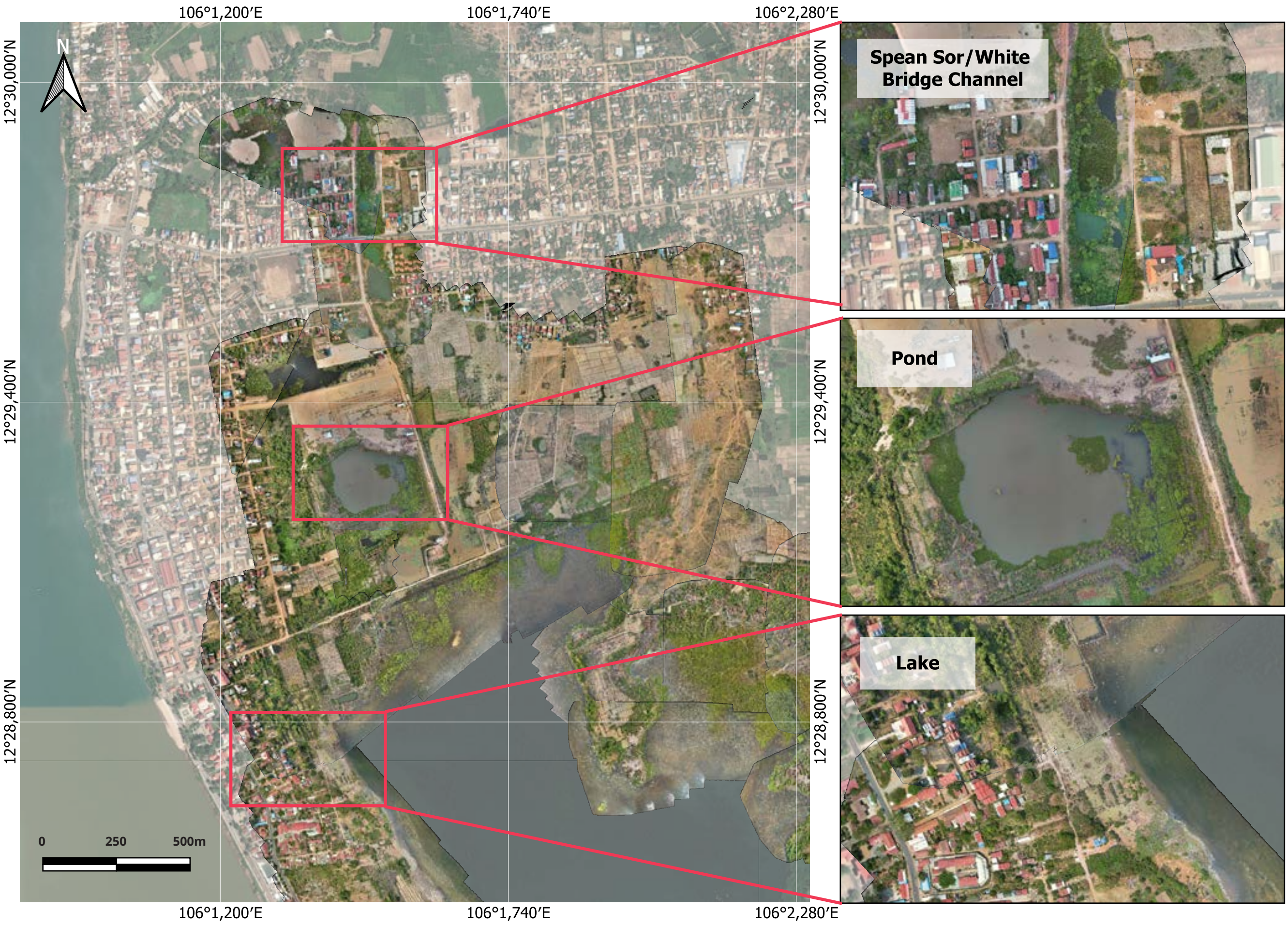
Located between terrestrial and aquatic ecosystems, the Lake Area acts as natural sponge, absorbing and storing huge amounts of water during the wet season within a complex network of vegetation and soil and by allowing inflows from the Mekong River. This absorption capacity significantly reduces the volume of water that could otherwise inundate the urban area and local communities, thereby mitigating the risks associated with flooding. Preventing the immediate runoff of water into nearby rivers and streams that reduces the speed and volume of water flow contributes to reducing flooding further downstream.

Figure 56. Boeungs (lakes and wetlands) in the vicinity of Krong Kratié (Source: Own Work based on Copernicus Sentinel-1 Data, 2018; CNES/Airbus; & Maxar Technologie)

Figure 57. The lake area as natural system of flood control - Aerial photo of Boeung Romleach (Source: Smith, 2014)

Unregulated land use changes, such as the haphazard infilling of floodplains, can fundamentally transform the flood dynamics in the Lake Area. Any significant disruption to the inflow into the Lake Area could cause precarious backwater effects and heightened flood risk in the urban locality. Any urban planning initiative must view the excessive infilling that significantly hampers flood flow as a crucial concern.

It may be essential to pinpoint infrastructural solutions that will facilitate effective water flows. For instance, extensive infilling at Boueng Romleach could diminish its water absorption capacity substantially, escalating the flood hazard risk considerably. Furthermore, the Spean Sor / White Bridge Channel plays a vital role in the Lake Area's tributary system and should be considered as crucial infrastructure that must continue providing this function under any circumstances (See Figure 58).



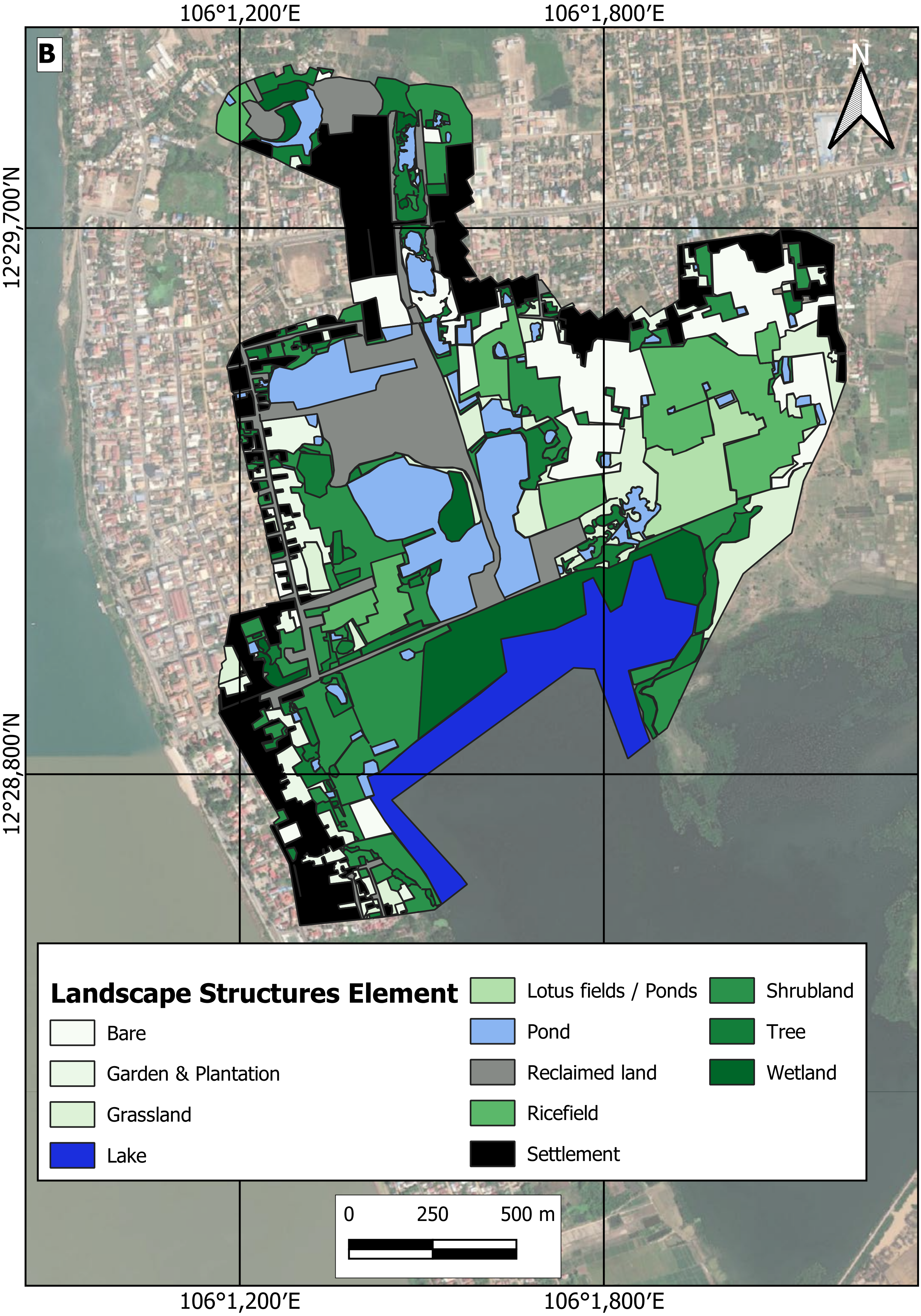
The Lake Area's Function as Natural Cooling System

Krong Kratié finds itself under increasing pressure to enhance its urban climate resilience as the challenges presented by global warming become more apparent. The continual heating of the city's environment is a significant threat to the overall livability of Krong Kratié and presents considerable public health risks. Interestingly, the Krong's urban Lake Area plays a critical role in mediating local climate effects, offering a natural defence against rising temperatures.

The presence of a diverse range of vegetation and a large body of water in the Lake Area of Krong Kratié can generate a cooling effect throughout the year, irrespective of the dry or rainy seasons (See Figure 59). This phenomenon occurs as the Lake Area absorbs solar radiation during the day and releases it as water vapour during the night, a process known as evapotranspiration. This acts as a natural thermostat, reducing the city's ambient temperatures and enhancing the quality of life for its residents.

Figure 58. [top] Northern part of Boueng Romleach with its blue-green network
Note: High Resolution imagery in the suggested boundary
(Source: Drone image mosaics obtained and processed by the Authors in 2023. Own Work).

Figure 59. [right] Land cover in Krong Kratié in 2021
(Source: Own Work based on Drone imagery (March 2023), Microsoft / Maxar Technologies 2023 (Bing Satellite))



B
N
106°1,200′E
106°1,800′E
12°29,700′N
12°28,800′N
Landscape Structures Element
Bare
Garden & Plantation
Grassland
Lake
Lotus fields / Ponds
Pond
Reclaimed land
Ricefield
Settlement
Shrubland
Tree
Wetland
0
250
500 m

However, as urbanization increases and land-use patterns shift, the urban heat island effect—a phenomenon wherein urban areas are significantly warmer than their surrounding rural regions—could pose a severe challenge. This is particularly concerning given the backdrop of global warming and climate change. Research highlights the remarkable cooling effects of urban lakes. Studies on lakes similar in size to Kratié's Boeung Romleach indicate a temperature reduction of around 2.5°C within a 200-meter radius (Phuc et al, 2022; Biswajit et al, 2021). Such a blue-green network associated with the Lake Area is important for a pleasant urban climate.

In light of these findings, future urban development and infrastructure planning in Krong Kratié must consider the importance of maintaining and augmenting this natural cooling effect. It is crucial that new residential developments are integrated within a broader strategy that preserves sufficient areas for such vital green-blue infrastructure, fostering an environment that is both sustainable and livable for the future.

The Productivity of the Lake Area – Rice Farming, Fisheries and Biodiversity

The productivity of the Lake Area is manifested not only through its land-use patterns that demonstrate its importance for the livelihoods of local communities but also in its subsistence and commercial activities in agriculture (See Figure 60).

A notable segment of the population earns their living through rice farming. Rice farming is a very common primary occupation for many males and females. Official data suggest that notably almost all males in Toul Monorum in Kra Kor Sangkat are engaged in rice farming as a primary occupation and over three-quarters of females are engaged in this. More broadly, for the other sangkats, except Kratié, the rates reach over 50 and 60% for males and females respectively. While the rates for secondary occupations are lower and discrepancies in official data may occur, a trend is similar in that over three quarters of males in Toul Monorum report being engaged in rice farming as a secondary occupation while for the other sangkats rates are lower at around 30% of both males and females engaged in this secondary occupation (CDB, 2020).

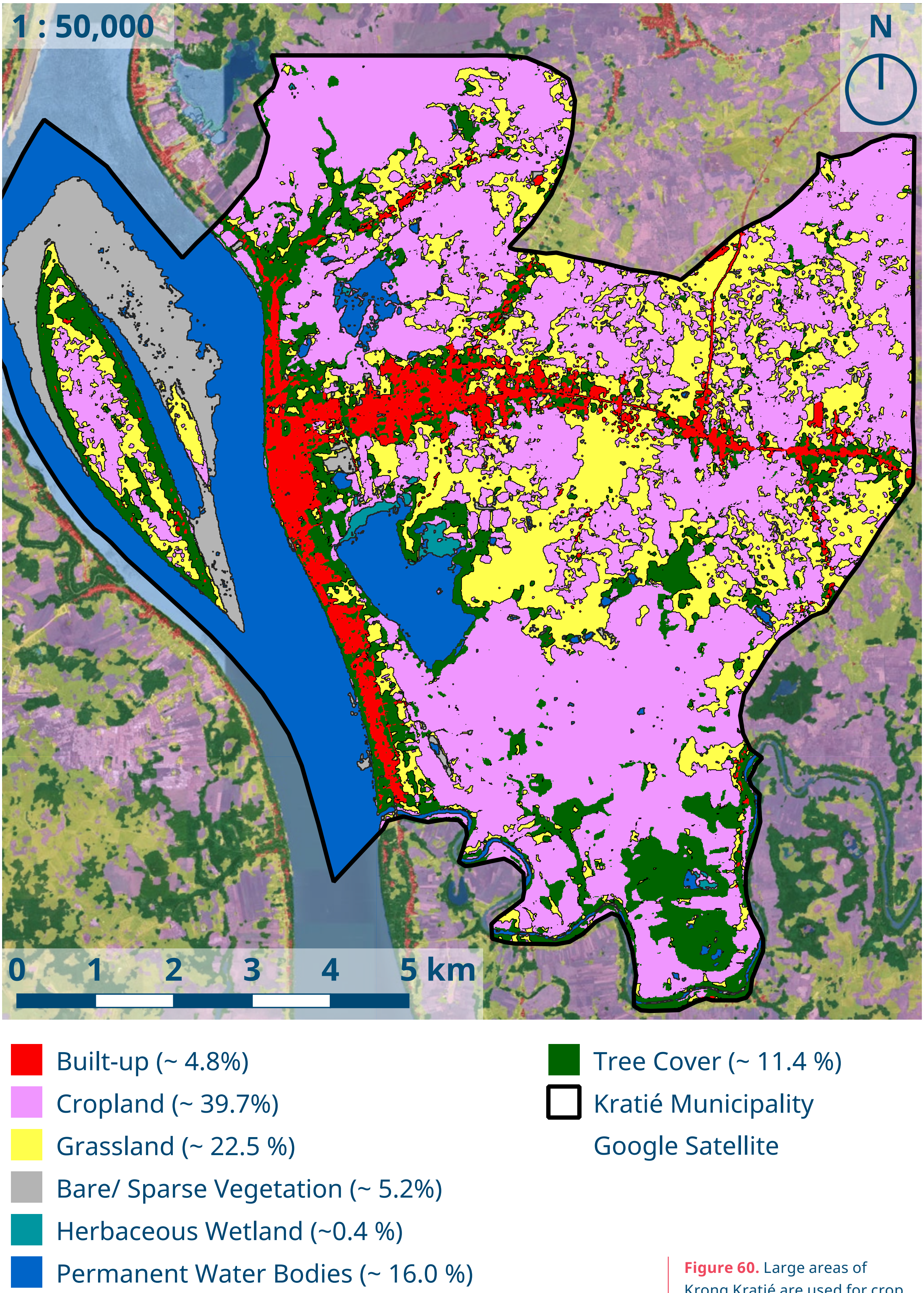


Figure 60. Large areas of Krong Kratié are used for crop production
(Source: Own Work based on Zanaga et al., 2021)

The continuous soil input of sediments, the water retention capacity, combined with its high moisture content, create favourable conditions for rice farming. However, the intense use of chemical fertilizer may contribute to water pollution (Sor, et al, 2021) (See Figure 61).

The communities surrounding the Lake Area, due to their heavy reliance on rice farming, are significantly exposed to risks associated with changes in water flow patterns and the broader impacts of climate change. The preservation of their livelihoods and enhancement of their resilience to water-related challenges hinges on the ability to maintain an effective flow regime, a task requiring well planned infrastructure planning.

Adoption of climate-smart agricultural practices, which allow for increased water productivity in rice cultivation, is certainly a part of the solution. Equally important is the strengthening of the water management capacities within these communities. This will equip them better to navigate the uncertainties and challenges brought about by changing environmental conditions.

In all the sangkats, the prevalence of fishing as a primary and secondary occupation is generally less than 5%. Notably, in Sangkat Kratié, there's no record of residents participating in fishing, and a number of villages in Sangkat O'Russey also report no fishing activities. Ti Mouy village in Sangkat Kra Kor stands out with the highest proportion of males participating in fishing as a main occupation, though it's just slightly above 7% (CDB, 2020).

While the data on exact earnings from fishing are not available, it's evident from field observations that fishing serves as more than a means of subsistence for some households (CDB, 2020). Indeed, it is employed as a

Figure 61. Continuous input of sediments but the use of chemical fertilizer are significant rice farming inputs in the lake area (Source: Own Photo taken in 2022)

supplemental income stream to aid in loan repayments, and for a significant number of households, it even constitutes their primary occupation (CDB, 2020) (See Figure 62).

The Rich Biodiversity of the Lake Area under Pressure

Kratié Province is renowned for its rich biodiversity, with the iconic Irrawaddy dolphins symbolizing this ecological richness. The Lake Area in Krong Kratié as well hosts a wide variety of biodiversity - from a wide variety of fish, bird and plant species to essential micro-organisms.

The unique natural characteristics and ecological interactions within the area provide a diverse habitat for a wide range of flora and fauna, including endangered fish species such as the Giant Catfish (Pangasianodon gigas) and Try Trasak (Probarbus jullieni), and threatened bird species such as the Sarus Crane (Grus Antigone), Greater Adjutant (Leptoptilos dubius), White-shouldered Ibis (Pseudibis davisoni), White-winged Duck (Cairina scutulata), Bengal Florican (Eupodotis bengalensis), Nordmann's Greenshank (Tringer guttifer), Spot-billed Pelican (Pelecanus philippensis), Lesser Adjutant (Leptoptilos javanicus), and Milky Stork (Mycteria cinerea) (Baran, 2005; Kosal, 2004).

Figure 63 presents the wide biodiversity that exists around Krong Kratié, as it shows some of the species of flora and fauna that can be found in the lakes and wetlands there.

The lakes and associated wetlands, flooded grasslands, and flooded crop fields in and around Krong Kratié support the local communities and enhance their well-being by providing essential provisioning ecosystem services, such as fish, aquatic plants, and agricultural products (Sorn & Veth, 2019).

Figure 62. Fishing activities in the Boeung in Krong Kratié
(Source: Own Photo taken in 2022)

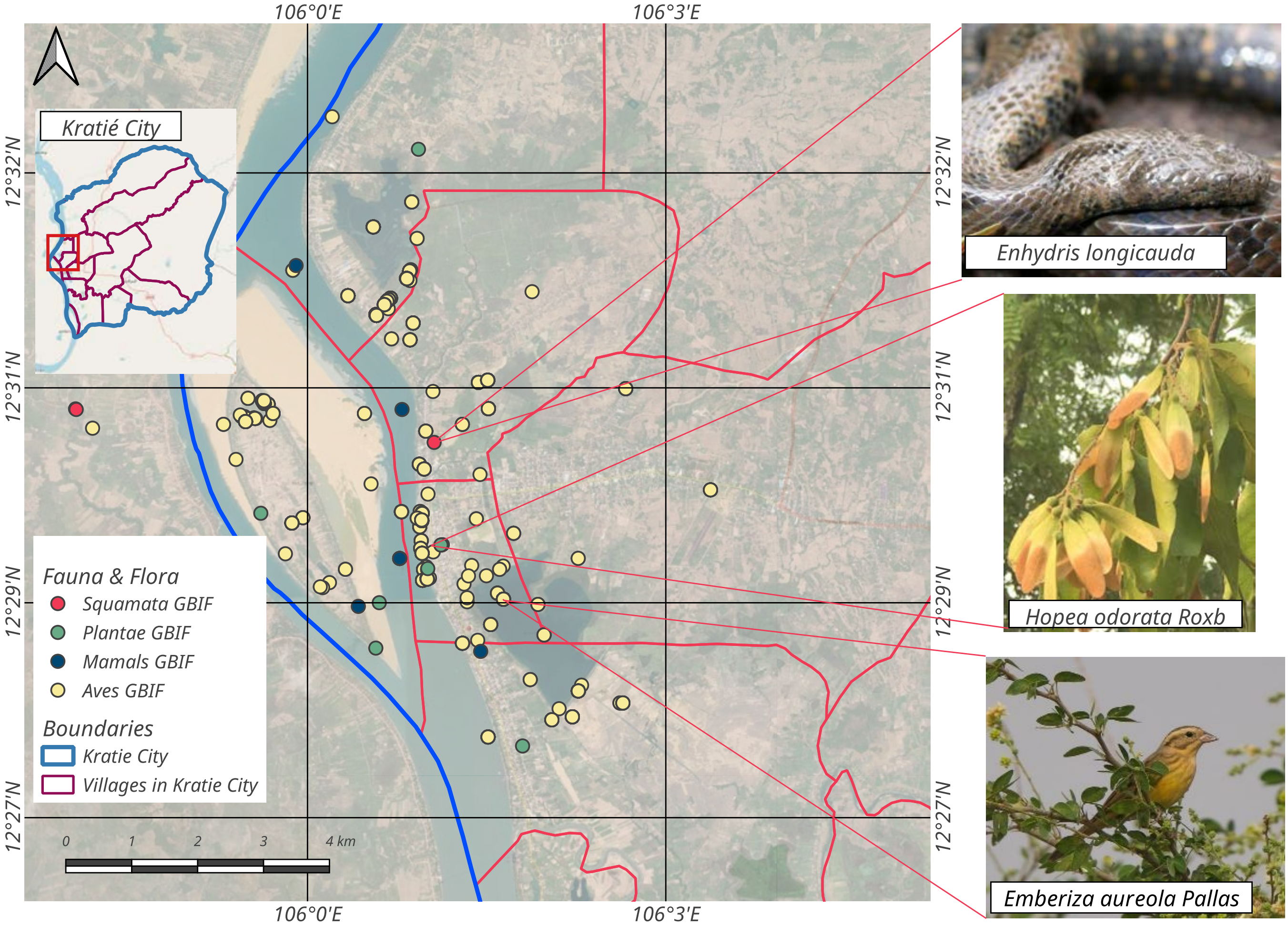


Figure 63. Examples of flora and fauna biodiversity in the lakes and wetlands of Krong Kratié.
Note: Presented here are three species with critical conservation statuses: a. Emberiza aureola Pallas, first identified in 1773-critically endangered, b. Enhydris longicauda Bourret-Vulnerable, first identified in 1934, c. Hopea odorata Roxb – Vulnerable. These species have been identified based on their respective coordinates of occurrence

(Source: Own Work based on GBIF, 2023 and Microsoft / Maxar Technologies 2023 (Bing Satellite)

The health and stability of the Lake Area's ecosystems rely heavily on a steady influx of water. A decrease in water inflow can diminish the water quality, adversely affecting both plant and animal life in the area. Many species' survival depend on these wetland environments, and any disruptions could trigger a decrease in biodiversity. This, in turn, could potentially set off a cascade of consequences for the ecosystems and the overall biodiversity. The loss of biodiversity and natural resources can significantly impact the provision of ecosystem services, including clean water, food, and cultural amenities, that support the well-being of the local communities (See Figure 64).

Presently, the biodiversity of the Lake Area is under serious threat, particularly from water pollution and hydrological modifications. High levels of water contamination, either

Figure 64. Valuating the lake area for tourism development: Eco-lodges under construction on northern end of Boeung Romleach in 2023 (Source: Own Photo taken in 2022)

from untreated wastewater or agricultural runoff, have been reported. Moreover, the impacts of these threats can have long-term, detrimental effects on the health of the local ecosystems, leading to additional losses of biodiversity, natural resources and ecosystem services (Blackham, 2017; Kosal, 2004; Torell et al., 2004).

The full extent of these alterations to the wetlands' biodiversity remains unclear. Nonetheless, it's probable that these changes could reduce productivity, as some seasonal wetlands might not adequately fill up, and others could dry out prematurely.

Mitigating Flood Vulnerabilities in Krong Kratié

Key Messages of Section

1. Flooding of wide urban areas especially during the monsoon season is part of the annual cycle for Krong Kratié and Kratié Province.
2. Significant infrastructural plans for improved stormwater and flooding management are in the planning stages, but no final decisions have yet been made on their implementation and these plans do not apply to new development areas, such as the recently filled areas to the east of Sangkat Kratié and north of the remaining parts of Boeung Romleach.
3. Any effective flood protection should consider the overall flood regime and flood types in Krong Kratié including the Mekong itself, its tributaries and the Lake Area.
4. Krong Kratié exhibits an increased level of vulnerability to flooding hazards. Sealing of the urban area, infilling of parts of the Lake Area and limited installation of stormwater drainage or sewage systems may exacerbate such flooding while climate change impacts may contribute to even further vulnerability.
5. Every flood and disaster management approach should go beyond the standard methods, such as only relying on grey infrastructure-based drainage systems. It is imperative to understand the essential role of the Lake Area: at minimum Boeung Romleach north to Boeung Kbal Dun Soun, and how these areas accommodate floodwater and rainwater during the wet season. Without this understanding, any major disruptions to the water absorption capacity and hydraulic flow could notably escalate the risk of severe flooding in Krong Kratié to areas previously considered not vulnerable to flooding.
6. The consideration of the Lake Area as "green infrastructure" or as a "nature-based solution" is of strategic importance for comprehensive stormwater management, especially given the technical and financial challenges to establishing a highly sophisticated drainage system in the inner city area.

Krong Kratié's Flood Vulnerability

Krong Kratié exhibits an increased level of vulnerability to flooding hazards. This is due to several influencing factors:

1) The flow regime of the Mekong River and its tributaries.
2) The Krong's specific location on the bank of the Mekong River and the topography of the area.
3) Insufficient and poorly maintained infrastructure facilities that impede effective stormwater drainage.
4) The escalating sealing of the surface and soil compaction caused by construction activities.
5) The potential increase in infilling of the lake region adjacent to the Krong, exacerbating the disruption of the water flow, particularly during the rainy season.

Types of Flooding in Kratié

Krong Kratié itself is prone to three distinct types of flooding (CIUS, 2019):

1) **Gradual Onset Flooding:** This type of flooding is a yearly occurrence due to the rise in the Mekong River's water levels, leading to a reversal in the flow of several tributaries north and south of the Krong. This process results in a slow inundation of the lower regions within and surrounding the urban area.
2) **Sudden Monsoon Flooding:** Krong Kratié is regularly subjected to this type of flooding, typically instigated by intense rainfall. Several elements contribute to this occurrence:
    - The primary area of the town centre features some form of drainage system, tracing back to the colonial period. However, comprehensive records detailing the size or state of these drainage systems have been only minimally maintained.
    - The surface drainage system is insufficient due to deterioration and neglect. The existing drainage network often lacks connectivity rendering it ineffective.
    - Moreover, despite the Krong's expansion along the road to National Highway No. 7 effective surface drainage is lacking.

- Although certain drainage pipes and channels exist, they are prone to blockages and frequent replacement.
- Urban development and filling of previously vacant land interrupt the drainage outflows.
- The urbanization process has resulted in hardened surfaces, increasing runoff.

3) **Mekong River Inundation:** This rarer type of flooding occurs when the Mekong River overflows directly into parts of the Krong. Although this type of flooding is still infrequent, the city's topography exacerbates the issue.

Impacts of Flooding on Krong Kratié

In 2018, a MRC Council Study concluded for the region that (i) without protective measures, flood damages are predicted to escalate quickly by a factor of 5-10 due to development; (ii) the accumulation of sediments in the proposed Upper and Lower Mekong Basin dams will accelerate river erosion, necessitating substantial bank protection efforts; (iii) if not regulated, the reduction in floodplain storage due to development will lead to heightened river flood levels and increase the frequency of river and surface water flooding; (iv) climate change is very likely to bring about significant augmentations in floods, especially in the upper part of the basin and in the Mekong delta (MRC, 2018).

This statement may apply to large extent to Krong Kratié as well. As a result, reliable data for decision-making regarding the construction of flood protection structures and floodplain infrastructure is required. The MRC report encompasses an illustrative mapping of major cities within the Lower Mekong Basin, predicting potential flood events by 2040. It demonstrates the anticipated flooding in Krong Kratié under conditions of 1:5 and 1:50 year flood levels in the absence of flood defences, and relative to the built-up area developed (See Figure 65).

As per these projections, future floodplains could potentially span a much larger area than they do today during peak water levels. On Figure 66, the purple-coloured lines represent the extent of the floodplain on August 8, 2018, when the water level of the Mekong River reached approximately 22.27 meters, surpassing the alert level of 22 meters.

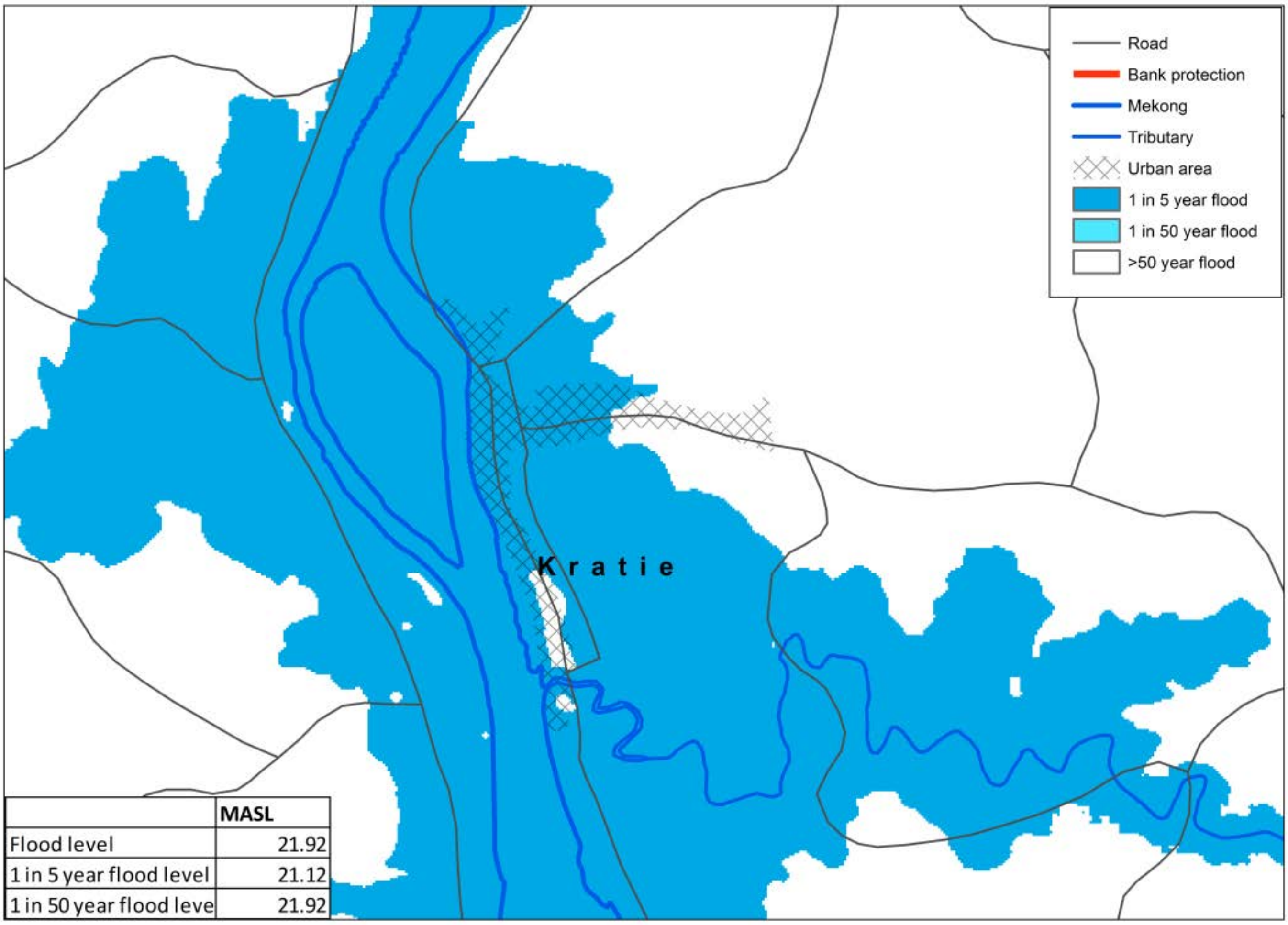


Figure 65. Krong Kratié: predicted potential flood events (Source: MRC Council Study, 2018, p.81)

Current Planning for Improved Flood Management in Krong Kratié

The existing infrastructure, predominantly established during colonial times, is insufficient to meet the demands of modern urban development and requires substantial upgrades (See Figure 67).

The present drainage system within the municipality is plagued with multiple challenges (ADB, 2018b) (See Figure 67):

Functionality Deficiency: A significant portion of the current drainage network is in a state of decline due to age and insufficient maintenance.

Limited Drainage Coverage: Beyond the Sangkat Kratié region, the drainage system's reach is considerably constrained. This issue is particularly noticeable around the east-west access road that links to National Highway No. 7 in Sangkat O'Russey, a region undergoing considerable municipal expansion. Here, constructed drainage channels and pipe sections, especially those along unpaved roads, can frequently become clogged with soil and thus lose their functionality.

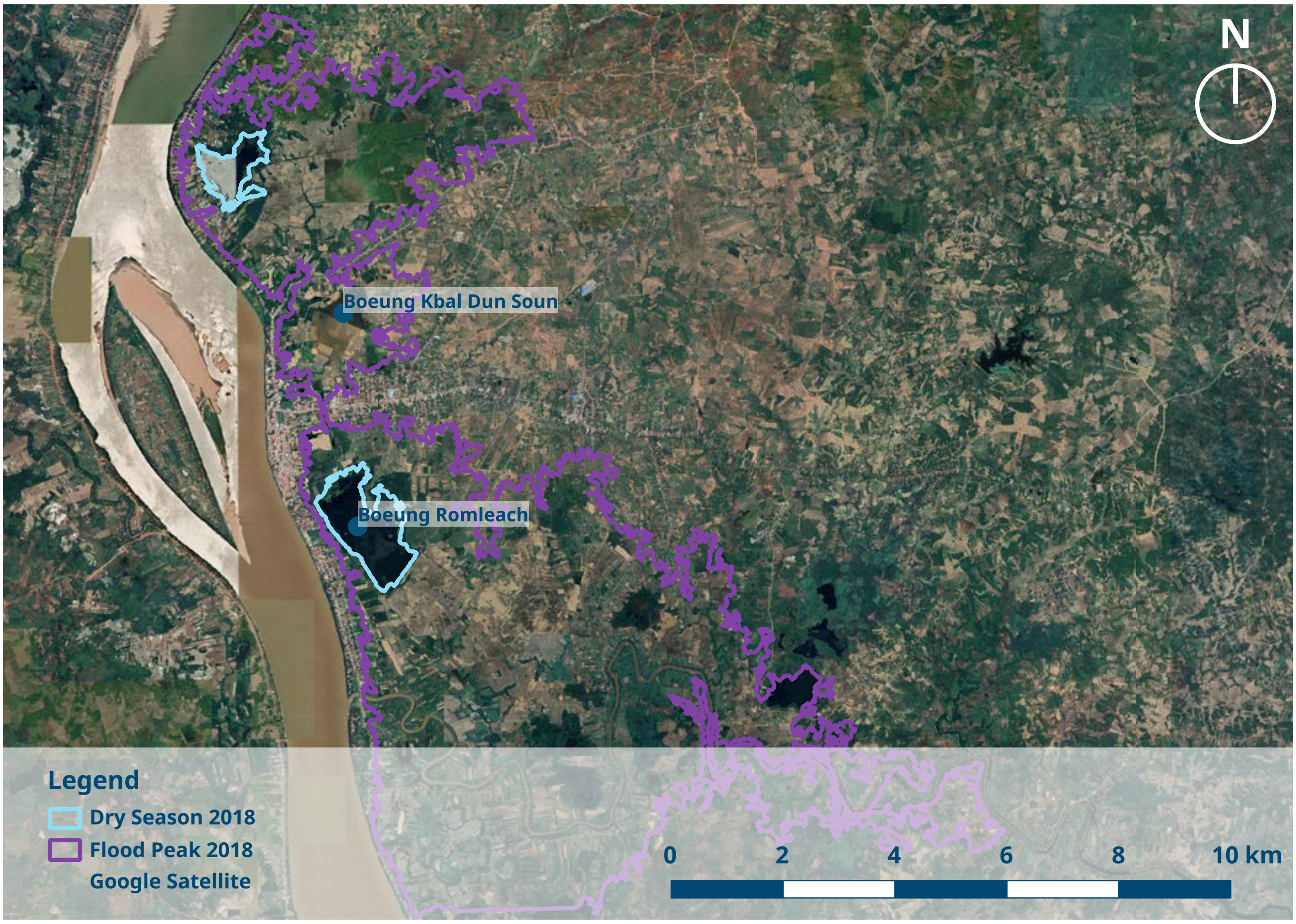


Figure 66. Urban water levels during the dry season and when flooding peaks in 2018. (Source: Own Work based on Copernicus Sentinel-1 Data [2018], CNES/Airbus, Maxar Technologies 2023 (Google Satellite))

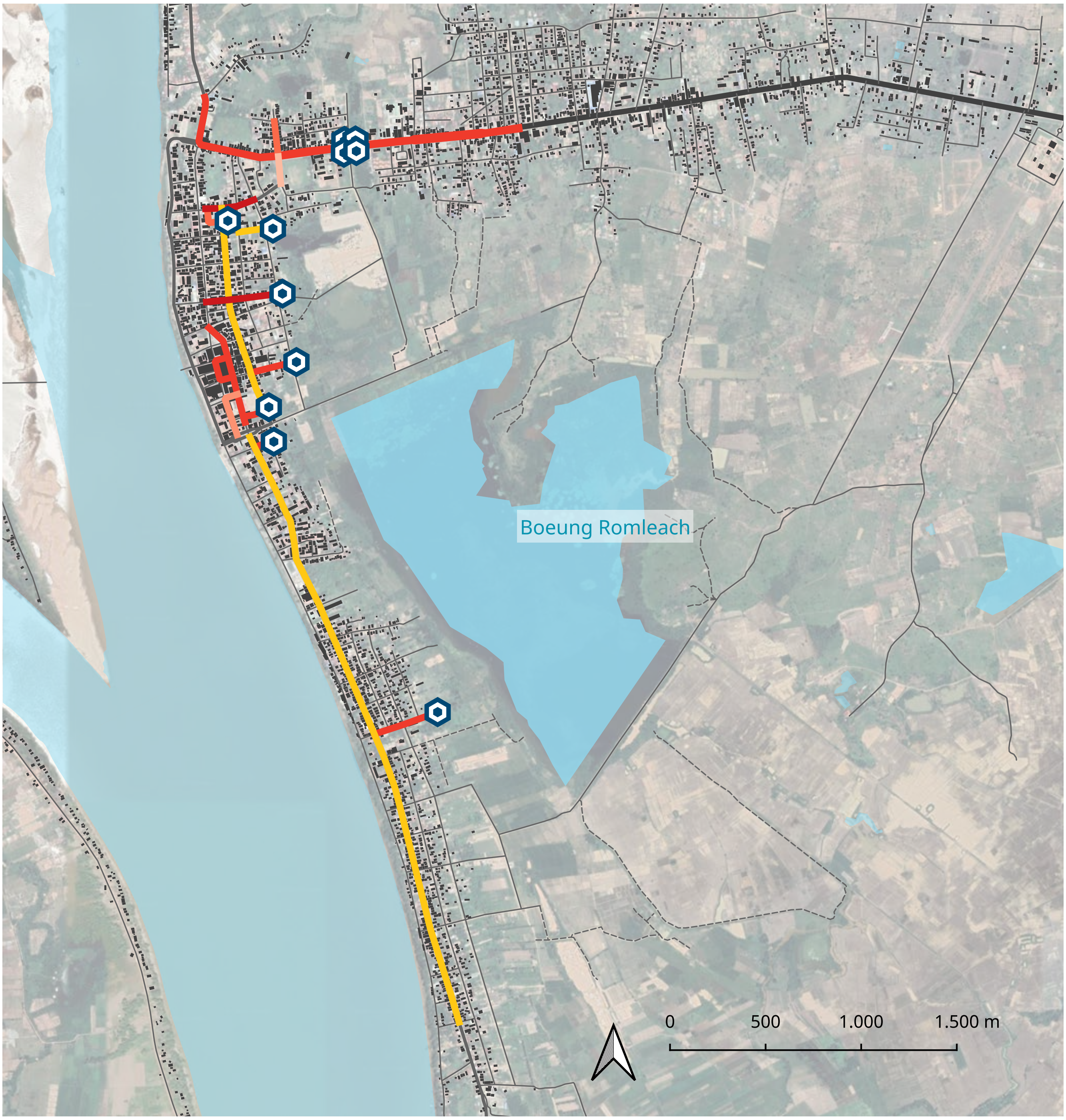
Incoherence in Drainage Systems: Newly constructed drainage facilities often remain isolated from the existing network, failing to integrate into a unified, effective drainage system.

Blocked Drainage Outflows: Drainage outflows are obstructed as the previously open lands, once providing drainage access to the Lake Area, are filled, thereby impeding the effective outflow of drainage.

Urban Hardening: Urban expansion and development have led to the hardening of surface areas within the municipality. This hardening reduces the ground's capacity to absorb water, increasing the amount of runoff during rains.

Challenging Topography: The municipality's topography, characterized by slight rises and depressions, both decreases and increases the flooding risk in different areas. Parts of Sangkat Kratié, especially around the main market, are slightly lower-lying areas that can experience annual flash flooding due to the monsoon rains.

Inadequate River Connectivity: There's a noticeable lack of connection between the town's drainage system and the



Sewer Network and Discharge Gates

- Water Discharging Gate
- round sewers cross section 0,3
- round sewers cross section 0,4
- round sewers cross section 0,6
- round sewers cross section 0,8
- round sewers cross section 1
- U shape sewer cross section 0,5x0,5m
- Built area
- road
- main road
- national road
- Water body

Figure 67. Current drainage system Krong Kratié (Source: Own Work based on RGC, 2022, p.115)

Mekong River. The infrastructure to effectively channel the runoff into the river is limited. Currently, only two to three pipes discharge to the Mekong River, with excess rainwater temporarily accumulating as flash flooding along the main road and flowing back to the east of the riverside toward the lower lying central market area.

Road Flooding poses challenges to the road network, particularly in low-lying and riverfront areas. Between 2000 and 2019 a reported 4,490m of road were damaged according to the Cambodian Disaster Loss Database (CIUS, 2019). Adverse effects include temporary road closures, infrastructure damage, and restricted access. Flooding can affect roads, disrupting transportation locally and to other areas. Prolonged flooding damages road surfaces, bridges, and culverts. Restricted access to flooded areas hinders residents, businesses, and emergency services. A household survey in Krong Kratié conducted by CIUS in 2019, reported annual flooding causes access to homes to be cut off resulting in reduced mobility for 54 of 364 surveyed households (See Figure 68).

To effectively manage the runoff from rainfall, prevent flooding or damage to the road infrastructure (See Figure 69), common elements of combined stormwater and wastewater drainage systems along roads are found through the urban area:

1. **Elevated Roads:** in various areas these help to mitigate the impact of flooding on road infrastructure and provide a safe and accessible route for vehicles, bicycles, and pedestrians, preventing disruptions to daily

Figure 68. Flood event and its impact in 2019 on Bus Station area and Promenade (Source: Own Photos taken in 2019)

Figure 69. Road network in urban core and around Boeung Romleach (Source: Own Work)

activities and emergency services. Additionally, in case of emergency, they can potentially serve as evacuation routes during flood events and help enhance resilience and minimize the economic and social disruptions caused by flooding (See Figure 70 & Figure 71).

2. **Gutters:** Shallow channels or channels with curbs along the sides of the road collect and convey water towards designated drainage points (See Figure 72).

3. **Pipes and culverts:** Underground pipes or culverts convey stormwater to the discharge points, such as the Lake Area (See Figure 73).

4. **Road camber:** roads are sloped to allow water to flow towards designated drainage points, such as gutters or ditches.

Upon examination, a significant number of residential and commercial zones in Krong Kratié retain their traditional stilted structures, with the upper floors matching the raised road level. Consequently, there exists a potential for the accumulation of rainwater and stormwater on the lower floor of the properties. However, the inability of these waters to drain away is caused by neighbouring buildings occupying or filling their ground floors (See Figure 74). This situation creates impediments to water flow and presents health hazards related to stagnant water, including the transmission of diseases, such as dengue fever.

In order to mitigate the vulnerability to flooding events, extensive enhancements are in the works for urban drainage infrastructure within the GMS project in

Figure 70. [left] Elevated dirt road in central residential area (Source: Own Photo taken in 2022);

Figure 71. [Right]: Elevated dirt road in central residential area (Source: Own Photo taken in 2022)

Figure 72. Gutter in central area
(Source: Own Photo taken in 2019)

Figure 73. New roadside drainpipe in central residential area
(Source: Own Photo taken in 2019)

Figure 74. Potential accumulation of rainwater due to adjacent construction walls on property boundaries (Source: Own Photo taken in 2019)

Cambodia, supported by the Asian Development Bank through the Fourth Greater Mekong Sub-region Corridor Towns Development Project. Nevertheless, the planning and decision-making process at the Ministry of Public Works and Transportation has not yet been completed as of July 2023.

Various facility designs have been discussed during the planning process.

1) A comprehensive combined drainage system, which utilizes large and small diameter reinforced concrete pipes, will be introduced for the whole urban area. This system will incorporate various elements, such as appropriate channels, Combined Sewer Overflows (CSO), and individual household connections. Given the flat topography of Krong Kratié and the need to maintain minimum self-cleaning velocities, the use of pumps may be necessary, especially for the CSOs.

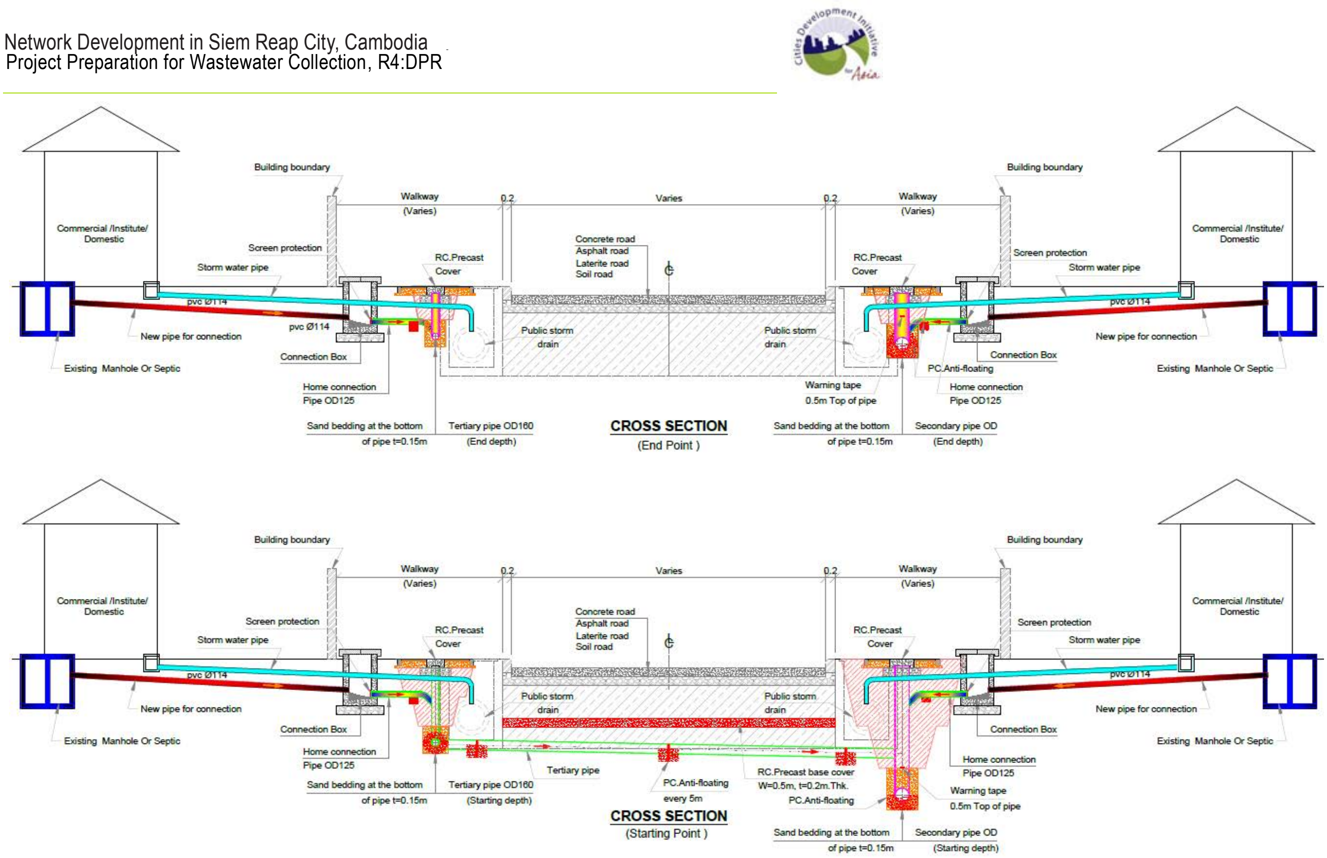
2) Implementation of a segregated sewer system covering the entire urban area. This system will involve the

use of reinforced concrete pipes and channels, both large and small in diameter, specifically designated for stormwater management. Additionally, a network of smaller diameter High-Density Polyethylene (HDPE) pipes will be installed for the exclusive purpose of handling wastewater. In some cases, the use of pumps may be necessary to achieve optimal flow velocities and ensure the self-cleaning capability of the separated wastewater pipe network.

For new urban areas, a 'standard' road and drainage system that is being used in other Cambodian cities may be applied (See Figure 75). The World Bank funded Water and Sanitation Project in Siem Reap connect stormwater, sewers and water supply systems.

Which of these infrastructural solutions is ultimately the most adequate for the situation in Krong Kratié requires an in-depth analysis that cannot be provided here. In such a decision-making process, however, parameters such as sustainable financial viability, sustainable institutional anchoring with regard to maintenance and operation, and sustainable technical performance must be considered in detail, in addition to theoretical effectiveness (see also the chapter on "Wastewater").

Figure 75. Indicative schematic of new road and associated infrastructure, Siem Reap, Cambodia
(Source: CDIA, 2019, p. 44)



The Flow Regime of Floods in Kratié

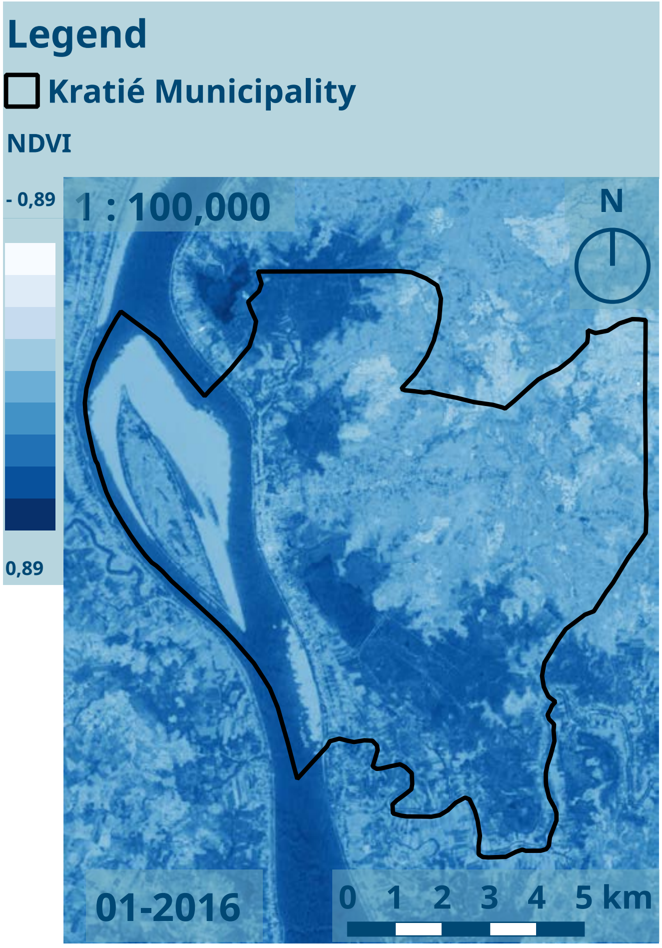
As with other major urban centers on the lower Mekong River, which include cities such as Phnom Penh, Vientiane, and Pakse, Krong Kratié is located directly on the riverbank. This is due to the natural dams that rivers form during floods, as the slowing of water in the floodplain leads to increased sedimentation, making the immediate riverbank higher and less susceptible to flooding. Behind these cities are extensive low-lying areas that include large lakes and wetlands that fill during the flooding season (Campbell 2023) (See Figure 76 & Figure 78).

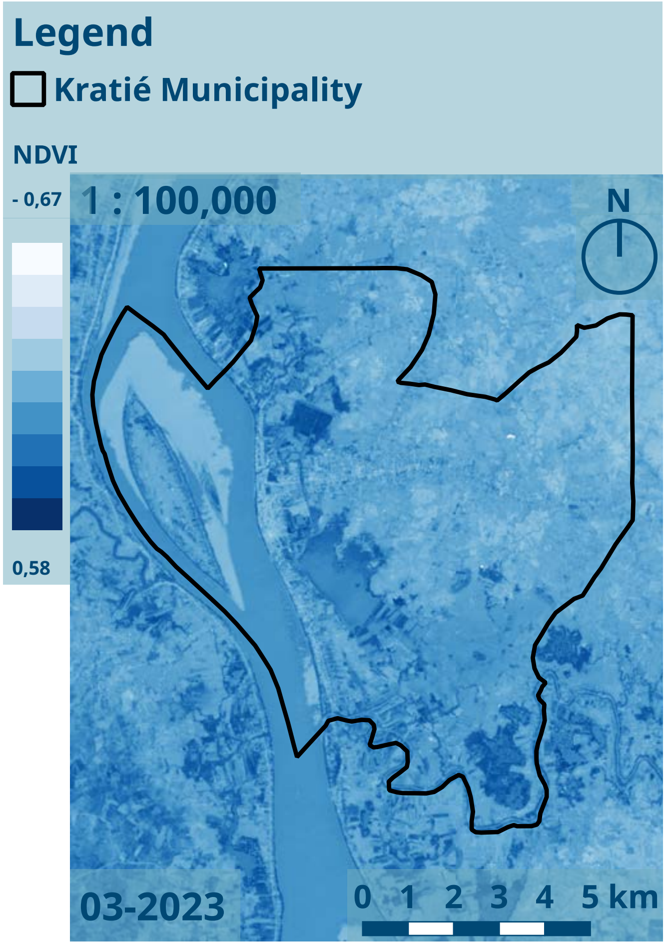
Located behind the elevated Mekong embankments, the land descends and is subject to gradual flooding by the ascendant Mekong River during the monsoon season, which typically spans from June to November. The rise in the Mekong River's water level leads to the influx of floodwaters into the Lake Area situated behind Krong Kratié.

One lake, Boeung Kbal Dun Soun, situated to the north of Krong Kratié, play a crucial role in this natural water cycle. It contributes to collecting both the rainfall and the floodwaters from the Mekong River that flow in a North-South direction towards the Lake Area. These waters, before circumventing the Krong, traverse through the Spean Sor / White Bridge channel on National Road No. 73, an engineered channel approximately 80 meters wide. This channel, partially bordered by embankments, maintains a consistent North-South direction (See Figure 77).

In the urban center, the surface and stormwater are directed eastward away from the Mekong River through distinct outlets. Owing to the elevated positioning of the riverbanks, these outlets eventually gravitate towards the Lake Area. Beyond the immediate Lake Area consisting of Boeung Romleach and Boeung Kbal Dun Soun adjacent to the Krong, a number of other water bodies exist: Boeung Khos Sorkrom, Boeung Pralit, Boueng Udom Rath, and Boeung Pouthi (See Figure 56).

These water bodies combine to form a massive body of water that can remain for several weeks or even months (See Figure 79). An assessment based on wet season references between 2015 to 2022 show that these water bodies merged into a large water body in 2017, 2018, 2019, and 2022 (Own Work, 2023. Based on ESA Sentinel 1 Assessment). (See Annex IV)


Legend
Kratié Municipality
NDVI
- 0,89
0,89
1 : 100,000
N
01-2016
0 1 2 3 4 5 km


Legend
Kratié Municipality
NDVI
- 0,67
0,58
1 : 100,000
N
03-2023
0 1 2 3 4 5 km

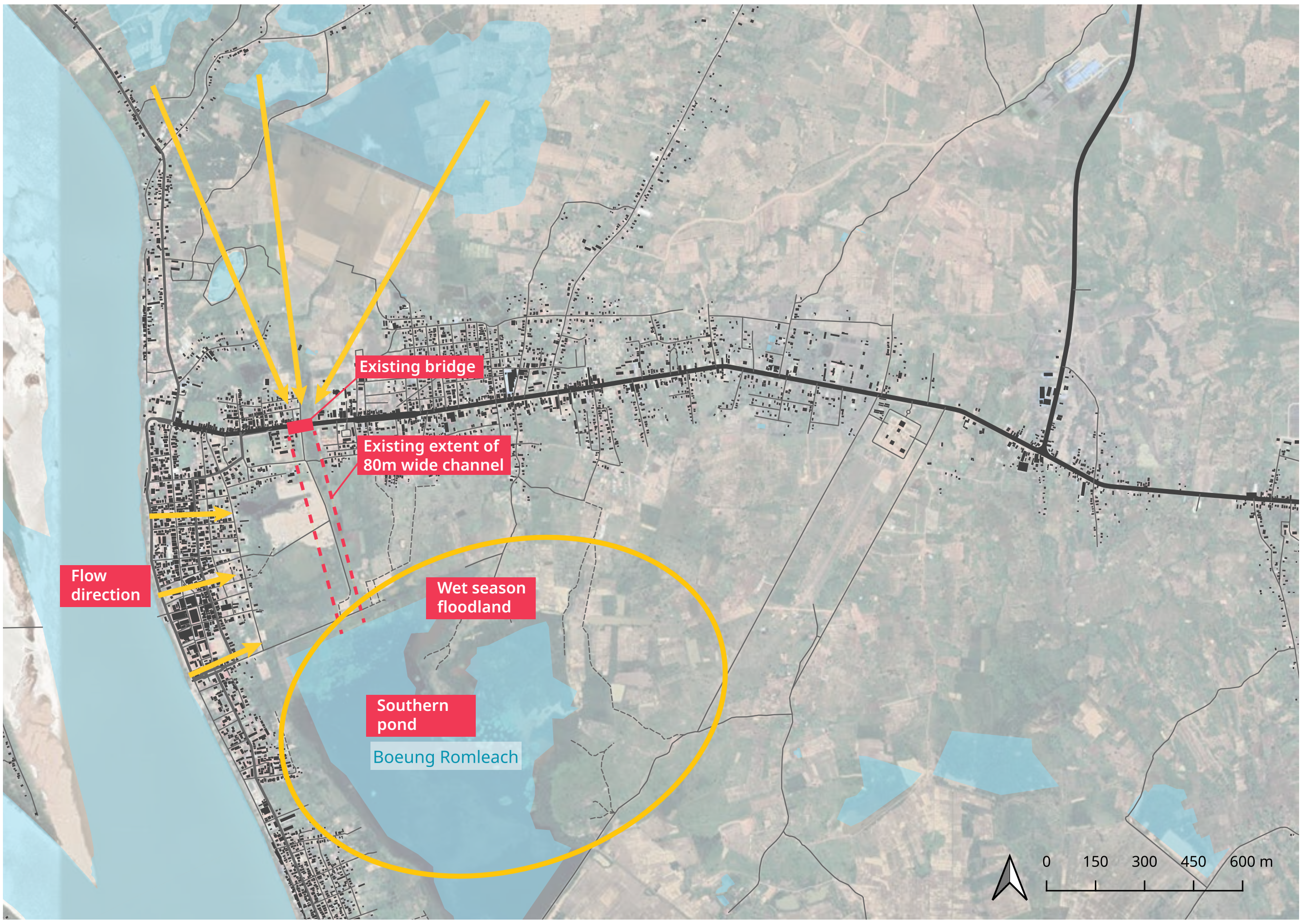

Existing bridge
Existing extent of 80m wide channel
Flow direction
Wet season floodland
Southern pond
Boeung Romleach
0 150 300 450 600 m

Table 5 indicates that when water levels reach 19.78 meters in Krong Kratié's urban area - a scenario classified as low hazard – there is a 100% probability of occurrence, subsequently inundating over 38% of the Krong. Moreover, a flood with medium hazard potential occurs with a 33% probability, leading to 44.69% of the urban area being submerged. Nevertheless, the Mekong River Commission emphasizes that a hazard does not necessarily translate into damage (MRC, 2005).

As Figure 79 shows, the alert level, which is a 22m flood level, is exceeded in 2018 and 2019 during the 2015-2022 period. A level above 22m is reached with a probability of occurrence of 5-10 years.

As noted above, during the rainy season the Lake Area notably acts as a sponge, soaking up substantial amounts of floodwater and rainwater (Rau, 2022). According to computations by PolyUrbanWaters, Boeung Romleach held an average water volume of 75,946,298m^3 in 2015 and 2022. This volume was replenished by floodwater and rainwater. The water was then dispersed through evaporation, seepage, and a receding flow effect back into the Mekong.

The analysis implies that flood and disaster management strategies in Krong Kratié must transcend traditional approaches, such as infrastructure-based drainage systems. Undeniably, enhancements to the Krong's drainage system and flow patterns at the Spean Sor / White Bridge Channel are crucial. Nonetheless, understanding the flow dynamics and functions of the Lake Area and its wetland system is also vital.

Any substantial interruptions to its water absorption capacity, its role as buffer zones, and its hydraulic flow could substantially heighten the risk of intense and damaging floods in Krong Kratié. In particular, increased backwater effects can lead to a considerable rise in water levels and potential increased water intrusion into urban areas.

Figure 76. [top-left] Krong Kratié natural water resources dry season 2016 (left) & 2023 (right) (Source: based on Copernicus) Sentinel-2 Data [2016 & 2023])

Figure 77. [bottom-left] Current drainage flows for Krong Kratié (Source: Own Work based on ADB, 2018)

Table 5. [right] Area inundated compared to total area applying flood frequency assessment (Source: Own Work based on MRC, 2023; NASA Shuttle Radar Topography Mission (SRTM), 2013; & Global Administrative Areas (GADM), 2012)

Name	Water Level (m)	Probability (%)	Area Inundated (%)
Medium Hazard	21.6	33	44.69
Low Hazard	19.78	100	38.58

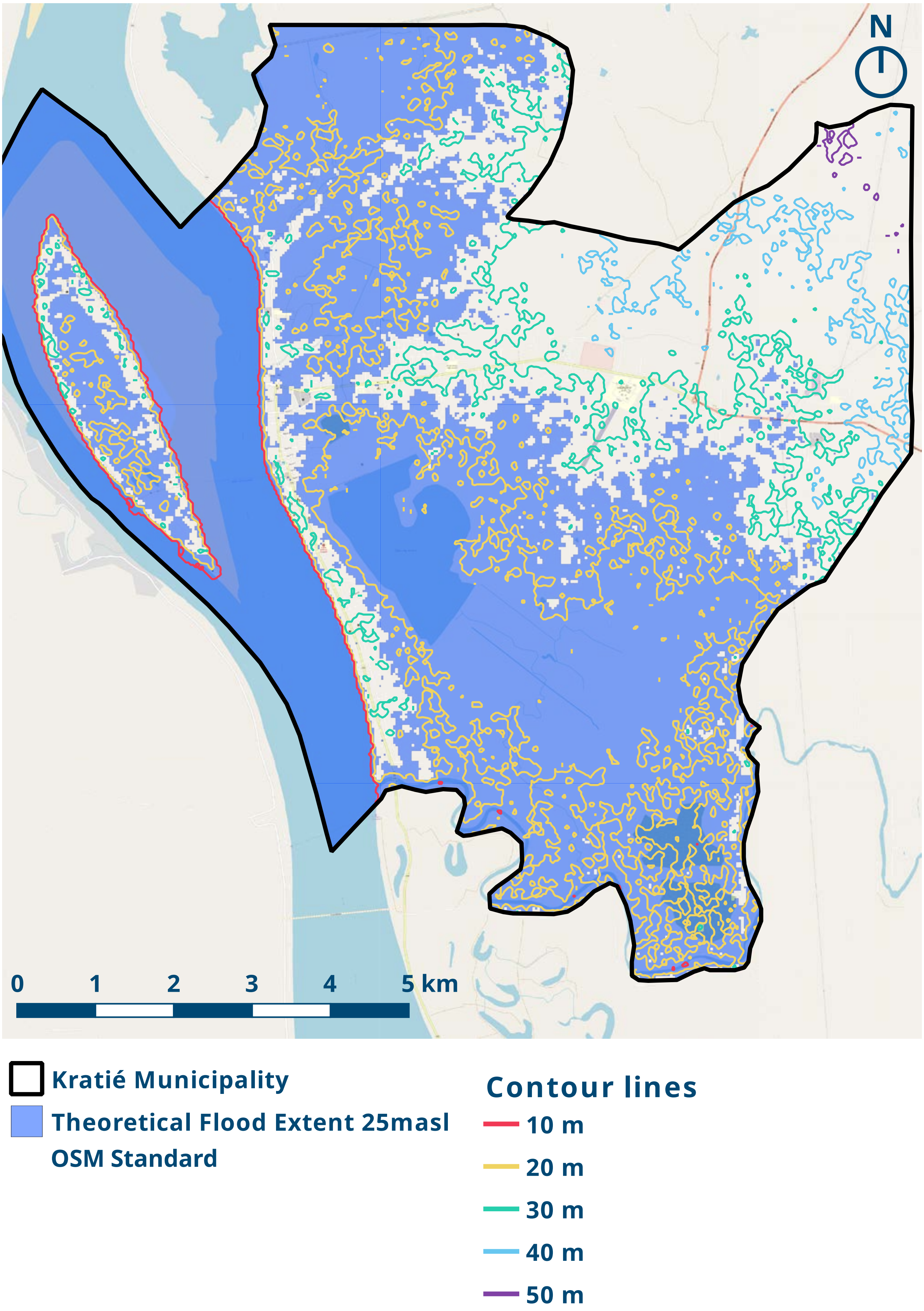
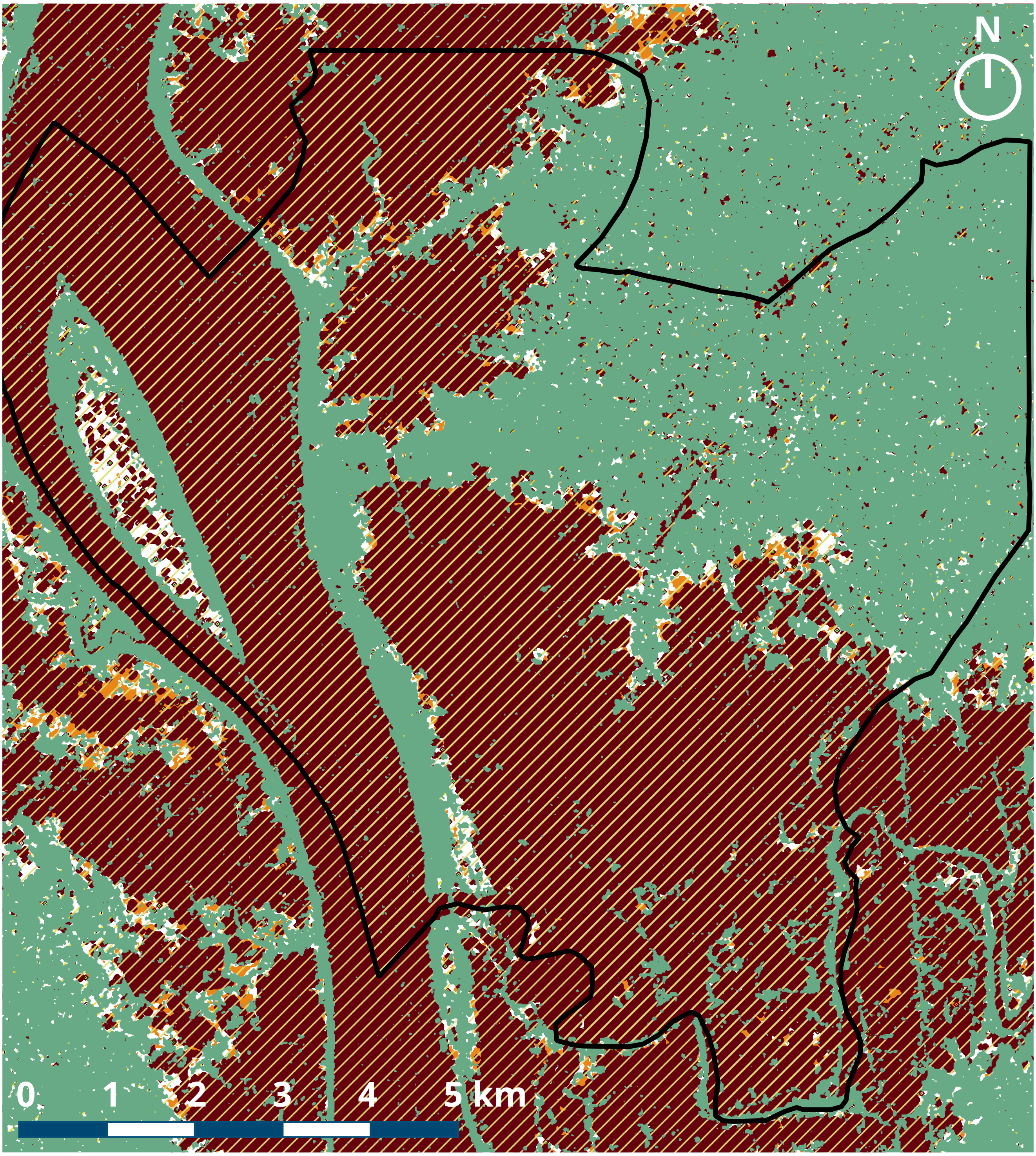


Figure 78. [top] Elevation-based flood model for Krong Kratié
(Source: Own Work based on Global Administrative Areas 2012; NASA Shuttle Radar Topography;& Flood Map, n.d.)



Peak Areas Inundated

Kratié Municipality

No recorded flooding since 2015

Ca. 5 - 10 years return period (2018 & 2019 ~22.27 - 22.69m)

Ca. 2 - 5 years return period (2017 ~21.26m)

Ca. < 2 years return period (2015,2016, 2020 -2022 ~17.07-20.54m)

Figure 79. [right] Peak areas inundated between 2015 and 2022
(Source: Own Work based on on Global Administrative Areas (GADM), 2012; & Copernicus Sentinel-1 Data [2015 - 2022])

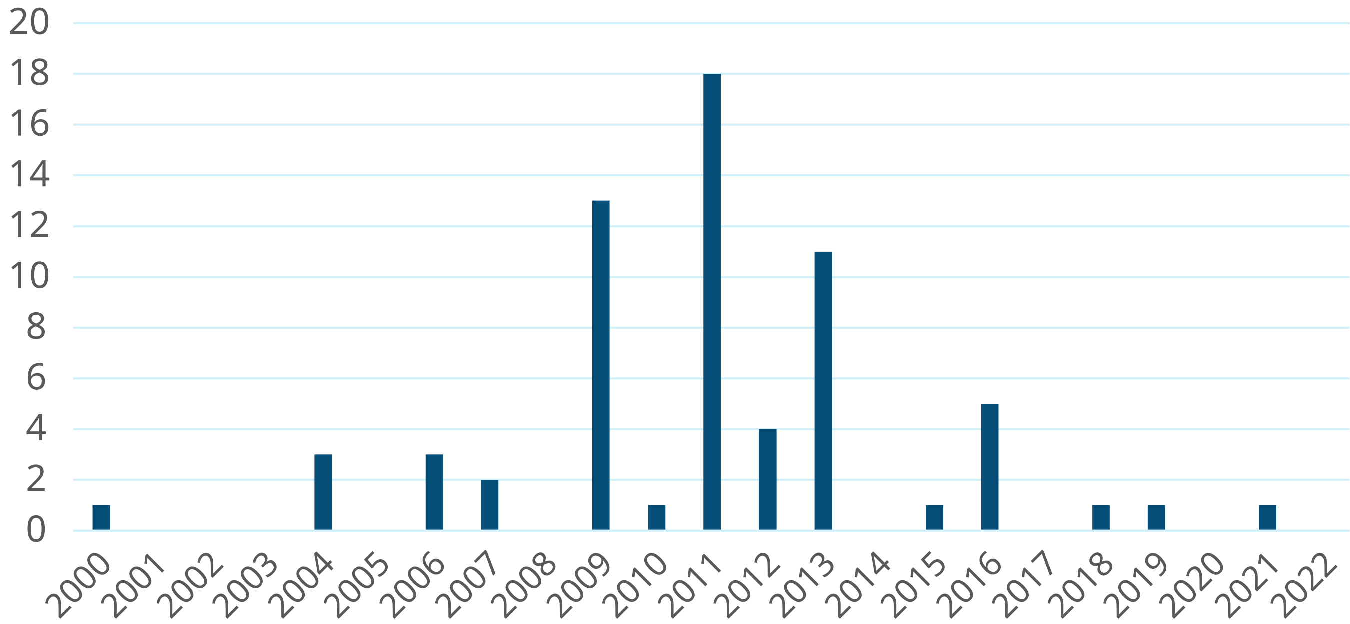


Figure 80. Number of recorded disasters per year in Krong Kratié (Source: CamDi, 2022)

The sustainable management of these "green infrastructures" holds importance that extends beyond their role in effective flood management. Any significant disruption to their functions would necessitate counter measures that often result in high investment and maintenance costs.

Impacts of Damaging Flooding Events in Krong Kratié

Over the last decades, Kratié Province has experienced serious and damaging flood events in the years 1996, 2000, 2001, 2011, 2013, and 2019 (MoE, 2022). In 2019, 64,488 people were recorded as being directly affected by floods across the province with almost 10,000 in Krong Kratié (CamDi, 2023).

The Cambodia Disaster Loss Database (CamDi) records a total of 65 disaster incidents in Krong Kratié from 2000 to 2022 (See Figure 80). A substantial majority of these events are flood-related, accounting for 69% or 45 incidents. Storms also contributed a significant portion, making up 13% or nine incidents. Notably, only 3% of the incidents, which amounts to two events, were due to drought (See Figure 81). However, official data recorded on this database may only represent a portion of the flood and drought incidences occurring.

Within this period (2000-2019), CAMDi reports five deaths attributed to either floods or storms, while 34,166 people

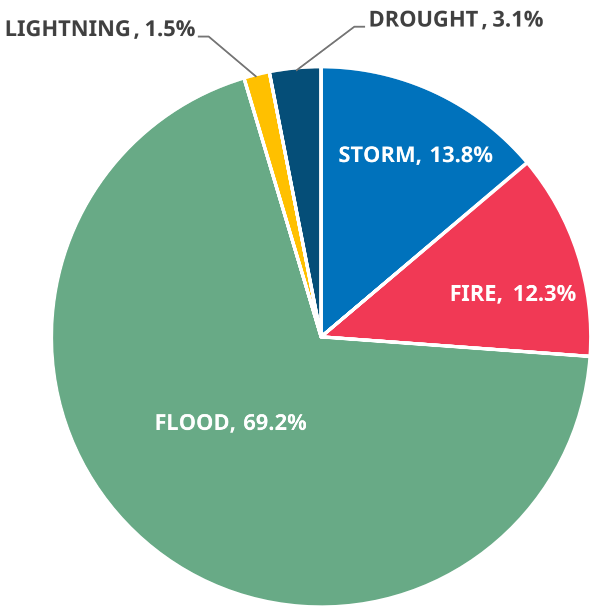


Figure 81. Incidence of disasters in Krong Kratié from 2000 to 2022 in percentages (Source: CamDi, 2022)

are reported as being victims of these (flood/ storms only) reported disaster events. In terms of other impacts, 64 houses have been destroyed and 112 damaged in Krong Kratié. Cumulative 10,941 hectare of crops have been damaged as have a reported 4,460 metres of roads (CAMDi, 2022).

A survey conducted by PolyUrbanWaters in 2020 showed that half (47%) of the surveyed households reported experiencing some flooding of their households in recent years, these reports came from 15 of the 16 villages in the municipality. The exception was one of the villages on Koh Trong (Chong Koh). The majority of respondents (95% 160/169) indicated that flooding of their households occurs at least once per rainy season with the others reporting flooding occurring twice per season. Flooding usually persisting for longer than one week was reported by 64% of those households affected. Nearly two thirds of those reporting flooding persisting for longer than one month (64%) while the remainder reported flooding persisting for between one week and one month.

Given the high rates of dengue fever infections in Cambodia and the predictions of a significant outbreak in 2023, for example, prolonged periods of flooding in an urban area with poor drainage can contribute to standing water providing ideal breeding habitats for the species of mosquitoes (Aedes Aegypti) that are the primary vector for dengue fever (Khouth, 2023; Bigio, et al, 2022).

Water Supply Development of Krong Kratié

Key Messages of Section

1. Kratié's current water supply networks, primarily serving mainland residents, are a strong base for future expansion and improvement.
2. Despite high satisfaction with the water services of the two licensed operators, residents report boiling water or prefer consuming bottled water, keeping piped water for washing or bathing.
3. A number households continue to access free water from relatively shallow pump wells as their main source of water as well as to supplement the piped water system.
4. Notably, household rainwater harvesting is rare, even in regions unserved by the piped water network as on Sangkat Koh Trong.
5. Water supply upgrades in Krong Kratié are projected to meet future needs considering the slow population growth rates.
6. Uncertainties exist regarding the willingness of residents in currently unserved areas to pay for connections and the profitability of network expansion into less populated regions, given high operational costs and the necessity to reduce non-revenue water (NRW).
7. Sourced from the Mekong River, Krong Kratié's water supply is unlikely to deplete, but potential changes in water quality may pose treatment challenges.
8. Piped water supply coverage to new development areas in the Lake Area responds to demand rather than being installed as part of an overall area plan prior to building construction.

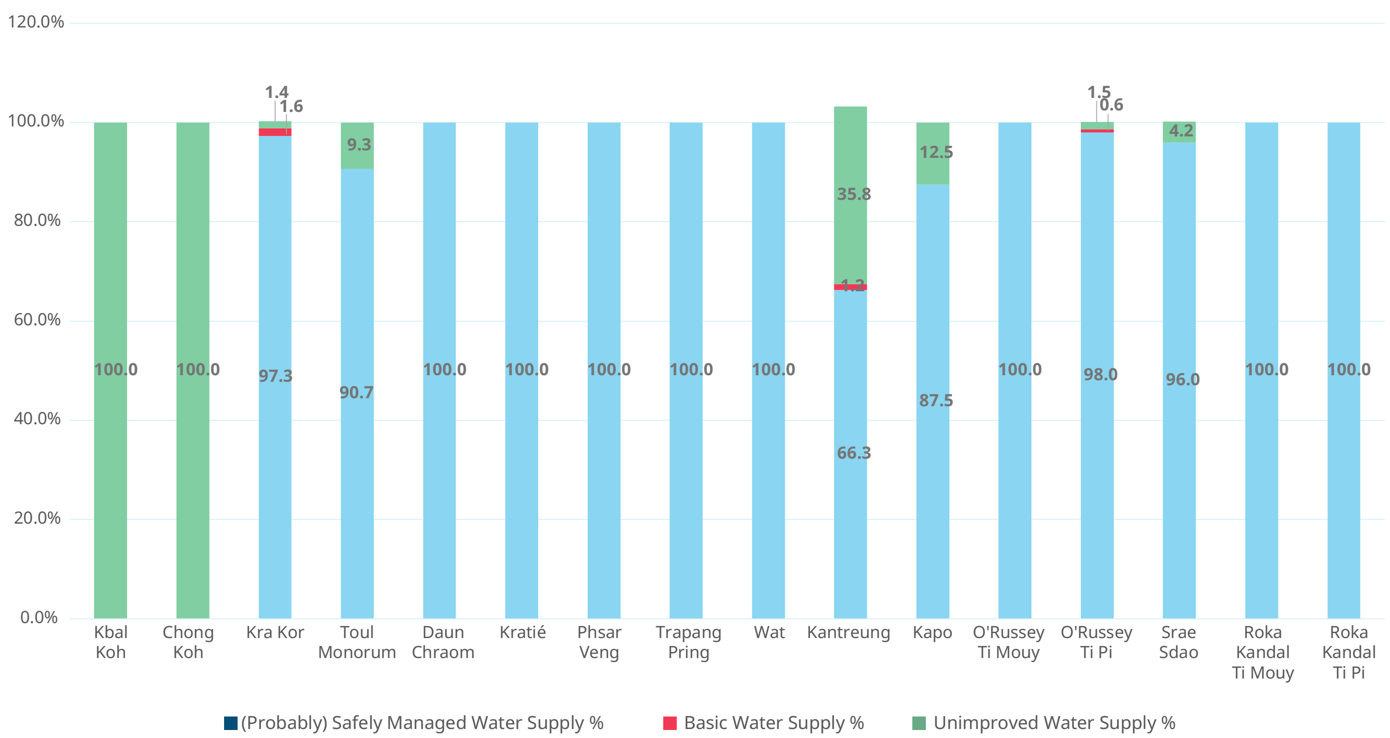
Water Supply Coverage

Most of the population of the four main-land sangkats are serviced by the water supply network. As this does not include Koh Trong Sangkat because it is an island and not within the water supply network, 91% of the total of 7,701 families recorded in the 2020 Commune Database, an increase from 84% of 7,145 families recorded in 2018, report accessing a safely managed water supply system that provides treated potable water (CDB, 2020). The vast majority (90%) of the total water demand comes from the central downtown areas of Krong Kratié (RGC, 2022).

Further data from the largest of the two water supply operators in Kratié for 2020 indicates that 6,021 households, which account for roughly 80% of the total 7,701 households, had access to water network in 2020. This signifies that a considerable majority of households in the municipality are connected to treated piped water supplies (CDB, 2020).

The 2020 Commune Database reports that half of the 16 villages in Krong Kratié have 100% access to an improved water source (access to the piped water network). However, just under 10% of all families, equating to approximately 666 families do not have access to an improved water source: less than 9% have access to an unimproved water source, such as a well, and less than 1% have access to a basic level of service, such as a protected well. It should

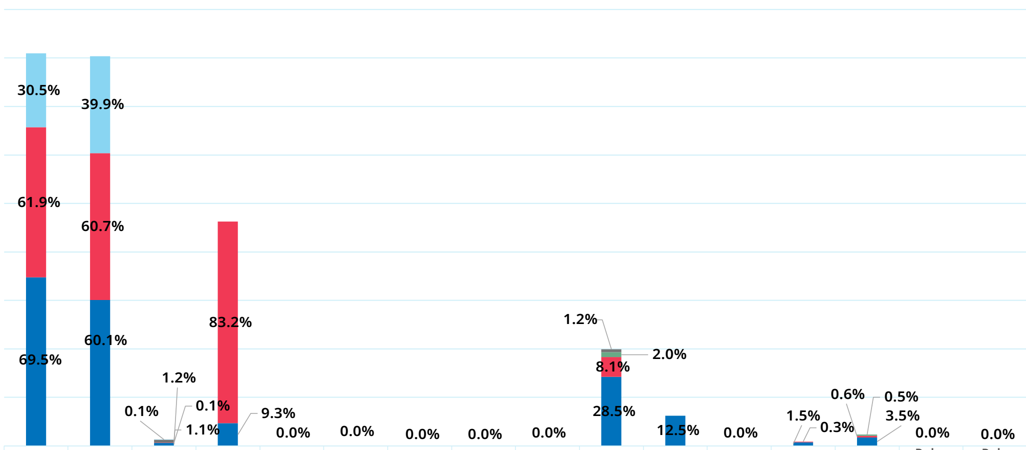
Figure 82. Families accessing safely managed, basic or unimproved water supply in percentages (%) (Source: Own Work adapted from CDB, 2020)



be noted that some families report accessing more than one water source. Tuol Monorum in Sangkat Kra Kor, and Kapo and Kantreung in Sangkat O'Russey have significant proportions of households accessing an unimproved water supply service: 9%, 13% and 36% respectively. Both villages on Sangkat Koh Trong have 100% access to unimproved water sources only. These figures indicate a need for improved water supply services to be extended to areas that are currently deficient, particularly as there is no regular monitoring of water quality of wells and other unimproved sources in areas where groundwater might be contaminated by arsenic (See Figure 82).

According to the Ministry of Public Works and Transportation, for households resorting to informal water sources, the common practice is to extract groundwater through unprotected wells. This pattern is particularly marked in Sangkat Koh Trong, where upwards of 60% of households rely on pump wells or drilled wells. In contrast, in other regions, the reliance on wells is markedly lower, varying from less than 5% to just under 30%. It's worth noting that Toul Monorum in Sangkat Kra Kor exhibits a significant rate of well usage, with over 80% of households using this method for their water needs (See Figure 83).

Figure 83. Households using other water sources than water supply in percentages (%) (Source: Own Work adapted from CDB, 2020)



	Kbal Koh	Chong Koh	Kra Kor	Toul Monorum	Daun Chraom	Kratié	Phsar Veng	Trapang Pring	Wat	Kant-reung	Kapo	O'Russey Ti Mouy	O'Russey Ti Pi	Srae Sdao	Roka Kandal Ti Mouy	Roka Kandal Ti Pi
% from rivers, streams, lakes, streams	30.5%	39.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% Rainwater	0.0%	0.0%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% from Pond	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%
% Drilled Wells	61.9%	60.7%	0.1%	83.2%	0.0%	0.0%	0.0%	0.0%	0.0%	8.1%	0.0%	0.0%	0.3%	0.6%	0.0%	0.0%
% Pump Wells	69.5%	60.1%	1.2%	9.3%	0.0%	0.0%	0.0%	0.0%	0.0%	28.5%	12.5%	0.0%	1.5%	3.5%	0.0%	0.0%

Moreover, it is observed that newly extended areas remain largely unserved by piped water systems. Given the slow progression of piped water systems in these regions, households and users are compelled to depend on wells (Own Work, 2023). Extension of the piped water system will be in response to increased demand rather than installed as part of an overall area development plan prior to construction of new buildings.

On the whole, the utilization of surface water sources, such as rivers, lakes, or streams, is restricted to approximately 30 to 40% of households on Sangkat Koh Trong. Rainwater harvesting is almost non-existent, with minimal rates reported in Kra Kor Village in Sangkat Kra Kor and Kantreung in Sangkat O'Russey. Moreover, rainwater harvesting is not an observed standard feature of public buildings, institutions or large private buildings, including hotels (See Figure 83).

Water Supply Operators

The water supply networks are managed by two separate private concessional operators. The water supply network as of 2015 is illustrated below including planned expansion areas into Sangkat O'Russey and Chetr Borey Commune, which is outside of the current municipality boundaries (See Figure 84).

Water Supply Network Consumption Rate

According to data from the larger of the two Kratié water supply operators for 2020, 6021 households (approximately 80% of the total 7701 households in the municipality as per the 2020 CDB) accessed the water network in 2020.[13] This is approximately 24,948 people. If average consumption per capita is 145 L/day/person, residential water consumption is 3617.46m^3 / day in 2020 (RGC, 2022) (See Table 6).

For water supply consumption and cost, the Ministry of Public Works and Transportation's study on Krong Kratié's drainage surveyed users and identified that households in 2020 were consuming on average 24.6m^3 per month at a cost of between 1,700 Riel and 1,800 Riel per m^3. This tariff rate is considerably higher than that charged by the Phnom Penh Water Supply Authority (PPWSA), for example, where the rate is less than 1,000 riels for a usage from 16m^3 to 25m^3 (PPWSA, 2023).

13 The assumption is one connection per household/family.

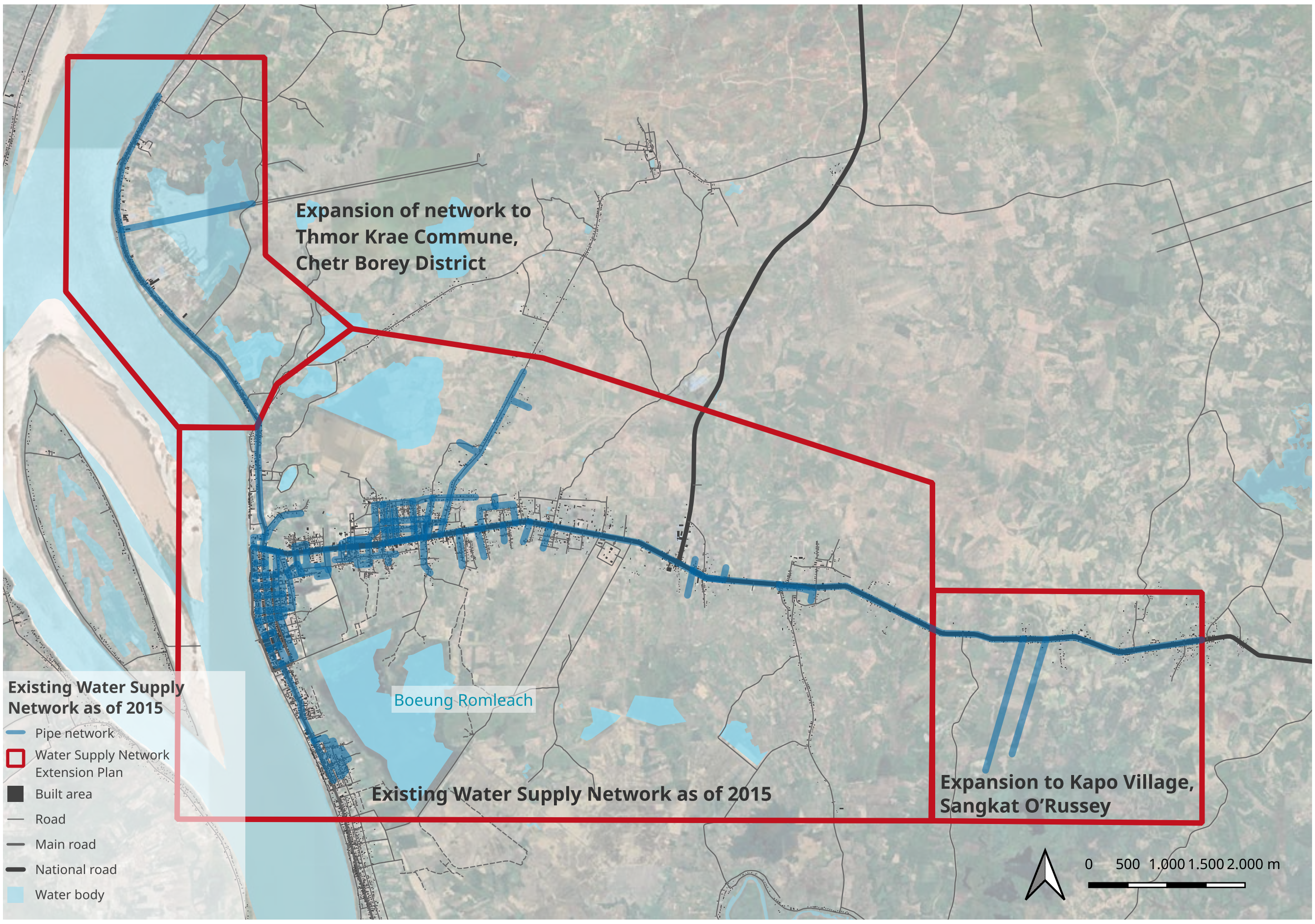


Figure 84. Largest water supply network in Krong Kratié as of 2015 (Source: RGC, 2022)

	Consumption			Cost	
Interviewed	**From**	**To**	**Average**	**From**	**To**
Households	23m³/month	84m³/month	24.6m³/month	1700 riel/ month	1800 riel/ month
Hotels/ Guesthouses	200m³/month	650/month			
Assumption consumption is for 2020 based on Siem Reap.	145 liters / day / person (International) OR 150 l/d/p JICA Siem Reap				
Residential Total	3,617m³/day by 2020				
Restaurant	47m³/month	375m³/month			
Businesses	25m³/month	450m³/month			

Source: MPWT pp. 60-64

Table 6. Piped water supply consumption rates and costs per m³ (Source: RGC, 2022)

Hotels/guesthouses are recorded as consuming up to 650m3 per month depending on the season, restaurants up to 375m3 per month, and 450m3 per month for businesses. Each are charged the same rate as households: between 1700 and 1800 riel per m3 per month. In contrast, the PPWSA, for example, charges a different tariff rate for the type of customer: Domestic, Public Administration Institution and Embassy, Commercial, Autonomous State Authorities and Wholesalers (PPWSA, 2023).

Water Supply Network Production Rate

To service the water demand of 6021 households, the largest operator can produce 700 to 800m^3 per hour for eight hours a day producing 181,141m^3 of clean water distributing 149,758m^3 with a NRW of 16% to 18% overall. The connection charge is USD50 and the cost of water depends on the quantity used and varies between 1,500 riel/m3, 1,750 riel/m^3 and 1,800 riel/m^3. This operator has 106 km of piping and as with the other of the two operators, uses the Mekong River as the source for the water supply network (See Table 7).

Generally, households report satisfaction with the water supply service forming a good basis for future upgrades, expansions and improvements (RGC, 2022). However, There are questions over the financial viability of the operators and the maximization of profits given the relatively small

Table 7. Piped water supply operator production rate (Source: RGC, 2022)

Water Supply Operator	Connections	Capacity of the operator
Total Households	6,021 Households / 24,948 Households	700-800 / hour capacity
%	80%	at
Coverage	for Kra Kor (1 village), Kratié (6 villages - most connections in these villages), O'Russey (2 villages)	8 hours / day
Quantities		as of September 2020
		181,141 m3 of clean water produced
		149,758 m3 distributed
Service Fee		serivce fee of USD50
Pricing		Clean water costs 1500 riel /1750 riel /1800 riel / m3
Source		Source: Mekong River
Piping		Piping 106 km
Non Revenue Water		NRW is 16 - 18%

Source: MPWT pp. 60-64

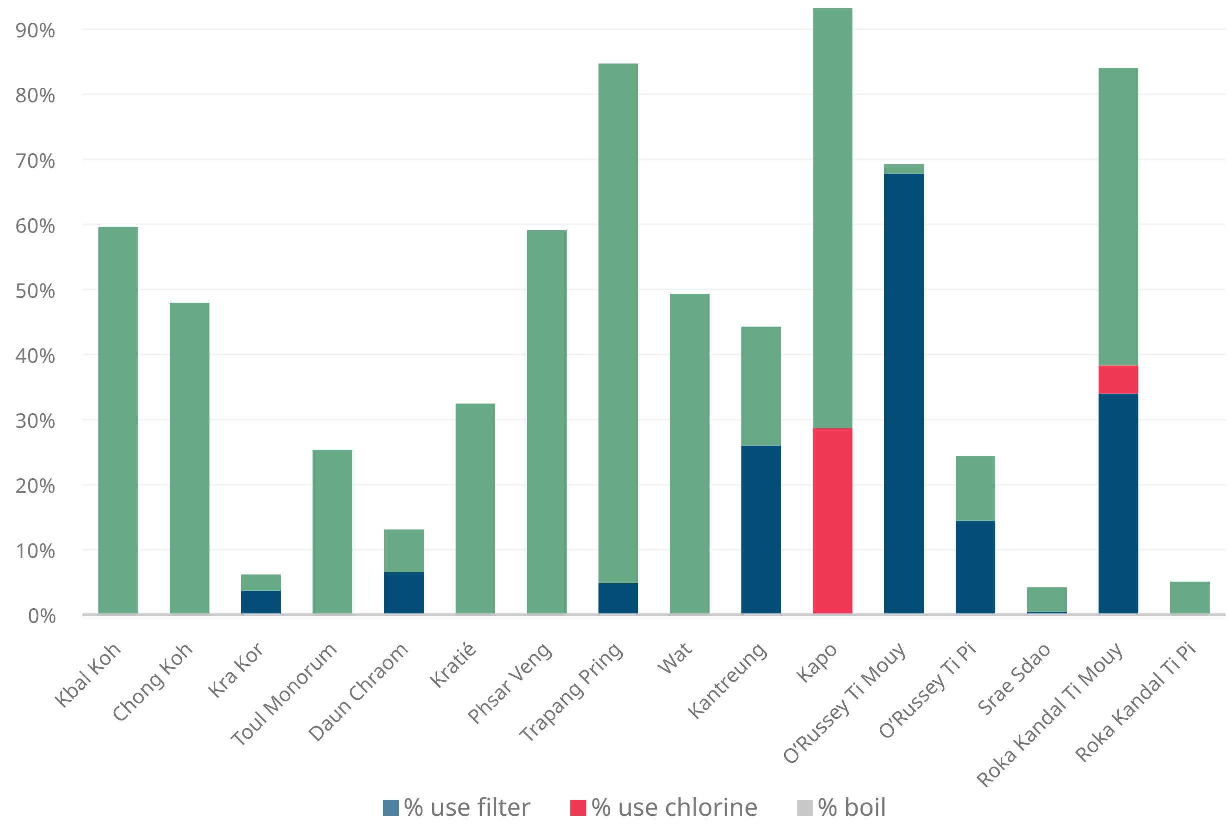
size of the networks, the cost of inputs (chemicals and electricity), local capacity to operate the system, reported 16 to 18% non-revenue water, and the extent that this situation will improve if networks are expanded into new areas, such as neighbouring peri-urban Chetr Borey Commune.

The tariffs for Krong Kratié are higher than those for more populous and generally prosperous areas of the country, such as Phnom Penh. Furthermore, it is unclear whether changes in the quality of the Mekong River's water will negatively impact the efficiency of water supply operators' treatment systems.

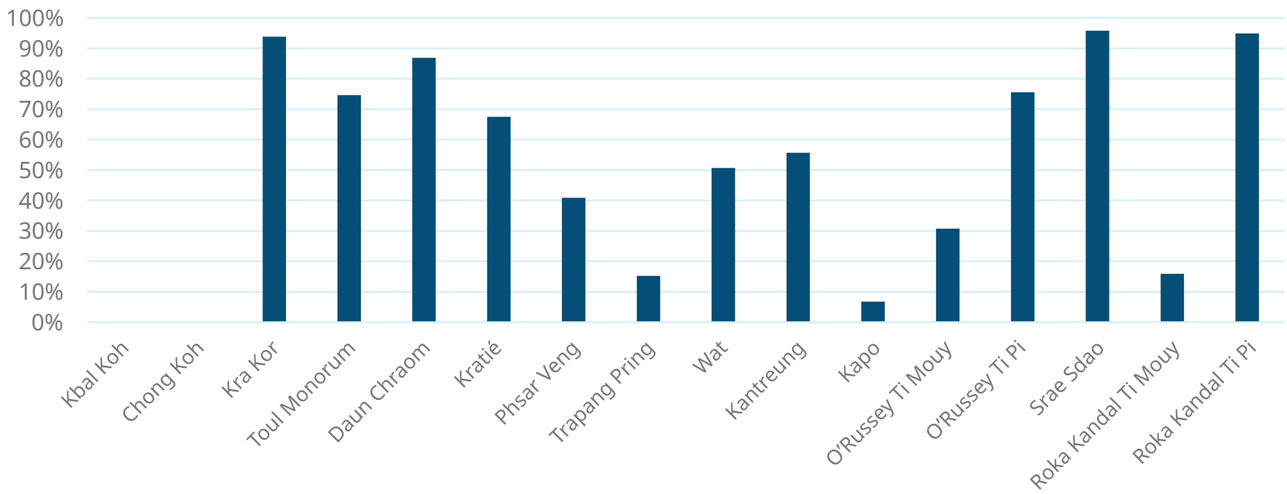
Water Quality in Krong Kratié

In 2009, the Krong Kratié point in the lower Mekong showed satisfactory water quality levels, except for elevated Polycyclic Aromatic Hydrocarbons (PAH) in sediments (Ongley, 2009). As of 2017, the water quality remained relatively unchanged, suitable for aquatic life (MRC, 2019b). However, specific concerns regarding As, Ba, Fe, and Mn in Krong Kratié due to its geological setting were noted (Phan et al., 2013). In two villages in Krong Kratié, arsenic levels exceeded WHO limits in the ground water (ADB, 2018d). A 2020 study confirmed pollution from household and artisanal mining wastewater and excessive groundwater bacteria levels (RGC, 2022).

To investigate surface water implications, a systematic sampling, including heavy metal and arsenic, was conducted in December 2022 and March 2023 in the water bodies surrounding Krong Kratié and the Prek Te tributary on behalf of PolyUrbanWaters. Boeung Kbal Dun Soun exhibited eight parameters above standard values in both sampling times, indicating potential contamination from human activities, agricultural waste, fertilizer use, and leaded fuel usage. The Prek Te Upstream site also showed deteriorating water quality due to human activities and agricultural waste discharge, with 13 of 18 parameters exceeding the Cambodian Water Quality Standards (Own Work). Based on water quality sampling conducted by Vorn in December 2022 and March 2023).



90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Kbal Koh
Chong Koh
Kra Kor
Toul Monorum
Daun Chraom
Kratié
Phsar Veng
Trapang Pring
Wat
Kantreung
Kapo
O'Russey Ti Mouy
O'Russey Ti Pi
Srae Sdao
Roka Kandal Ti Mouy
Roka Kandal Ti Pi
% use filter
% use chlorine
% boil



100%
90%
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70%
60%
50%
40%
30%
20%
10%
0%
Kbal Koh
Chong Koh
Kra Kor
Toul Monorum
Daun Chraom
Kratié
Phsar Veng
Trapang Pring
Wat
Kantreung
Kapo
O'Russey Ti Mouy
O'Russey Ti Pi
Srae Sdao
Roka Kandal Ti Mouy
Roka Kandal Ti Pi

Water Consumption Practices in Krong Kratié

These findings align with the prevalent perception among local residents: surface water sources, such as ponds and lakes in and around Krong Kratié are generally deemed unsafe due to their close proximity to human activities, including domestic wastewater disposal and agricultural chemical usage. As a result, these sources are not utilized for drinking water (Own Work, 2022). Most households, despite the cost, are connected to the piped water system indicating reasonable satisfaction with the service providing water to their immediate location.

Figure 85. Households that treat their drinking water before consumption in percentages (Source: CDB, 2020)

However, most households resort to boiling their water before consumption as traditionally materials to boil water were easily sourced in the locale. The usage of chlorine or water filters is considerably less common than boiling although the rate of water filter usage surpasses that of chlorine. The latter is only utilized in two villages: Kapo and Ti Mouy, both in Sangkat O'Russey. In Ti Mouy Village, the use of water filters considerably exceeds that of boiling (68% compared to 1.5%). A similar pattern is observed in Ti Pi Village within the same Sangkat although the difference is less pronounced (14.5% compared to 10%) (CDB, 2020) (See Figure 85).

These practices result in an additional cost burden, opportunity cost, and environmental cost for households boiling their water in terms of paying for charcoal, wood or gas or collecting wood for boiling and the associated boiling time[14].

There is a pervasive lack of trust in the quality of piped water and consumption rates of piped water might be increased if trust among households was improved. Some households have reported using the water supply exclusively for bathing and washing while they purchase drinking water in 20-litre blue bottles (Own Work, 2022; Own Work, 2023).

Figure 86. Households consuming tap water or pure water in percentages (Source: CDB, 2020)

Across the four mainland sangkats there are varying rates of households that consume their water directly from the tap without treating it prior to consumption. It is noticeable that for Trapang Pring, Kapo, and Ti Mouy villages in Sangkat Kratié and Sangkat O'Russey respectively less than 20% of households consume water directly from the tap while other villages vary from 40% to over 90% of households (See Figure 86).

14 These forms of household water filtration systems are commonly purchased at local markets and pharmacies or donated by local non-governmental organizations or civil society organizations supporting the most vulnerable households.

Considering, the data on households treating their water prior to consumption and households consuming water directly from the tap without treatment, it is noticeable that around 50% of households on Sangkat Koh Trong only boil their drinking water, yet none of the households have access to the piped water network and so those households not treating their water are consuming untreated water from an unimproved water source raising concerns over the health of the residents.

Those households reliant on other sources of water than piped water complain that these sources are limited during the dry season, and water is purchased in 20-litre blue bottles during periods of the year when wells run dry (PUW, 2018). For those households accessing water via drilled 'tube' wells, these are reported as being between 20 and 30 metres deep but are not used for drinking as they are reported as contaminated with excessive 'lime' (Own Work, 2023).

Wastewater Management Development in Krong Kratié

Key Messages of Section

1. Krong Kratié, as with many Krong (secondary and tertiary cities) in Cambodia, grapples with the complex task of developing an efficient wastewater management system for a modern city with an increasing population long after the urban area has been developed. The key challenges in this pursuit are predominantly regulatory, administrative, financial, and technical in nature.
2. Krong Kratié, as with other urban areas in Cambodia, took advantage of the existing natural water bodies and wetlands to efficiently process its wastewater prior to population increases and changes to local land use and water bodies making such solutions ineffective.
3. The Krong's existing sewer system, a combined network handling both sewage and stormwater, only covers approximately half of Krong Kratié. This system discharges untreated waste directly into the "Boeung" to the east of the main urban core, posing considerable health and environmental risks.
4. Most households appear to have constructed some form of non-standard unsealed soak-pit – reports of infrequent desludging indicate that existing septic tanks are likely leaking into the environment and maybe contaminating water bodies.
5. There is a tabled proposition for funding from the Asian Development Bank to establish a centralized treatment plant. However, this proposal faces various hurdles, including issues around management, operation, and maintenance. Additionally, there might be resistance from households reluctant to pay for sanitation services.
6. Current road developments have a tendency to elevate the level of the road well-above the ground floors of the properties they serve. This results in main sewers and roadside storm drains being considerably above the ground level of the properties. This dissuades households from connecting to systems that will not function to remove wastewater from their homes.
7. Strategic planning, potentially through a City Sanitation Plan, could be a valuable tool for addressing these issues. This plan should be designed with a clear understanding of Kratié's distinct spatial characteristics, socio-economic conditions, and financial capacities. It should also explore a combination of centralized

and decentralized solutions that can be progressively introduced, allowing for flexibility and adjustment based on actual needs and responses.

8. Crucial to any successful strategy is the development of the public institutions' capacities. These institutions need to be able to plan, mandate, and enforce regulatory requirements effectively. This is absolutely vital for creating an enabling environment

Wastewater Management in Cambodia

In most Cambodian krong, including areas of Phnom Penh, the capital, wastewater and sewage are typically discharged directly into rivers and lakes without any treatment, leading to significant environmental and health issues. It is estimated that only a very small proportion of urban wastewater is treated safely.

This performance results from a systemic sectoral weakness, mainly due to a still insufficient regulatory framework and its enforcement at the local level. The lack of strategic planning, financial instability at the krong-level, and the minimal awareness among polluters - be they households, institutions, or businesses - about the dangers of untreated wastewater, further exacerbate the situation.

Progress is being made towards improved sanitation, but the metrics for safely managed sanitation remain uncertain. Where sewer connections are in place, low bill recovery is a prevalent problem, with incentivizing users to pay their sewer bills posing a significant challenge in urban areas with sewer systems.

While Siem Reap, Sihanoukville and Battambang (See Figure 1) have wastewater treatment plants, even these growing urban conurbations continue to face challenges because the current capacity of their facilities is insufficient to meet their needs and maintenance and operation face huge challenges (Kov, 2022).

Nearly 80% of toilets in urban settings are linked to “septic tanks”. The growth rate of toilets associated with septic tanks has outpaced those connected to sewers by a factor of 5.6.

Even septic tank systems, serving as basic wastewater management tools, are not universally installed across all buildings. When these systems are in place, they often underperform because of flawed design or insufficient maintenance.

Currently, the Water Supply and Sanitation Policy (2003) is undergoing revisions, and a corresponding Water Supply and Sanitation Law will be crafted subsequently. The framework for wastewater cost recovery has been finalized, and the tariff framework for wastewater and sanitation services is currently being prepared.

It is obvious, investments directed towards wastewater management must place a greater focus on sustainability aspects, such as household connections, tariffs, and the institutional framework for operation. Operational oversight of wastewater systems often have to cope with restricted capabilities and low financial turnover.

Significant challenges for the advancement of efficient wastewater management systems, whether centralized, decentralized, or combined, exist in establishing decision-making processes at the local level. This includes developing technical and planning capacities and defining clear roles and responsibilities for relevant stakeholders. In the absence of such frameworks, efforts, such as the development of effective Faecal Sludge Management, and broader engagement of the private sector, may face considerable hurdles.

The high initial investment costs and financial needs for sustainable management and operation of centralized wastewater systems make decentralized solutions a particularly valuable option for the development of effective wastewater systems in less populated urban areas. For strategic planning, City Sanitation Plans can provide valuable guidance, helping to inform decisions based on each urban area's specific characteristics, especially considering their institutional and financial capacities. These plans can play a critical role in shaping effective and sustainable wastewater management infrastructure tailored to the unique needs and resources of each krong.

For municipal level wastewater units, the lines of accountability to provincial administration are blurred. The absence of a performance contract and lack of defined indicators compound the issue. Human resource management is subpar, and managerial autonomy is lacking. The scarcity of strategic and activity plans is largely due to limited financial resources and advisory support. Nevertheless, sustainable finance is integral for ensuring quality service delivery.

Access to Sanitation and Fecal Sludge Management in Krong Kratié

Many of the above points - whether analytical or strategic - also apply to the situation in the Krong Kratié.

The available sanitation access data from the CDB, as of 2020 displays significant variations across the 16 villages within Krong Kratié. It is reported that 87% of the 7,701 families have access to some form of basic sanitation. However, it remains unclear whether these sanitation services are safely managed. Just over 4% of these families reportedly utilize some form of unimproved sanitation, while no data is provided for the remaining 13% of families. This lack of data raises questions about the reality of sanitation coverage and the safety of these systems.

Figure 87 indicates the reported household sanitation coverage and highlights potential data gaps. Notably, Kantreung in Sangkat O'Russey has significantly low coverage, at almost 60% of families accessing either unimproved systems or are unaccounted for. For Kbal Koh and Chong Kaoh on Sangkat Koh Trong almost 40% of households are unaccounted for with no data available. Additionally, Kapo and Ti Pi in Sangkat O'Russey have low rates of coverage with just over 60% each with access to an improved sanitation facility.

It is crucial to recognize the low levels of safely treated faecal sludge in Krong Kratié. A Sewage Flow Diagram published by the Ministry of Public Works and Transportation in 2022 graphically displays the current situation and the low level of safely managed wastewater in Krong Kratié (See Figure 88).

For any strategic planning, it is important to note that faecal sludge is, in essence, neither safely treated nor disposed of in a safe manner. This situation accentuates the urgent need for a comprehensive and effective wastewater treatment approach and mechanisms across the Krong.

Faecal sludge discharge from residences and tourist sites is estimated at 5,025m^3 per year (4,950m^3 for residences and 75m^3 for tourists). Of this, an estimate of 1,475m^3 (29.4%) is discharged to the drainage network from residences and 25m^3 (0.5%) is discharged to the network from tourist establishments (RGC, 2022) (See Table 8).

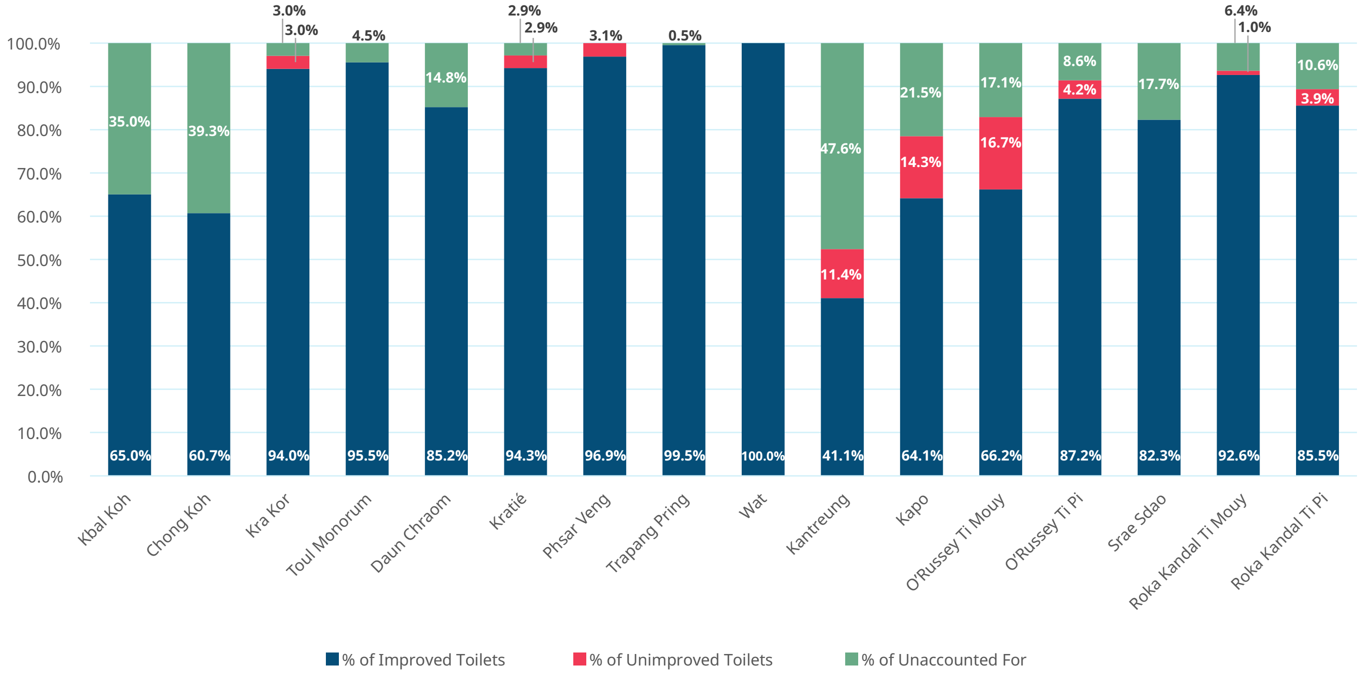

Figure 87. Reported access to sanitation in percentages (%)
(Source: CDB, 2020)

	Stored Fecal Sludge		Emptied Fecal Sludge		Transported Fecal Sludge		Treated Fecal Sludge		Recycle Fecal Sludge/Safely Disposed Fecal Sludge	
	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe	Safe	Unsafe
Toilets to Drainage Network	27.9%	0.0%	27.9%	0.0%	12.2%	15.7%	0.0%	12.2%	0.0%	0.0%
Toilets to Septic Tank	32.1%	0.0%	32.1%	0.0%	9.1%	23.0%	0.0%	9.1%	0.0%	0.0%
Toilets to Storage Tank	33.5%	0.0%	33.5%	0.0%	9.5%	24.0%	0.0%	9.5%	0.0%	0.0%
Defecation outside the Toilets	0.0%	6.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Fecal Sludge Safe / Unsafe	93.5%	6.5%	93.5%	0.0%	30.8%	62.7%	0.0%	30.8%	0.0%	0.0%

100% of Fecal Sludge is Discharged into the Environment Unsafely

Figure 88. Sewage Flow Diagram
(Source: RGC, 2022)

Total faecal sludge discharge	m3/year		%		m3/year
	Residences	Tourists	Residences	Tourists	Total
Discharge quantity through the toilets	4.950	75	98,50	1,5	5.025
Discharge quantity from toilets to drainage network	1.475	25	29,40	0,5	1.500
Discharge quantity from toilets to septic tanks	1.700	25	33,80	0,5	1.725
Discharge quantity from toilets to pits/environment	1.775	25	35,30	0,5	1.800
Discharge quantity through out-side defecation	350	0	100	0	350
Defecation outside the toilet (m3 /year	350	0	100	0	350
Total quantity of faecal sludge waste discharge	5.300	75	98,60	1,40	5.375

Table 8. Estimates of fecal sludge discharge
(Source: RGC, 2022)

Figure 89. Krong Kratié Slaughter House
(Source: Own Photos taken in 2022)

Figure 90. Kratié’s Referral Hospital
(Source: Own Photos taken in 2022)

Existing Wastewater Handling Practices

Combined Wastewater and Stormwater Sewer

At present, Krong Kratié has a combined system to manage liquid waste, including sewage, wastewater, and stormwater. Certain segments of this system, notably in Sangkat Kratié, date back to the colonial era in the 1920s.

Additional stormwater-sewer networks have been incrementally installed in other sangkats over time. Unfortunately, these additions have been irregular, and exhibit limited interconnectivity and grading. This inconsistency stems from the varied construction teams, each with differing budgets and plans, and the absence of a centralized institution to ensure coordination and alignment.

Recent urban developments in and around Krong Kratié have further complicated the situation as the installed systems are designed to discharge into open environments and water sources. These recent developments have caused the drainage network's discharge gates to be blocked or disconnected from their intended discharge points due to the in-filling of land or the presence of rice fields (See Figure 67 & Annex V).

Currently, approximately 48% of the Krong (equating to 12,173m of total roads) is serviced by the existing combined system (RGC, 2022). Designed to discharge directly into Boeung Romleach to the east of the urban center without any prior treatment, the system leads to substantial pollution of these water bodies, posing serious public health and environmental threats (See Figure 89 & Figure 90).

Furthermore, no designated institution is responsible for the operation, maintenance, repairs, planning, and monitoring of the wastewater network. There is also a notable absence of a tariff system to charge property owners for discharging wastewater into the local sewage network.

100% of restaurants are connected to the public sewer system, approximately 40% of guesthouses/hotels and 32% of residences. 49% of residences have no access to a sewer network although 11% have access but have not connected. Similarly, 60% of guesthouses/hotels have also not connected to the network despite its proximity (See Figure 91).

For residences that have not connected to the local network, 70% of respondents to a survey had not done so because they did not want to spend more on this service, 90% of respondents had a septic tank/collection unit available to manage the sewerage, while another 40% indicated that the network was either damaged or higher than their property and so they could not connect to it (See Annex VI).

Non-Sewered Practicies

In non-sewered areas (urban sangkats and peri-urban areas), there is a heavy reliance on on-site sanitation facilities, such as septic/collection tanks, and pit latrines. Most wastewater is primarily collected in 'septic tanks' at each house. In some instances, overflow may be discharged into public drainage systems or into the environment.

A survey conducted in 2020 of 363 households, revealed that 14% of those surveyed did not have any form of toilet facility in their household. The data suggests a significant correlation between socio-economic factors and a lack of access to or usage of sanitation facilities. Specifically, three-quarters of the households without sanitation facilities were categorized as either poor or low-income households (PUW, 2018).

Among those households that have sanitation facilities, the majority (93%) are equipped with pour-flush toilets, with the remaining 7% having flushing toilets. This data could imply a prevalence of relatively basic sanitation facilities, even among households that do have access to them (PUW, 2018).

Field observations and the infrequency or irregularity of desludging suggest most households have likely constructed some form of unsealed soak-pit, especially for residences (See Figure 92). This may contribute to ground water pollution. This practice exposes households and communities not only to water risks but also significant health risks for those located in flood-prone areas. The contents of the soak-pits are likely to be discharged into the environment when the pits are flooded or become inundated. Furthermore, during the rainy season, the effluent in the tanks or pits may leak out due to the rising groundwater table, causing it to be dispersed near the surface (Own Work, 2022).

Additionally, households generally could not provide specific information about their on-site sewage treatment process, including the type of septic tank used and its specifications.

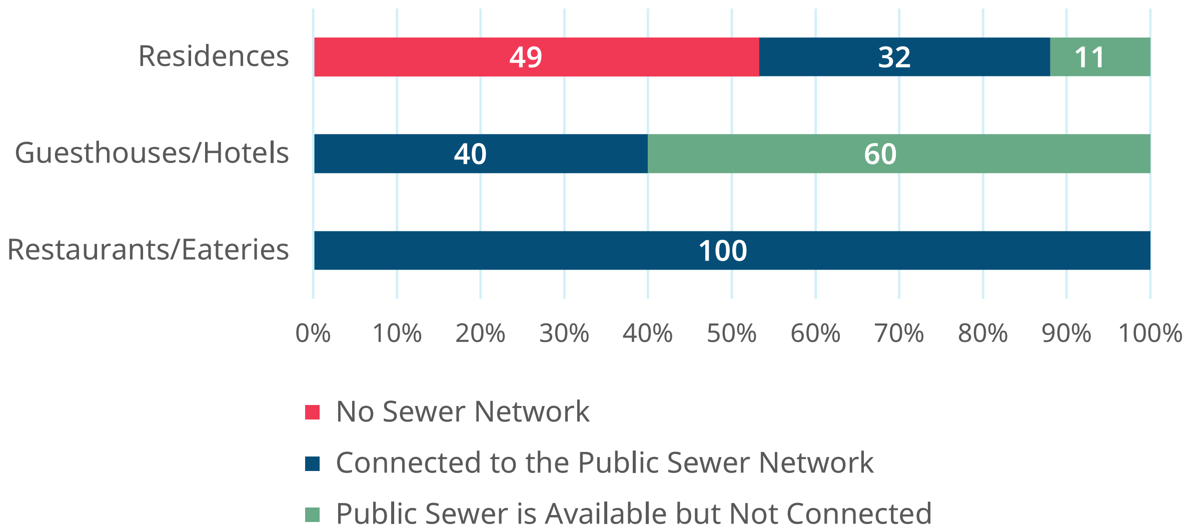

Figure 91. Types of establishment connected to public sewer network in percentages (%) (Source: RGC, 2022)

New development areas are not being planned in conjunction with wastewater management systems (centralised or decentralised), and these will have to be installed post-development contributing to further inefficiencies and risks. It was observed that septic tanks have been built close to wells providing water for domestic purposes that may result in water pollution used for domestic purposes.

Open defecation is still practiced with some people burying their faeces or defecating in the open. This may be due to a lack of hygiene awareness or due to adherence with traditional yet unsanitary behaviors. Low incomes may also be a factor in which poor households are unable to purchase and build an improved latrine. Furthermore, population density in more peri-urban areas of the municipality is low and uninhabited areas offer some privacy to practice open defecation.

There is no directly mandated entity that manages the on-site wastewater management system (septic tanks) and this includes appropriate operation and maintenance, construction specifications and the provision of relevant authorization letters.

Sludge from septic tanks collected by private enterprises is often improperly dumped in the open. The most common method for sludge treatment is dumping and backfilling (Namo, 2022). There are two sludge management operators in the Krong. One operator confirmed in an interview conducting only one or two emptying's of cesspits/septic tanks per week. Each operator manages one small locally constructed 'vacuum truck' (a tanker with an attached pump).

Sludge and sewage is collected and disposed of informally, with it being reported that the season influences how the sludge/ sewage is disposed. In some instances, it is dumped on farmland (for a small fee) as fertilizer, on other occasions pumped onto vacant land, the owner's land or into watercourses. There is apparently no system in place to record/ document and monitor faecal sludge disposal (PUW, 2018; PUW, 2022, unpublished data).

Proposed Lagoon-Based Wastewater Treatment Plant (WWTP) Financed via ADB's GMSCTDP

A centralised WWTP and piped network system have been proposed to be financed through loans to the government by the Asian Development Bank as part of a GMS project, "Fourth Greater Mekong Subregion Corridor Towns Development Project" (GMSCTDP-4) (RGC, 2022).

The goal of the project is to build a wastewater treatment plant and install a sewer network to collect and transfer sewage and waste water for treatment. This is intended to prevent a mix of stormwater and sewage flooding parts of Krong Kratié (RGC, 2022).

The proposed combined sewer will include the main urban center along the Mekong River and the new urban area eastwards along National Road 73 toward the junction with National Highway No.7. The service area will cover parts of sangkats Kratié, Kra Kor, O'Russey, and Roka Kandal, to serve 100%, 25%, 50% and 10% of their populations, respectively.

The WWTP will be a lagoon-based wastewater treatment system constructed on a 10.5 ha public land site, located to the southeast of the main urban area. Initially designed to collect and treat stormwater and waste water until 2040, ADB describe how the WWTP may be extended through the acquisition of further land for a parallel set of lagoons, or through retrofitting to increase the capacity, such as the installation of aerators or trickling filters. The final treated effluent from the WWTP will be discharged into the nearby Boeung Romleach (ADB, 2018c) (See Figure 94 & Annex VII).

The WWTP is estimated to cost 18.62 million USD and its benefits are described as promoting people's well-being, a clean Krong, sanitized Krong, protection of the Krong's environment, prevention of the Mekong River's water being polluted, and economic development, especially the tourist service sector in the Krong as well as Kratié Province (RGC, 2022).

However, while there is no formal management of this sector, the ADB's plan for a modern WWTP may be undermined by the availability of the capacity and finances to sustainably operate the facility being unclear with local people reticent to pay fees to connect and use the service because limited enforcement will not motivate them to connect to and fund the system. More specifically, a World Bank's assessment of the challenges for existing and planned wastewater utilities in Cambodia, may

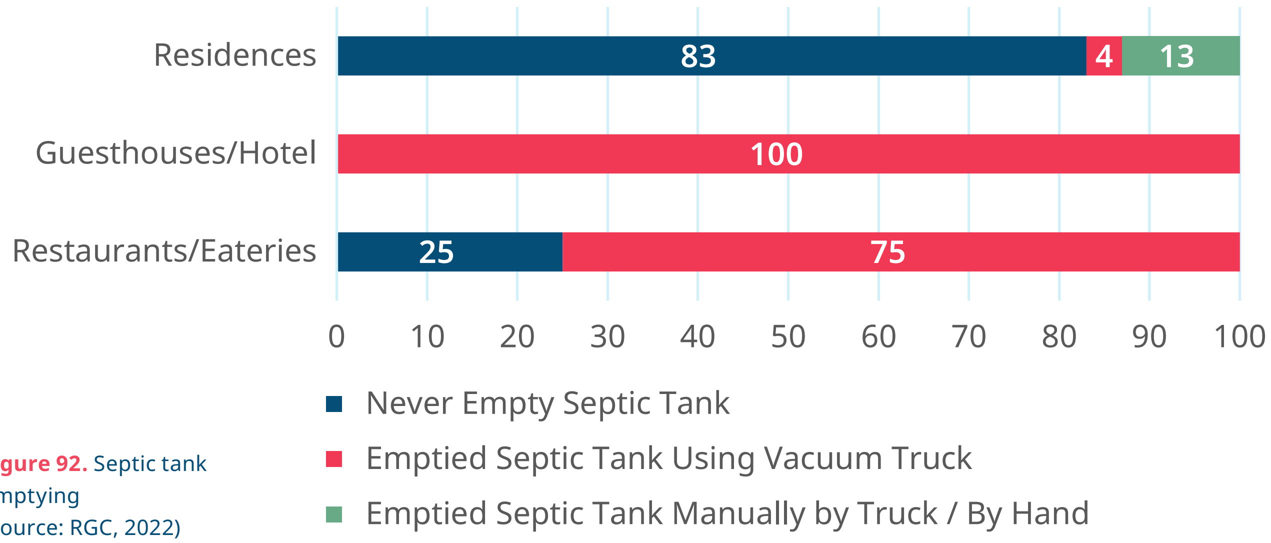

Figure 92. Septic tank emptying (Source: RGC, 2022)

Figure 93. Krong Kratié's Bus Station public toilets (Source: Own Photo taken in 2022)

also apply to Krong Kratié: (i) Clarify the legal status, (ii) Stabilize operations: Set up performance agreements, set up advisory board/committee overseeing the operations, consider bridging funds, undertake customer verification, review organizational structures and include faecal sludge services, strengthen human resource system/policies; (iii) Consider a cost reflective tariff and combine this with the water supply bill; and (iv) Set up the WWTP as a State-Owned Enterprise or engage the private sector (Kov, 2022).

An assessment by PUW of the original proposal for the Kratié WWTP agrees with the concerns over the cost of the investment and the challenges that may arise in generating sufficient revenue to appropriately operate and maintain the facility while also ensuring loan repayments. It also points out that while lagoon-based systems are easier to operate and maintain, they can produce substantial odors even if operated appropriately. Moreover, if the system is intended to flush itself, dust and silt will block the pipes in between periods of rain. As Krong Kratié is relatively flat the WWTP can only function if pumps are utilised and this will add to the overall cost of operation and maintenance in terms of equipment and electricity (Own Work, 2019).

In this regard, in mid-June 2023, the WWTP has been delayed as the location is unsuitable as it will require substantial filling and raising of land to flood proof the facility. The Ministry of Economy and Finance is reviewing the procurement for the facility to identify if a more appropriate location can be funded.

In the event that a decision is made to further delay or postpone the investment in the WWTP, other potential interventions need to be considered as Krong Kratié will continue to discharge fecal sludge and sewage into the environment. Therefore, a form of city-wide sanitation mapping may need to be implemented to identify particular ‘hotspots’ in the city for remedial interventions to manage sewage and fecal sludge, such as the slaughterhouse, referral hospital and bus station (See Figure 89, Figure 90, & Figure 93).

Service Area and Location of WWTP in Krong Kratié

Proposed force main to WWTP

Proposed access road to WWTP

Service area

WWTP

road

Water body

Figure 94. Map showing the service area and location of the WWTP in Krong Kratié (Source: RGC, 2022)


Boeung Romleach
0
1.000
2.000 m
Scale

Solid Waste Management Development in Krong Kratié

Key Messages of Section

1. Currently about two-thirds of Krong Kratié is served by a solid waste management (SWM) service collecting waste to be disposed of at a dumpsite approximately 5km outside of the town.
2. Current SWM services are inadequate to manage the Krong's existing waste and while a new land fill site is proposed with better management standards, significant areas of the Krong are left un-served with the population managing their own waste, usually to the detriment of the surrounding environment.
3. Recycling efforts are generally informal in nature practised by local families of recyclers with valuable waste resold to intermediary companies and waste recyclers in other parts of the country and Phnom Penh.
4. Separation of waste at source and localized composting of organic waste is limited, which may result in a rapid exhaustion of the capacities of the new landfill.
5. The private sector waste collection contractor experiences difficulties in collecting the waste collection fee. Such experiences suggest there might be challenges in ensuring the new landfill site is a financially viable operation.
6. Through systematic capacity building of the local governments, the enabling environment should lead to improved business cases for the waste collectors and thus to the strengthened financial viability of the entire waste management system.
7. Comprehensive awareness campaigns are needed to educate the population and communities on the need for and benefits of waste separation and management at the household level.
8. Implementing preventive maintenance of drainage systems is vital to mitigating urban flooding incidents. This strategic intervention can significantly contribute to enhanced waste management, leading to a substantial positive impact.

Waste Generation in Cambodia

Cambodia's accelerated economic development, extensive urbanization, and considerable growth in both domestic and international tourism have precipitated a major rise in the generation of solid, plastic, and hazardous waste.

- **Municipal Solid Waste (MSW):** The principal constituents of MSW include organic materials, plastics, paper, glass, and metals. However, waste collection services remain inadequate, particularly in rural areas. This lack of service has resulted in a significant portion of waste either being dumped in open spaces or incinerated, which subsequently leads to grave environmental and public health complications (See Figure 95).
- **Hazardous Waste:** The production of hazardous waste, which includes medical waste, chemical waste, and e-waste, has seen a sharp upsurge in recent years due to the expansion of the industrial sector. The secure disposal and treatment of hazardous waste continue to pose significant challenges, mainly due to the absence of necessary infrastructure and technical proficiency. The hazardous waste is generated in line with industrial growth and increased consumption of goods with hazardous substances. Currently, hazardous waste is merely collected, transported, and discarded at landfill sites or in an uncontrolled manner into the environment.
- **Medical Waste:** The rise in medical waste mirrors the expansion of the healthcare sector, especially in Phnom Penh where healthcare services are concentrated. In this region alone, around 40 tons of medical waste are generated each month. Unfortunately, medical waste is frequently mixed with general waste and consequently ends up in municipal landfill sites.
- **Electronic Waste (E-waste):** The evolution of the Cambodian consumer economy has triggered a significant increase in e-waste, primarily in the form of televisions, personal computers, refrigerators, air conditioners, and washing machines. An informal network of waste pickers plays an indispensable role in collecting recyclable materials from this e-waste (EuroCham Cambodia, 2019).

Contributing to this limited management effectiveness is the lack of appropriate regulatory frameworks, policies, and enabling conditions (World Bank Press Release, May 2023).

Figure 95. Uncontrolled dumping of municipal solid waste near to a water body in Krong Kratié
(Source: Own Photos taken in 2023)

Figure 96. Municipal solid waste blocking drainage systems in Krong Kratié
(Source: Own Work taken in 2022)




For Krong Kratié, despite a waste management system being in place, much waste is still dumped in the open, especially around Sangkat Koh Trong and along the banks of waterways. While a new landfill is being constructed, there are questions as to its long-term sustainability as it is some distance from the municipal centre, potentially increasing collection costs for the waste management operators (CRDT, 2022; GIZ, 2022) (See Annex VIII).

Strategic options

- **Capacity building at the local government level:** In order to improve the enabling environment for effective waste management, local government agencies have to be capacitated in planning, monitoring and communication. Standard operational procedures have to be elaborated with respect to waste collection, segregation, transportation, treatment, and disposal.
- **Planning on strategic interventions:** As an example, a proactive approach needs to be adopted for the maintenance of drainage systems. Routine inspections and clearing operations should be scheduled before the onset of the wet season. This anticipatory approach can prevent system blockages and consequent flooding, promoting overall community well-being and safety (See Figure 96).
- **Public Awareness:** To address the current issue of limited awareness, a comprehensive campaign needs to be implemented focusing not only on proper waste disposal but also emphasizing the principles of reducing, reusing, and recycling. The replacement of aging signboards with new, more appealing ones can act as a constant visual reminder for the public. Furthermore, community workshops, social media campaigns and educational programs in schools could be effective in ingraining sustainable waste management practices among residents of Krong Kratié.

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Profile of PolyUrbanWaters

PolyUrbanWaters is a research and project network funded by the German Federal Ministry of Education and Research (BMBF) that consists of academic institutions, municipalities, local and national government agencies, civil society and private-sector stakeholders from Indonesia, Cambodia, Laos, Thailand, Vietnam and Germany.

PolyUrbanWaters responds to the strong need to generate deeper, transferable and scalable know-how for the effective localization of polycentric approaches to urban water resources management in secondary and tertiary cities of the SEA region.

The project intends to demonstrate the importance of polycentric approaches to the management of urban water resources, contributing to the water-sensitive transformation of secondary and tertiary cities in SEA towards resilient, inclusive and livable urban areas, thus contributing to the fulfillment of national and global sustainability agendas.

In order to do this, the project will elaborate an empirically proven conceptual framework for these approaches with: a) development of relevant instruments for its implementation and scalability; and b) a sustainable contribution to the systematic emergence of a new interdisciplinary practice-oriented research and economic-academic cooperation context.

The PolyUrbanWaters international research collaboration focuses its research activities around three Living Labs located in Sleman (Indonesia), Sam Neua (Laos) and Kratié (Cambodia), which provide a representative cross-section of the challenges faced by fast-growing secondary and tertiary cities in the SEA region in diverse governance contexts.

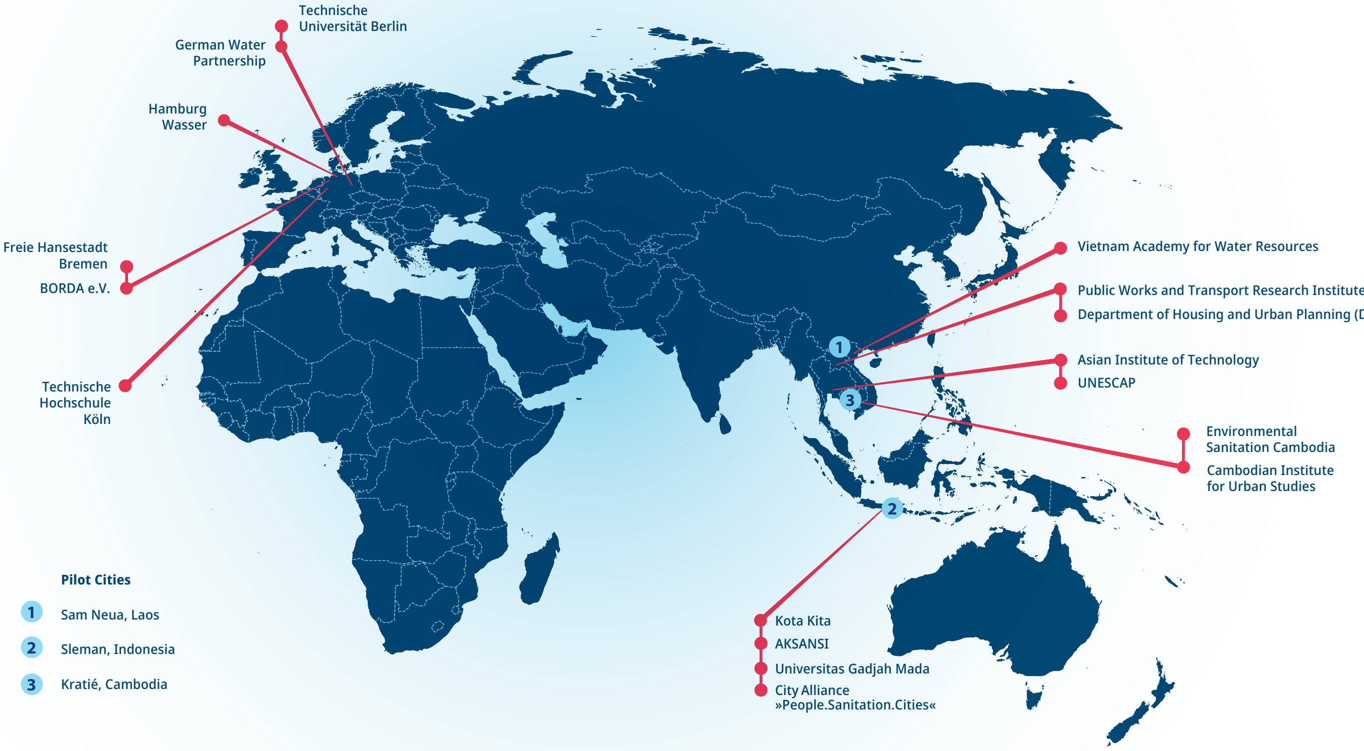
Within this framing, PolyUrbanWaters pursues the following core questions:

1. How can a diverse set of stakeholders contribute to building an inter- and transdisciplinary local knowledge base on water and urban development-related challenges in the SEA region? How can this knowledge be systematized, scaled and regularly updated to serve as a basis for inclusive and future-oriented municipal planning approaches across the region?

2. How can effective and sustainable water-sensitive urban development be fostered through a combination of centralized and decentralized technical and social-ecological innovations – including nature-based solutions, participatory strategic planning and effective water management structures – as an integral part of a systemic polycentric nexus approach (water, waste, energy, housing, IT, food, community development, etc.) and innovative financing schemes for the management of urban waters?

3. How can “water” serve as a strategic entry point to integrated, inclusive and resilient urban development that is guided by the SDG framework? Which polycentric, intersectoral and participatory governance approaches are required to plan, develop, sustainably operate and finance integrated, water-sensitive development with the capacity to evolve further in line with dynamic urbanization processes?

4. How can local innovation processes inform new practice-oriented pedagogies, capacity building approaches and research agendas to strengthen a network of academic institutions in the region?



The PolyUrbanWaters-Partner Network and Pilot Cities

The economic development and liveability of Krong Kratié is highly dependent on the sustainable management of its eco-systems and its water resources. These have come under pressure in the wake of considerable changes in land use in the region over the past century and recent increasing urbanization. Furthermore, these pressures may increase considerably due to the manifestations of the impacts of climate change.

polyurbanwaters.org

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