Climate Risk and Vulnerability Assessment

Project Number: 53199-001
October 2021

Cambodia: Livable Cities Investment Project Kampot

ABBREVIATIONS

ADB	–	Asian Development Bank
ASL	–	Above Sea Level
AUSAID	–	Australian Agency for International Development now called Australian Aid
CC	–	Climate Change
CCCSP	–	Cambodia Climate Change Strategic Plan
CMIP	–	Climate Model Intercomparison Project
CRAA	–	Climate Risk and Adaptation Assessment
CSIRO	–	Commonwealth Scientific and Industrial Research Organisation
DRR	–	Disaster Risk Reduction
GCM	–	Global Climate Model
GHG	–	Greenhouse Gas
GIS	–	Geographic Information System
GMS1	–	Greater Mekong Subregion Southern Economic Corridor Towns Development Project
LCIP	–	Livable Cities Investment Project
LFG	–	landfill gas
MoE	–	Ministry of Environment
MA	–	municipal administration
MPWT	–	Ministry of Public Works and Transport
NAPA	–	National Adaptation Program of Action to Climate Change
NCDM	–	National Committee for Disaster Management
NCSD	–	National Council for Sustainable Development
RCP	–	Representative Concentration Pathway
SDGs	–	Sustainable Development Goals
SRES	–	Special Report on Emissions Scenarios
SST	–	Sea Surface Temperatures
SWM	–	Solid Waste Management
UNDP	–	United Nations Development Programme
UNDRR	–	United Nations Office for Disaster Risk Reduction
WWTP	–	Wastewater Treatment Plant

GLOSSARY

Adaptation	–	The process of adjustment to actual or expected climate and its effects in order to either lessen or avoid harm or exploit beneficial opportunities (IPCC 2014).
Adaptive Capacity	–	The general ability of institutions, systems, and individuals to adjust to potential damage, to take advantage of opportunities, or to cope with the consequences of climate change impacts. (Millennium Ecosystem Assessment).
CMIP Climate Model Intercomparison Project	–	An ensemble of global climate models used to generate projections of future climate conditions as part of the IPCC climate change Assessment Reports. CMIP5 models uses RCPs to represent CO_2 changes in the future, whereas CMIP3 uses SRES scenarios
Exposure	–	The nature and degree to which a system is exposed to significant climate variations here it describes the mapped extent of climate change impacts such as areas subject to flooding or storm surge.
IPCC	–	Intergovernmental Panel on Climate Change
Resilience	–	A measure of the current ability of a community to resist, absorb, and recover from the effects of hazards, by quickly preserving or restoring essential basic structures and functions.
Sensitivity	–	A measure of the degree to which a system is directly or indirectly affected by a particular climate stimulus
SRES Special Report on Emissions Scenarios CO_2 scenarios	–	A pathway of greenhouse gas emissions that leads to a particular concentration by the year 2100 adopted by the Intergovernmental Panel on Climate Change for its third assessment report (IPCC 2000). There are four emission scenarios based on future demographic, politico-societal, economic, and technological storylines. The scenarios used here are; SRES A2 considered to be a high CO_2 scenario where emissions are projected to continue to rise throughout the 21st century due to high population growth with slow technological change. SRES B2 a low emission scenario due low population growth and the introduction of clean and resource-efficient technologies.
RCP Representative	–	A pathway of greenhouse gas emissions that leads to a particular concentration by the year 2100 adopted by the Intergovernmental Panel on Climate Change for its fifth

concentration pathway	assessment report (IPCC 2014). There are four pathways, expressed as the amount of extra radiative forcing in Wm^{-2} in 2100 produced by greenhouse gases: Under RCP4.5, emissions are assumed to peak around 2040, then decline. Under RCP8.5, emissions are projected to continue to rise throughout the 21st century.

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EXECUTIVE SUMMARY

1. Cambodia's climate is tropical monsoon characterized by a rainy season which accounts for 90% of annual precipitation from May to early October with hot south-west monsoon winds and a dry season, from November to April with cooler north-east winds. The remnants of tropical typhoons crossing Vietnam from the Western Pacific result in tropical depression crossing Cambodia from east to west producing extreme rainfall events that result in widespread flooding. Conversely the heat intensity during the dry season causes water shortages and widespread drought.

2. The Intergovernmental Panel on Climate Change (IPCC) has concluded that global warming will cause sea level rise and significant climate changes throughout the world. The pattern of sea surface temperatures (SST) influences the distribution of rainfall (and typhoons) in the tropics. Climate change is projected to lead to increases in SST resulting in periods of more intense rainfall, increasing the impacts of flash floods and landslides. Higher air temperatures will also impact water supply by increasing losses of surface and groundwater through increased evapotranspiration which, coupled with more variability in rainfall, will potentially lead to greater water deficits in water supply catchments during droughts.

3. Being one of the most vulnerable countries to climate change, Cambodia has been one of the climate pioneers in Southeast Asia. Cambodia has been a Party to the United Nations Framework Convention on Climate Change (UNFCCC) since the ratification in December 1995 and ratified the Kyoto Protocol in 2002.

4. The Cambodia Climate Change Office (CCCO) established in 2003 and upgraded to the National Climate Change Committee (NCCC) in 2009 was responsible for a wide range of climate change related activities. The Cambodia Climate Change Strategic Plan for 2014 – 2023 and the supporting Climate Change Action Plan for 2016-2018 were developed as the first comprehensive policy document to respond to climate change issues to advance the development towards low carbon, resilient, equitable and sustainable society.

5. In 2015, the Royal Government of Cambodia recognized the importance of environmental protection and climate change in economic development efforts and that many environmental issues are cross-sectoral. Therefore, the National Council for Sustainable Development (NCSD) became the major mechanism for coordination of climate change response, improving coordination amongst government agencies, at both national and sub-national levels, and cooperation with all the stakeholders. The NCSD developed the Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV (2018) that incorporates adaptation and vulnerability reduction into overarching strategies.

6. Some of the key challenges to effective policy implementation are lack of involvement of key stakeholders, a communication disconnect at all levels, limited technical capacity and finances and the absence of functional implementation structures.

7. At the request of the Kingdom of Cambodia, the Asian Development Bank (ADB) is developing the Livable Cities Investment Project (LCIP) to facilitate long-term sustainable and economic growth. The project is aligned with the Government's policies and national strategies, in particular, the Government's Rectangular Strategy – Phase IV and ADB Strategy 2030.

8. The project is designed to facilitate long-term sustainable and economic growth in the secondary cities of Bavet, Poipet and Kampot by developing strategies to improve urban infrastructure with a focus on sanitation, solid waste management and stormwater drainage sectors. Based on Urban Development Scenario reports, Sector Master Plans identified infrastructure required to meet the future urban needs of the participating cities. The project in Kampot will focus on the development of the sanitation needs and is designed to complement previous and ongoing projects. The proposed infrastructure is set out for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040), as outlined below.

9. The proposed infrastructure for Kampot for implementation in the Short-Term (2020-2025) includes: (a) the construction of sewer pipes designed primarily for the selected existing built-up areas with some capacity for extensions for future growth, and connected to pump stations under construction through GMS2,[1] and (b) provision for GMS2 pumping station extension.

10. For the medium term (2025-2030) it is proposed that master plans are reviewed and updated. It is expected that medium-term infrastructure will include extensions of sewerage to growth areas can be accommodated with the additional pumping station, pipes, and house connections.

11. For the long term (2030-2040) it is proposed that master plans are again reviewed and updated to integrate the latest urban settlement and the current urban development, as well as reviewing the performance of drainage infrastructure, and incorporating updated climate projections.

12. The design period for infrastructure is laid out for three planning stages. However, this feasibility report presents an assessment of the proposed infrastructure that is proposed for the short term, i.e. the next five years. As the planning has been carried out for the period to 2040, this Climate Change and Adaptation Assessment (CCAA) presents an assessment of the potential impact of climate change on the project infrastructure by 2040.

13. Data on climate projections that are available from previous reports are presented for various time periods. Where possible ancillary information or interpolation was used to determine climate change projections for 2040. However, if there was insufficient information available to make an interpolation, then the projected parameter values for 2050 or 2055 were used to assess vulnerability.

[1] ADB. Second Greater Mekong Subregion Corridor Towns Development Project

14. Kampot province is located in the south of the country and has a coastline of around 45 km on the Gulf of Thailand. The western portion of the province is made up of the Mount Bokor National Park that preserves the Dâmrei Mountain range with elevations above 900 asl. Kampot City is the provincial capital of the Province located 5 km from the Gulf of Thailand on the estuary of the Praek Tuek Chhu River southeast of the Dâmrei Mountain range. Kampot municipality comprises built-up areas and rural areas on the east and west sides of the river and the sea coast, 37% of the city area is urban land use, natural forest is the second current land use at 27% of the city area; followed by agriculture land use at 26%, water, 8%.

15. Mean average temperatures in the City range from 26° to 29°C. Maximum temperatures above 32°C are common before the start of the rainy season and may rise to more than 38°C. Climate change models project an increase in temperature across Cambodia in the future with the average annual temperature for Kampot projected to increase by 0.6 °C by 2030, by 1.4 °C by 2050 and by 3.4°C by the end of the century. Temperature changes are projected to be relatively even across the year under RCP8.5.

16. The number of hot days (days above 35°C) in the region around Kampot is projected to change from 2-3 to over ten days per year by 2050 and the number of consecutive hot days will increase from <8 to over 10.

17. The average annual rainfall in Kampot is 1,873 mm. The projected change in rainfall from climate models is much more variable than it is for temperature. The average projection for annual rainfall from the global climate models (GCM) used in this study is for an increase by 2030 but little change into the future. Typhoons and tropical storms can bring widespread heavy rainfall and subsequent flooding. It is projected that rainfall events from tropical depressions crossing across Cambodia from typhoons landing in Vietnam will decrease in frequency, but each event will bring more rain. Additionally, the coastal location of Kampot indicates that increased wet season monsoons could be expected to result in larger rainfall from extreme events. Modeling studies project that extreme rainfall in 1-day events will increase by 3 - 10 mm.

18. When there are heavy rains along the coastline, runoff floods coastal areas along the base of the mountain ranges. Kampot becomes flooded due to the river overtopping the riverbanks and flooding across the meanders upstream of the city. As sea level rises, the base-level of the Teuk Chhou River will also rise, increasing the likelihood of flooding during high tide events. An additional hazard is a storm surge from a typhoon in the Gulf of Thailand extending up the river. Since typhoons produce heavy rainfall, storm surge will occur at the same time as river flooding and if it coincides with a high tide will significantly increase the height and extent of flooding through the city.

19. Drought assessments generally rate Kampot as low priority in terms of drought. However, impacts are found in the area around the city and a community survey indicated that there are strong connections with the agricultural sector. While drought will continue to impact Kampot into the future, the hazards presented to the proposed infrastructure is minimal.

20. A comprehensive social survey on the opinion of specific vulnerable groups on key features related to climate change (flooding/ drought/ hot weather) found that: around a half of participants had experienced flooding in the last ten years that they attributed to inadequate drainage, half of the groups thought that flooding had gotten worse in this time, three-quarters of the participants had been moderately impacted by drought with reduced income from crops or an agricultural business, thought drought periods had become longer in the last 20 years, all of the participants thought that hot weather had worsened health issues for members of their household, three quarters thought there are more extremely hot days and more consecutive hot days together compared to 20 years ago.

21. The review of risks indicates that flooding is the most important hazard that will impact Kampot by 2040. Under climate change, larger rainfall events will increase the depth and extent of the current flood problems if business as usual is continued. Drought will continue to impact Kampot Province into the future, but the hazards presented to project infrastructure is minimal. Heat stress due to high air temperatures may become an additional hazard, particularly if consecutive hot days occur.

22. Because of past experience with flooding, the Kampot municipality has a medium capacity to respond to extreme events. As a result, Kampot has the capacity to respond to any immediate impacts to infrastructure that result from flood events. However, there appears to be a limited understanding of the potential increase in the extent of flooding across the city due to climate change.

23. The risk from climate change to each project component was calculated as the likelihood of a hazard impacting an infrastructure element and the consequences of that impact. Project components are rated as Moderate.

24. The major climate change risk to infrastructure in Kampot is for increased flooding due to the projected increase in extreme rainfall events of 9% combined with sea level rise and further compounded by storm surge. Therefore, adaptation measures for the project are related to strategies to decrease the impacts of flooding. The major adaptation is a reappraisal of the extent of the city that will be exposed to flooding. Infrastructure design will assume that the entire city could potentially be impacted by floods.

25. The phased approach to planned improvements to infrastructure with a review of the master plan between each stage, means that the success of proposed flood mitigation projects and the exposure of infrastructure can be reassessed before the next phase is designed. Additionally, design parameters based on projections of changes to future rainfall and sea level based on the latest scientific understanding at the time can be applied. This allows for adjustments to future flood protection measures that may be required for planned urban infrastructure.

26. Some components of the project will require specific adaptations to make each element climate change resilient. The entire pipe network is expected to be exposed to flooding within the

design period. The pipes will be laid along road corridors and protection from flooding will be provided by the impervious surfaces such as the road and pavement surfaces. Added protection at crossing points to cater to city wide flooding is built into the design.

27. The provision of properly treated wastewater will decrease the sensitivity of the city by decreasing the number of households exposed to wastewater during flooding events. It will also increase the resilience of the population by improving the ability of households to recover from floods by reducing the impact of diseases from floodwaters on the community and the health system. The project supports Priority Outcomes of the Cambodia Climate Change Strategic Plan 2014 – 2023 and also contributes to Cambodia's international commitments. Therefore a proportion of the costs of the whole project can be considered to be a climate change adaptation, which is calculated as 30% of the total cost, which is $1.225 million.

28. The project will contribute to CO_2 emissions as infrastructure materials are made, transported, and installed. The increased connection of the community to the network and professionally managed treatment of wastewater will contribute to reducing emissions of N_2O and CH_4.

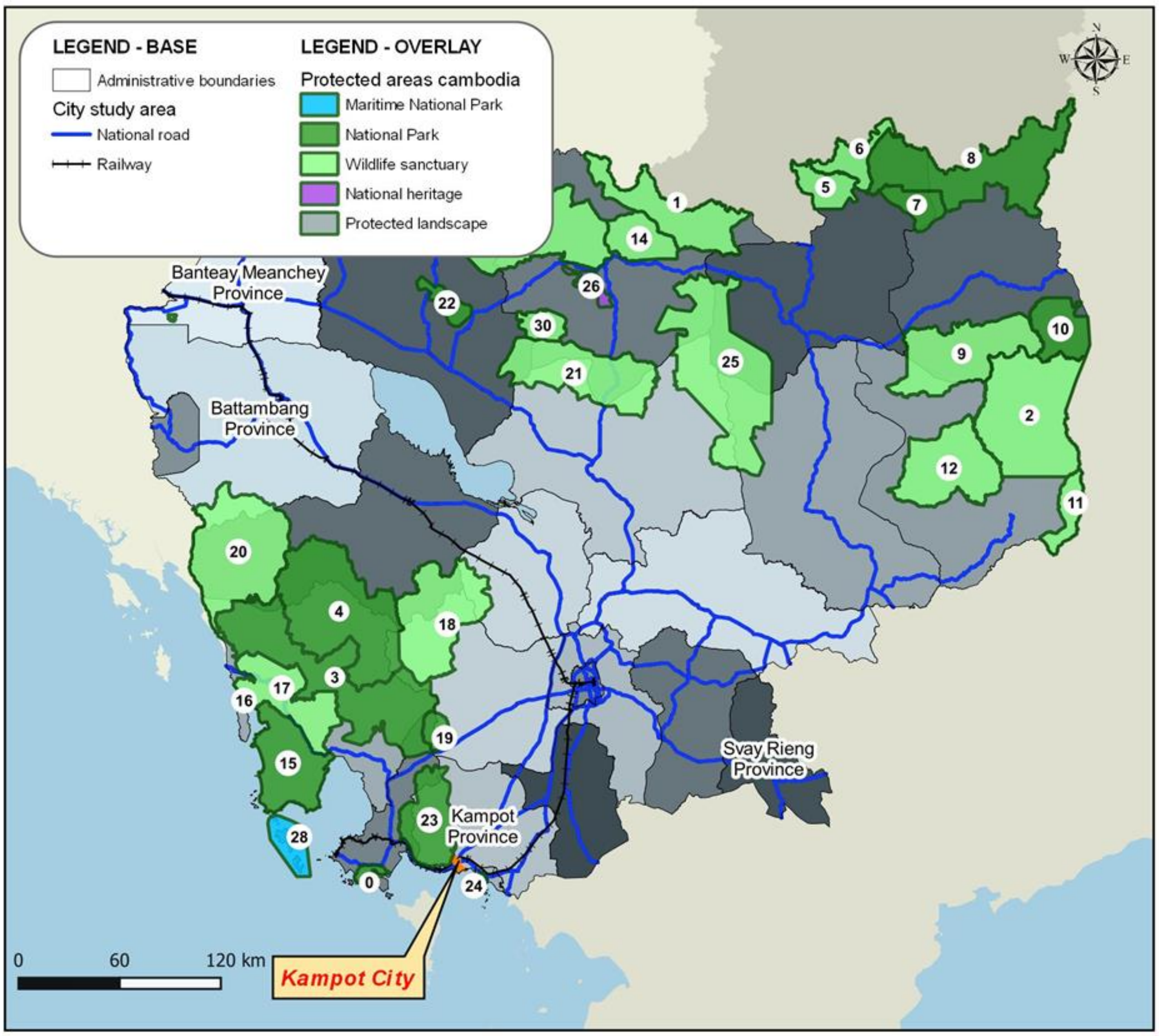
29. As the project is limited to the installation of pipes, there are no specific mitigations that could be costed.

I. INTRODUCTION

1. Study area description

1. Kampot province is located in the south of the country and borders Vietnam in the southeast. It is bordered by Takeo to the East, Kampong Speu to the north, Preah Sihanouk to the west and Koh Kong to the northwest. To the south the province has a coastline of around 45 km on the Gulf of Thailand. It is 4,873 km^2 and has low arable lands and abundant natural resources. The western portion of the province is made up of the Mount Bokor National Park (labeled 23 in Figure 1) that preserves the Dâmrei Mountain range with elevations above 900 asl.

Figure 1: Site Location



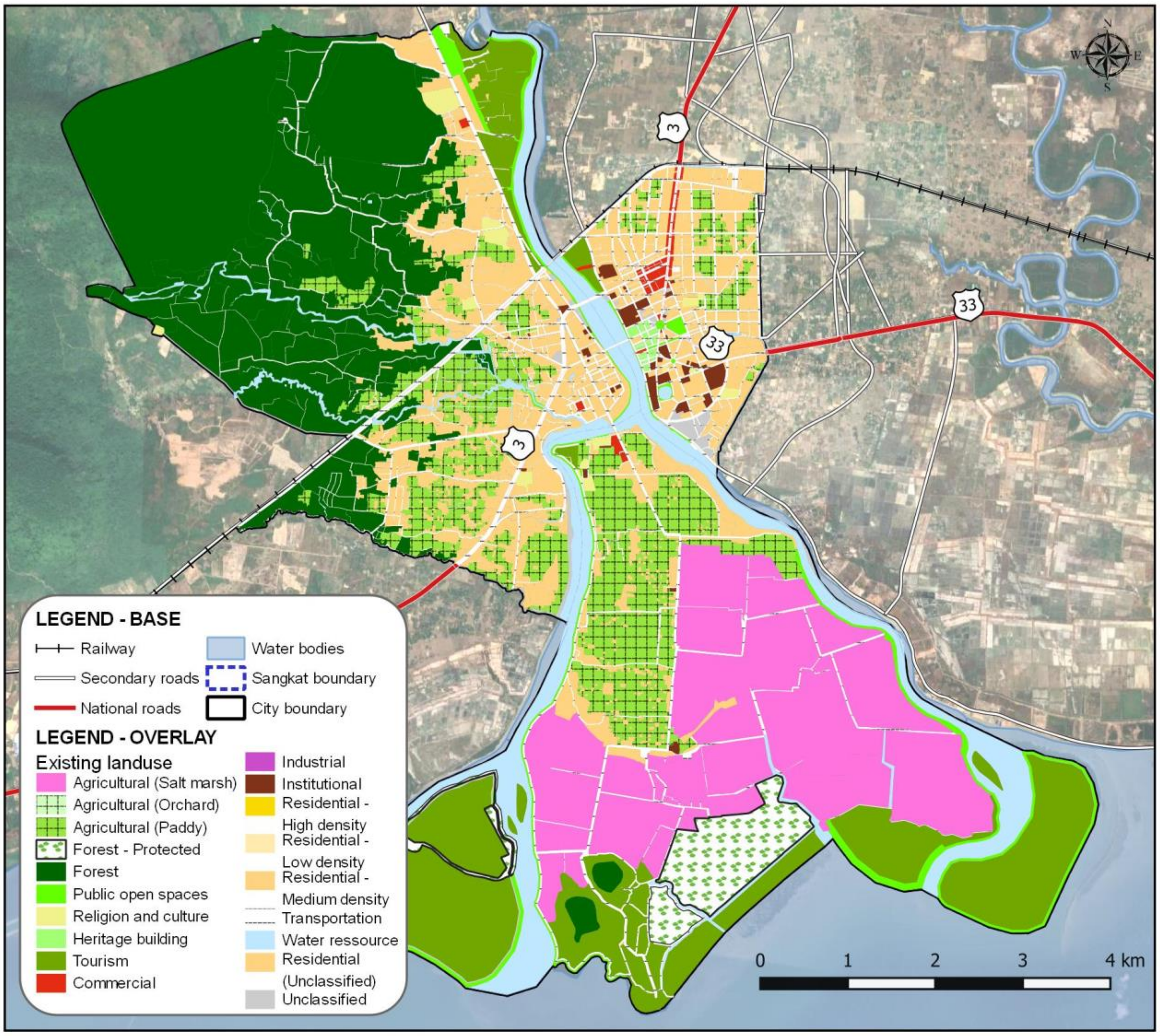
Source: Egis, 2021

2. Kampot City is the provincial capital of Kampot Province and is located on the southern coast of Cambodia on the Gulf of Thailand. Kampot lies in the estuary of the Praek Tuek Chhu River and is southeast of the Dâmrei Mountain range. The city center is around 5 km from the Gulf of Thailand. Kampot City is surrounded by the District Tuek Chhu at the west-north-eastern side and by the sea at the southern side and comprises of 5 Sangkats, and a total of 15 villages.

Kampot municipality comprises built-up areas and rural areas on the east and west sides of the river and the sea coast, with a total population of 48,000 and expected to grow to 77,000 by the year 2040.

3. The current land use of the province is shown in Figure 2. The total approved land area of Kampot City is approximately 54.10km2. The current urban land use covers about 37% of the city area. The natural forest is the second current land use at 27% of the city area; followed by agriculture land use at 26%, water, 8%, and other (i.e. unclassified), 2%.

Figure 2: Current Land Use of Kampot City



Source: Egis, 2021

2. Project description

4. At the request of the Kingdom of Cambodia, the Asian Development Bank (ADB) is developing the Livable Cities Investment Project (LCIP) to facilitate long-term sustainable and

economic growth. The project is aligned with the Government's policies and national strategies, in particular, the Government's Rectangular Strategy – Phase IV[2] and ADB Strategy 2030.[3]

5. The project will concentrate on the secondary cities of Bavet, Poipet, and Kampot, due to their economic potential and location at key trade and tourism zones. The project will focus on enhancing urban planning, building community resilience, and providing infrastructure. Project outputs include (i) output 1: policy and regulatory environment improved, (ii) output 2: urban infrastructure improved, and (iii) output 3: institutional effectiveness, and governance improved.

6. As a result of recent population growth, these cities have identified that the limited infrastructure is restricting their development potential. Existing services are no longer operating optimally and incapable of servicing demands. The LCIP proposes to adopt a holistic methodology, comprising of an integrated urban development approach, to ensure interventions consider land use, long term city needs, asset management, and asset financing for sustainable operations.

7. To ensure climate resilient and sustainable development of participating cities, the project adopts a climate-centric city development approach. Appropriate structural and non-structural measures are incorporated to ensure climate change risks is appropriately mitigated to avoid the future cost associated with the climate change impact.

8. The project components for Kampot under output 2 are improved wastewater management systems consisting of and network (the design and implementation of a wastewater treatment plant is included in GMS2).

9. Following the Urban Development Strategy (UDS), the sector Master plan (MP), and the Comprehensible Technical Options Study (CTOP), the Feasibility Study including this CRVA were completed.[4] The proposed infrastructure for LCIP in Kampot is set out for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined below.

2.1. Short term (2020-2025)

10. There is at present no public wastewater system in Kampot municipality. However, one is under construction to be delivered under the Second Greater Mekong Subregion Corridor Towns Development Project (GMS 2). This plant will not be sufficient to cater to the future growth of the city, and expansion will be required in the medium term. The assessment of the fecal and non-fecal waste disposal chain, both in rural and urban areas, suggests that 77% of fecal waste is not managed safely.

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[2] *Kingdom of Cambodia. 2018. Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV. Phnom Penh.*

[3] *ADB. 2018. Strategy 2030: Achieving a Prosperous, Inclusive, Resilient and Sustainable Asian and the Pacific. Manila.*

[4] Prepared under TA 9554-REG: Southeast Asia Urban Services Facility

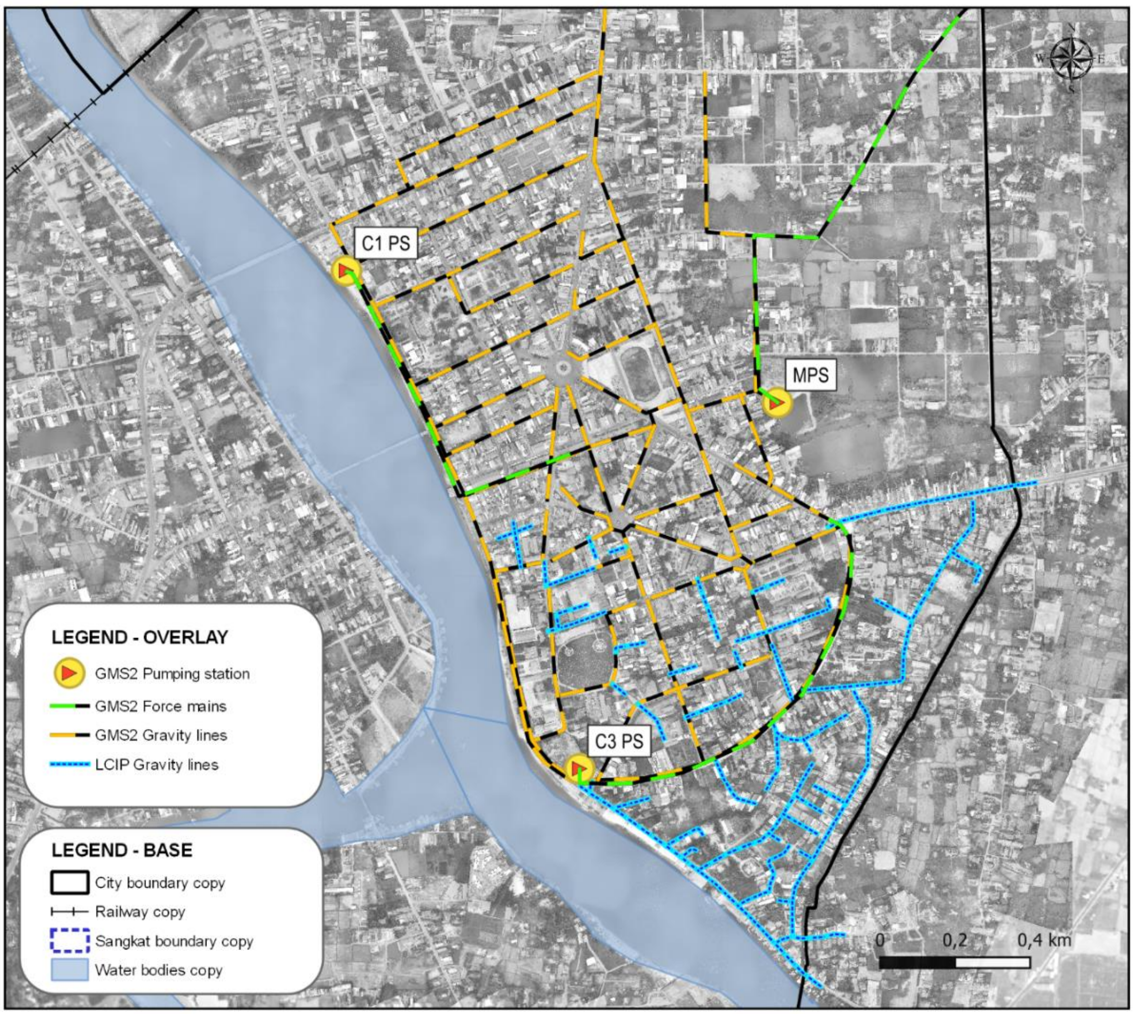
11. In 2018, 86% of the total population had access to a toilet reached 93% in 2020, mostly pour-flush toilets. 2% of the population are still practicing open defecation, and 5% sharing a neighbor's toilet in particular in specific villages such as Traeuy Kaoh Sangkat (south island). It is estimated that 77% of excreta generated is unsafely managed. Providing sewerage and connections to the existing population will be the priority but with the expected capacity required for the long term. The proposed priority infrastructure and the relationship with long term infrastructure is shown in Figure 3.

12. It is suggested to start the implementation with:

(i) Construct sewer pipes to service the south part of the city, which includes provisions to extend for future growth.

(ii) Provide households connection in the center of Kampot and south part of the city

Figure 3: Proposed Infrastructure showing Priority and Long Term Infrastructure.



Source: Egis, 2021

13. The Project focuses on the sewerage system for the areas delineated by the zoning 2025 (short term area) but provides infrastructure designed for future needs.

Table 1: Wastewater – Investment Horizon and Design Capacity

Item	LCIP – investment horizon	Design Capacity
Sewer Network	2025 – short term or priority area	2040

Table 2: Summary Table of Investment in Kampot (wastewater)

Investment Area	Components
Networks	7.5 km of gravity lines

2.2. Medium term (2025-2030)

14. For the medium term it is proposed that master plans are reviewed and updated. It is expected that the medium-term infrastructure will include the extensions of sewerage to growth areas can be accommodated with additional pipes and house connections. Longer-term solutions may include more decentralized treatment options at lower capital cost and operational expenditure. Designs and construction should be integrated with extensions to utilities for water, power, communications, and roads.

2.3. Long term (2030-2040)

15. For the long term it is proposed that master plans are again reviewed and updated to integrate the latest urban settlement and development trends, to respond to changes in flooding and sea level, to respond to any climate trends or new understandings of projected climate changes, and to update safeguard documents. This would also include integration of design and construction across all utilities for water, power, communications and roads.

16. The proposed review will include; ability of any new flood protection and urban drainage infrastructure to reduce flooding across the urban center, review of growth areas for extensions of sewerage and additional pumping stations pipes and house connections, and a review of the potential for the use of more decentralized treatment options at lower capital cost and operational expenditure. The review will inform any required adjustments to the design to respond to changes in areas of enhanced populations growth or to new understandings of projected climate changes based on the most recent climate change science available.

3. Methodology, scope, and limitations

17. Vulnerability per district can be assessed by examining exposure to climate change hazards, sectorial sensitivity and the capacity of the provincial and municipal authorities and the community to adapt to climate change. A staged approach was used to complete this CRVA. Existing information, data on historic climate from previous studies, and GIS analysis were used

to assess current exposure to climate change hazards. Then a future-explicit climate change vulnerability assessment was carried out using climate simulation models and GIS models. An assessment of potential risks of climate-sensitive project components to projected climate change and an assessment of climate resilience of the proposed design was followed by identification of possible additional adaptive measures.

18. The project is designed to facilitate long-term sustainable and economic growth in Kampot by developing strategies to improve urban infrastructure. Sector Master Plans identified infrastructure required to meet the future urban needs of Kampot for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040). However, this feasibility report presents an assessment of the proposed infrastructure that is proposed for the short term, i.e. the next five years. As the planning has been carried out for the period to 2040, climate change impacts will be assessed based on a design period for project infrastructure to 2040. However, climate projections that are available from previous reports are presented for various time periods. Where possible ancillary information or interpolation was used to determine climate change projections for 2040. However, if there was insufficient information available to make an interpolation, then the projected parameter values for 2050 or 2055 were used to assess vulnerability.

II. POLICY AND INSTITUTIONAL FRAMEWORK

1. Institutional framework

19. Cambodia ratified the UN Framework Convention on Climate Change as a Non-Annex I Party in 1995 and acceded to the Kyoto Protocol in 2002, which entered into force in February 2005.

20. In 2003, the Ministry of Environment (MoE) established the Cambodia Climate Change Office (CCCO), responsible for a wide range of climate change-related activities. The status of the CCCO was upgraded from office to department (Department of Climate Change (DCC)) in 2009.

21. In 2015, the Government recognized the importance of environmental protection and climate change in economic development efforts and that many environmental issues are cross-sectoral in nature, requiring effective coordination amongst government agencies, at both national and sub-national levels, and cooperation with all the stakeholders.

22. Therefore, the previous inter-ministerial mechanism for coordination of climate change response, the National Climate Change Committee (NCCC), was replaced with the National Council for Sustainable Development (NCSD). The NCSD comprises high-level representatives (Secretaries and Under-Secretaries of State) of concerned government ministries and agencies, with the Prime Minister as its Honorary Chair and the Minister of Environment as its Chair. Council membership has increased compared to NCCC, covering a greater number of ministries and agencies, and now includes provincial governors.

23. The Department of Climate Change now serves as the Secretariat for the NCSD, acts as the Secretariat of the Cambodian Designated National Authority (DNA) for the Clean Development Mechanism (CDM) and has been actively promoting CDM projects in Cambodia.

24. An important supporter of the disaster management system in Cambodia is the ASEAN Agreement on Disaster Management and Emergency Response (AADMER), a legally binding regional agreement between the countries in the region. AADMER contains provisions on disaster risk identification, monitoring and early warning, prevention, and mitigation, preparedness and response, rehabilitation, technical cooperation and research, mechanisms for coordination, and simplified customs and immigration procedures. AADMER provides support to disaster management in the ASEAN region and assistance in the member countries to enhance the harmonization of regional initiatives.5 AADMER is also ASEAN's affirmation of its commitment to the Hyogo Framework for Action (HFA).

2. Sector policy

[5] UNDRR. 2019. Disaster Risk Reduction in Cambodia: Status Report 2019. Bangkok, Thailand.

25. The Cambodia Climate Change Strategic Plan for 2014 – 2023 (CCCSP) was developed as the first comprehensive policy document to respond to climate change issues. It aims to advance the development towards low carbon, resilient, equitable and sustainable society by introducing linkages for supporting a harmonized approach to national development, poverty reduction and environmental sustainability. The CCCSP outlines strategies to increase the public awareness of climate change, improve the national capacity, enhance community resilience, and reduce national GHG emissions.

26. The Plan sets out eight Strategic Objectives, each with a series of specific strategies that aim to achieve each objective:

(i) Promote climate resilience through improving food, water and energy (FWE) security

(ii) Reduce sectoral, regional, gender vulnerability and health risks to climate change impacts

(iii) Ensure climate resilience of critical ecosystems (Tonle Sap Lake, Mekong River, coastal ecosystems, highlands, etc.), biodiversity, protected areas, and cultural heritage sites

(iv) Promote low-carbon planning and technologies to support sustainable development

(v) Improve capacities, knowledge, and awareness for climate change responses

(vi) Promote adaptive social protection and participatory approaches in reducing loss and damage due to climate change

(vii) Strengthen institutions and coordination frameworks for national climate change responses

(viii) Strengthen collaboration and active participation in regional and global climate change processes

27. The Climate Change Action Plan for 2016-2018 (CCAP) was created to support the implementation of the CCCSP. It identifies seventeen key climate change actions to address the eight strategic objectives presented in the CCCSP. The CCAP presents sectoral Climate Change Action Plans developed by fourteen ministries and government institutions (defining 115 different plans at the sub-national level), aimed towards better adaptation, preparedness, and mitigation of climate change impacts.

28. The National Action Plan for Disaster Risk Reduction (NAP-DRR) for 2014-2018, highlights poverty reduction as the primary development priority. NAP-DRR focused on capacity building, mainstreaming DRR, creating synergies between DRR and CCA, increased the pace of institutional reforms and highlighted the role of research and academic institutions in national disaster management (NCDM, 2013).

29. DRR and CR have been mainstreamed into development planning at sub-national levels and are considered as a cross-cutting theme in water resource management, agriculture and rural development. The National Strategic Plan on Green Growth 2013-2030 focuses on promoting economic development based on green growth principles and environmental sustainability.

30. The Government has also incorporated disaster and climate concerns into socio-economic development agendas. The Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV (2018), recognized climate change and disaster risk as development challenges and incorporated adaptation and vulnerability reduction into overarching strategies.

1 Voluntary National Review of SDGs (VNR) report 2019 identify country needs and priorities aligned to the international SDGs. It highlighted efforts to adapt and deliver the Cambodian SDGs (CSDGs) and their integration within the National Strategic Development Plan (NSDP) 2019-2023, focusing on six prioritized goals: Education, Decent Work and Growth, Reduced Inequalities, Climate Action, Peace and Institutions, and SDG Partnerships.

31. In order to mainstream the post-2015 development agenda comprehensively across sectors and to guarantee whole- of-government response for disaster risk reduction and climate change adaptation, the Strategic National Action Plan for Disaster Risk Reduction 2019 – 2023 currently being developed is intended to be aligned with the Sendai Framework for Disaster Risk Reduction, the Paris Agreement and the Sustainable Development Goals.

3. Institutional arrangements

32. The Ministry of Environment developed the Climate Change Action Plan 2016-2018, setting guidance for general directorates, departments, and units under its jurisdiction. A Climate Change Technical Working Group (CC-TWG) was officially established by the Minister of Environment and Chair of the National Council for Sustainable Development (NCSD). The CC-TWG brings together all government agencies involved in the climate change response and meets four times per year, including at least two sessions with development partners. It reviews progress in the implementation of Cambodia's Climate Change Strategic Plan and serves as a forum for coordination and policy dialogue.

33. On December 2, 2019, the National Law Sub-Decree 182 on Functions and Structure of Municipal Administration was adopted and is currently being implemented. [6] The sub-decree defines the functions, structure, roles, and accountabilities of all Municipal Administrations (MA) in the country. Responsibilities and functions for managing utility services and other activities were transferred to the MA. As a result of these changes, all responsibilities related to wastewater, drainage, and solid waste management are now in the hands of the MA. The Sub-decree creates several offices and units, in particular, a Public Works & Transport, Environmental, Sanitation, and Public Order Office (PWTESPO) in charge of: (i) Urban garbage, and Solid waste management.; (ii) Drainage and wastewater treatment system management. However, due to the recent implementation of the new decree 182, there are currently no dedicated units within the MA for Stormwater and wastewater management.

[6] Kingdom of Cambodia. 2019. No.182ANK.BK Sub-decree on Functions, and Structure of Municipal Administration. Phnom Penh.

34. MAs are accountable to the Government and the respective line ministries in carrying out their roles. Ministries at the national level are primarily responsible for setting policies, strategic plans, and technical standards to guide the operation of the MAs. Ministries are expected to provide technical assistance to MAs. As part of the CCAP process, sectoral Climate Change Action Plans have been developed by ministries and the relevant ministries are responsible for assisting MAs to implement climate change activities.

4. Challenges

35. Some of the key challenges to effective policy implementation are related to the fact that policies are mainly developed by central government agencies and most other actors are insufficiently involved and local communities are effectively excluded. There is also a communication disconnect between national and subnational levels going all the way down to the community level. Coupled with limited technical capacity and finances, political interference, and the absence of functional implementation structures across these levels, effective CCA is limited.

36. The Cambodia Climate Change Strategic Plan 2014 – 2023 acknowledged that limited human and financial resources at the local levels led to a lack of mainstreaming climate change into sub-national development plans. Also, disaster risk management policies and priorities often overlapped with climate policies, and the capacity for response could also be improved[7]. A World Bank review in 2017 found that lack of capacity, insufficient analytics and heavy focus on response was still obstructing a systematic approach to disaster management. The report also identified gaps in disaster risk financing and insurance in emergency response, indicating that short-term emergency response costs of flooding exceed the available resources.[8]

37. The added responsibility for the MA for the management of public utility services for sanitation, drainage, and solid waste management, as detailed in the new decree 182, has implications for the MA capacity in terms of the additional human resources and capacity development needed to undertake this function. The LCIP feasibility study reports identifies several risks associated with financial sustainability and the ability of the MA to fund the incremental Opex.

38. Specifically, this is related to the ability of Kampot municipality to raise more income through the formulation and agreement of the wastewater tariffs roadmap and a lack of capacity to carry out regular maintenance and monitoring and inventory.

39. The capacity of the MA is assessed as part of the risk assessment presented in Chapter V.

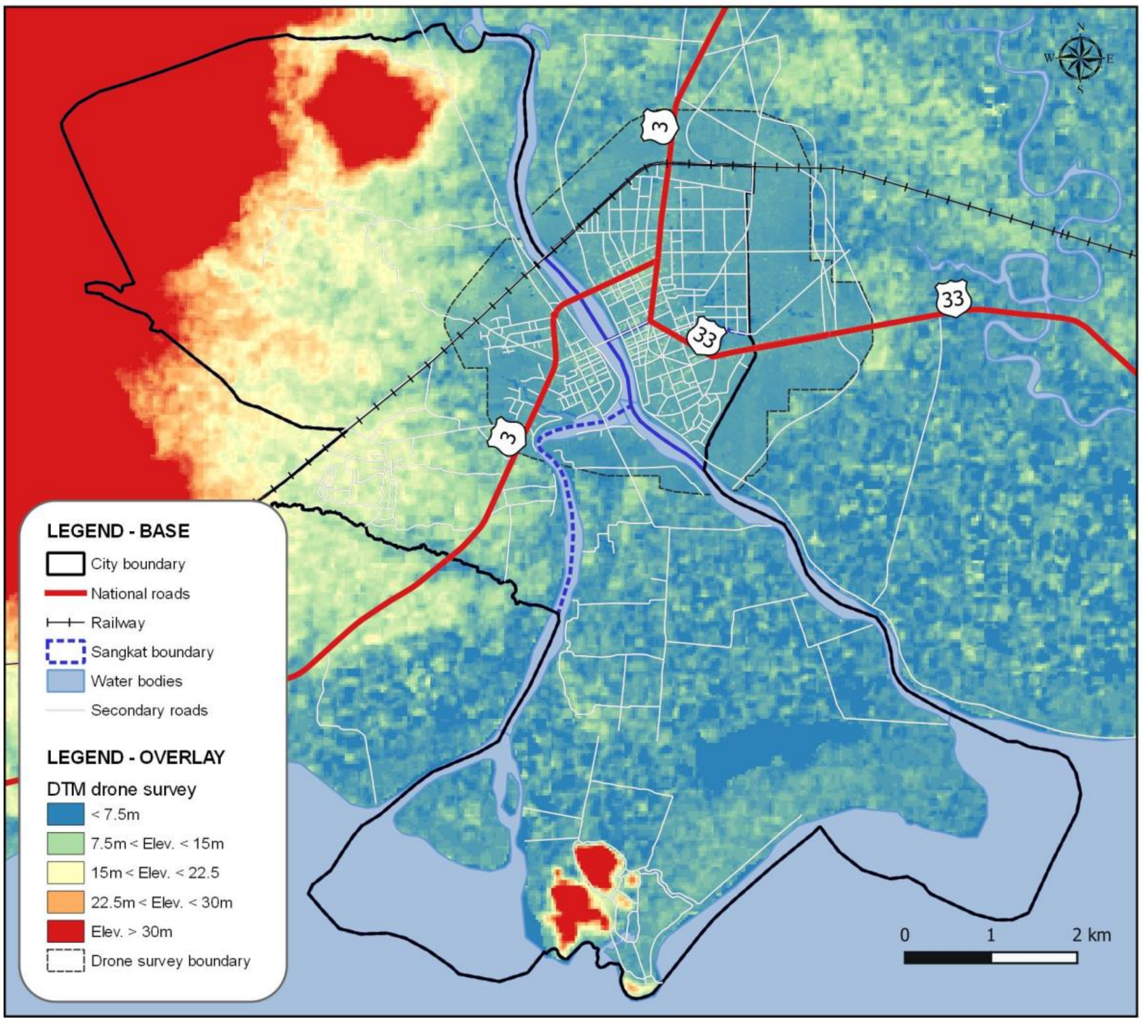
[7] National Climate Change Committee, 2013. Cambodia Climate Change Strategic Plan 2014 – 2023. Phnom Penh: Royal Government of Cambodia.
[8] World Bank & GFDRR, 2017. Disaster Risk Finance Country Diagnostic Note: Cambodia, s.l.: World Bank.

III. RISKS BASED ON CURRENT CLIMATE VARIABILITY

1. Geophysical setting and earthquake/volcano hazards

40. Kampot Province is located on the south coast of Cambodia, stretching westward from the border of Vietnam to the Dâmrie mountain range of Mount Bokor National Park. The Dâmrei Mountains with elevations above 900 above sea level (ASL) stretch 110 km from the coast in a north-south direction. The range forms a succession of the Cardamom Mountains.

Figure 4: Raw DTM Elevation Data



Source: Egis, 2021.

41. The densely wooded range intercepts the southwesterly monsoon and the resulting orographic rainfall leads to some of the heaviest rainfall in Cambodia, averaging 3,800–5,000 mm annually on the western slopes. Because of the rain shadow 1,020–1,520 mm falls on the eastern slopes. Kampot City is located on an estuary that forms part of the seaward catchment draining from the Mount Bokor national park and the large Kampot River runs through the center of the city. Elevations across the City are below 1-2 m asl. River flooding of up to 2 m is common across

the city during the wet season[9]. The construction of Kamchay Hydropower Dam upstream has not stopped the flooding.[10]

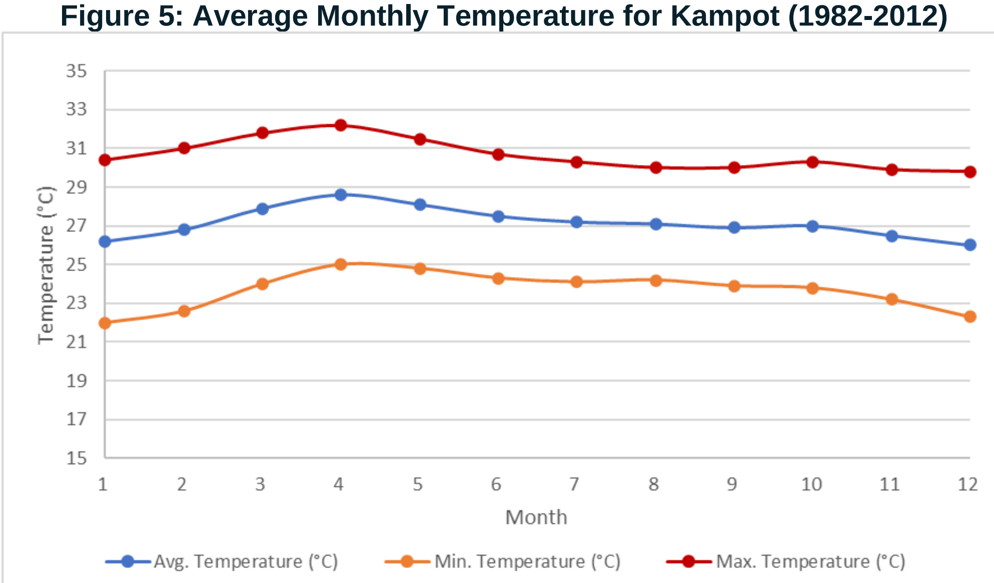
42. The area is geologically stable, and Kampot city is not considered to be at high risk of earthquakes. And while landslides are common in the Bokor National Park due to the high rainfall and steep slopes, the flat terrain of Kampot city means landslides and mass earth movements are not a problem in the city.

2. Temperature

43. North-east winds during the dry season brings drier and cooler air from November to March, and then south-west monsoon winds bring hotter air in April and early May. The mean maximum temperature is 28°C and the mean minimum temperature is 22°C. The average monthly temperature is shown in Figure 5. Maximum daily temperatures above 32°C are common before the start of the rainy season and may rise to more than 38°C.

44. Mean annual temperature across Cambodia has increased at a rate of around 0.18˚C per decade since 1960. The rate of increase is most rapid in the dry season (0.20 - 0.23˚C per decade) and slower in the wet season (0.13 - 0.16˚C per decade).[11] Mean annual temperature in Kampot has increased by 0.2 ˚C per decade since 1980.[12]

Figure 5: Average Monthly Temperature for Kampot (1982-2012)



Source: Climatedata.org

3. Rainfall

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[9] Khmer Times September 17, 2015. Thousands Affected by Kampot Floods. https://www.khmertimeskh.com/59506/thousands-affected-by-kampot-floods/ accessed 9/3/2020.

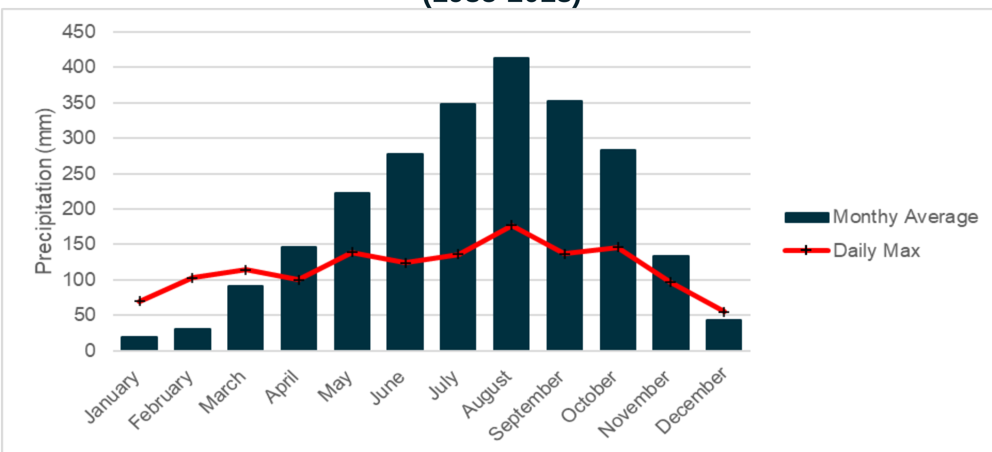
[10] Ibid.

[11] GSNCSD/MoE. 2020. Cambodia's Updated Nationally Determined Contribution (NDC). Phnom Penh.

[12] Based on modeled mean annual temperature from the KNMI. Climate Explorer Website (www.climexp.knmi.nl).

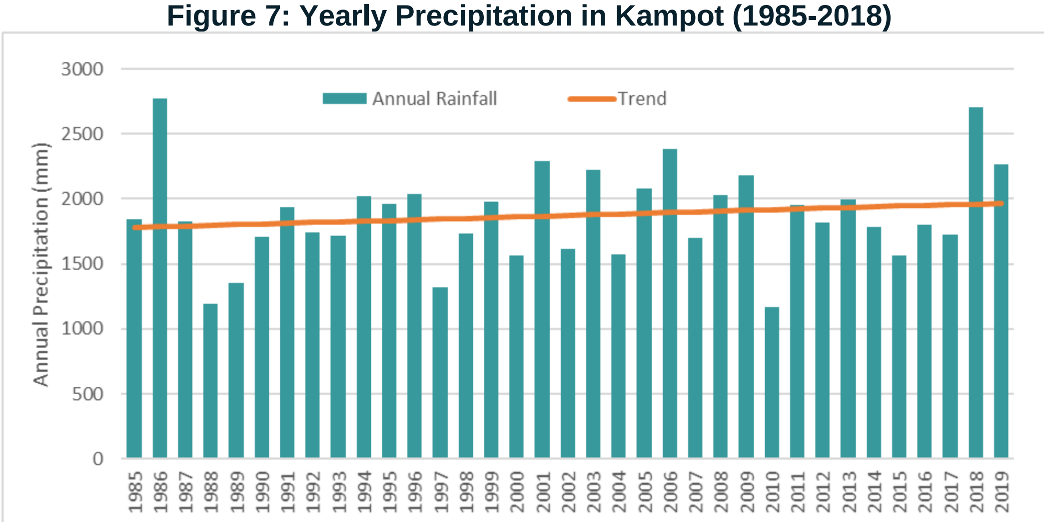
45. Kampot's climate is tropical monsoon characterized by a rainy season from May to early October, and a dry season, from November to April. The monthly rainfall for Kampot and the maximum daily rainfall for each month is shown in Figure 6. The average monthly rainfall ranges from 19.3 mm in February to 349 mm in October. Yearly precipitation from 1985 to 2018 is shown in Figure 7. The average annual rainfall in Kampot over the period is 1,873 mm. The average annual rainfall from 1985 to 2018 varied between 1,165 mm in 2010 and 2,775 mm in 1986. There has been a (not statistically significant) increasing trend of 55 mm per decade.

Figure 6: Monthly Average Precipitation and Maximum Daily Precipitation in Kampot (1985-2018)



Source: Data from MOWRAM.

Figure 7: Yearly Precipitation in Kampot (1985-2018)



Source: Data from MOWRAM.

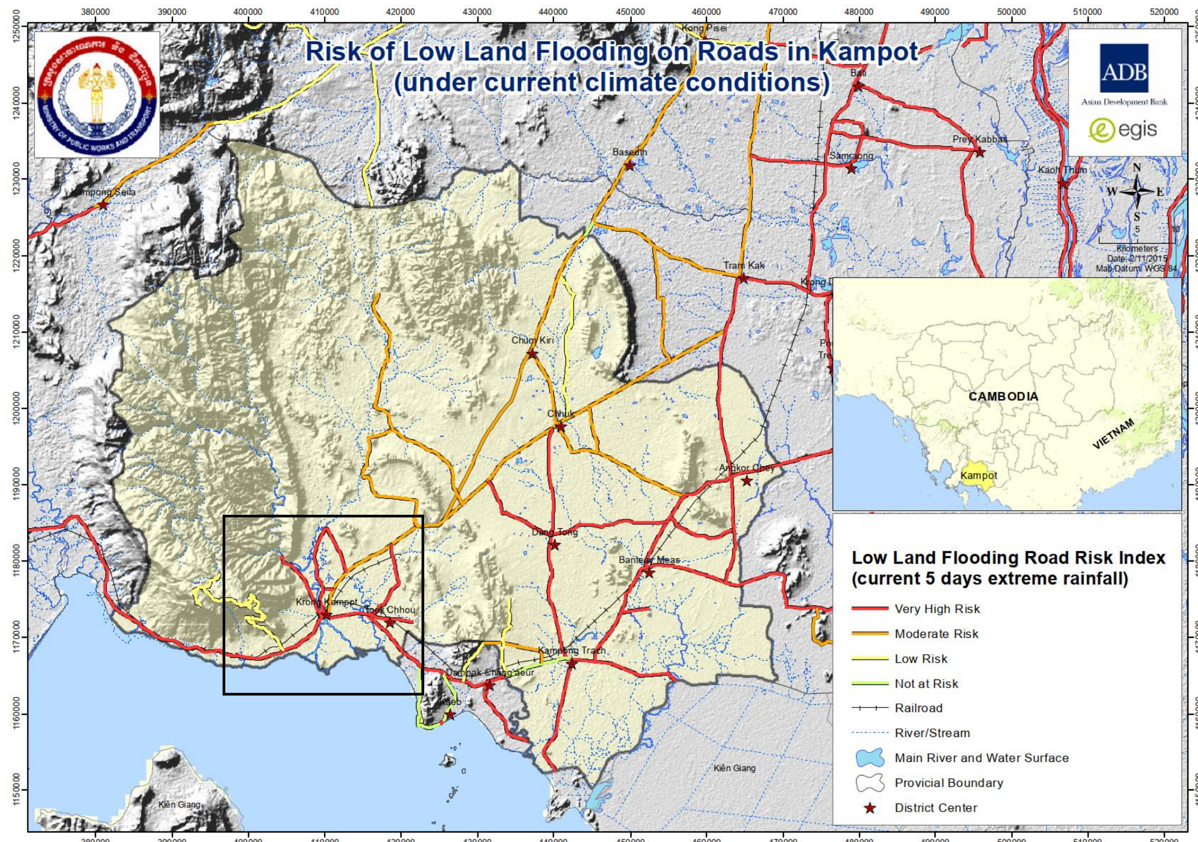
4. Extreme weather events and flooding hazards

46. The high wet season rainfall means that flooding is common across Cambodia. The remnants of typhoons and other large tropical storm systems produce flooding in the mountainous

provinces of the southern Provinces including Kampot[13]. Flooding in Cambodia is often linked to the El Niño-Southern Oscillation (ENSO). La Niña events are often associated with above-normal rainfall over Southeast Asia and sometimes extreme flood events. The recent La Niña event of 2020 has seen widespread flooding across Cambodia.

47. When there are heavy rains along the coastline, runoff swells the rivers draining the mountains and floods areas along the base of the mountain ranges. MPWT's in-house software used for determining the magnitude of flood risk, the Flood Risk Management Interface (FRMI), classifies all of the roads leading into Kampot as being at high risk of flooding (of type low land flooding) except NR3 that is rated as medium risk,[14] see Figure 8.

Figure 8: Road Flooding Risk Index for Kampot from MPWT's Flood Risk Management Interface.



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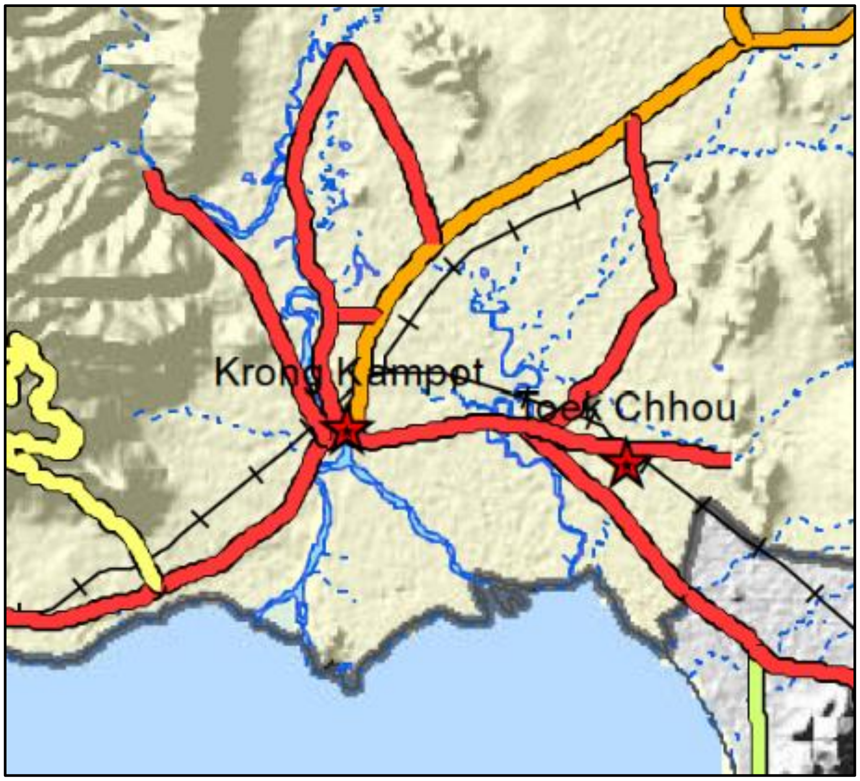
[13] GSSD 2015. Cambodia's Second National Communication Under the United Nations Framework Convention on Climate Change. Phnom Penh

[14] Ministry of Public Works and Transport. 2016. Vulnerability Mapping Report; 2839-CAM (SF)/ 8254-CAM and 0278-CAM Climate Resilience for Provincial Road Improvement Project. Phnom Penh



Source: Ministry of Public Works and Transport. 2018. Vulnerability Mapping Report; 2839-CAM (SF)/ 8254-CAM and 0278-CAM Climate Resilience for Provincial Road Improvement Project. Ministry of Public Works and Transport, Phnom Penh

48. Previous studies into the vulnerability of Kampot Province to flooding have found that the province is vulnerable to flooding[15]. The initial Survey of Cambodian Rural Households carried out as part of the Formulation of the 1st National Adaptation Program of Action to Climate Change (NAPA) found that Kampot was vulnerable to flooding. Kampot province was ranked the province as the 11th highest province out of 21 in terms of flood frequency, but based on fatalities, property losses and number of wells contaminated, Kampot was ranked as 5th highest.[16]

49. An assessment of flood vulnerability based on flooding in 2000 carried out in 2003 by the NCDM did not identify extensive flooding and rated the area around Kampot as a low priority in terms of flooding.[17]

50. Records of flooding for Kampot Province from the NCDM Cambodia Disaster Damage & Loss Information System (CamDi) is shown in Table 3. Mapping provided on the datnase indicates that 11-13 of the records related to Kampot City, involving 4-7 houses and >4 deaths.

[15] Humanitarian Response Forum (HRF). 2013, Cambodia: Floods Humanitarian Response Forum (HRF) Final Report - No. 07. Humanitarian Response Forum. Phnom Penh.

[16] MoE 2005. Vulnerability and Adaptation to Climate Hazards and to Climate Change: A Survey of Rural Cambodian Households. Phnom Phenh.

[17] National Committee for Disaster Management & United Nations World Food Programme. 2003. Mapping Vulnerability To Natural Disasters In Cambodia. Phnom Penh.

Table 3: Records of Flooding for Kampot Province from the NCDM Cambodia Disaster Damage & Loss Information System (CamDi)

Year	Records	Deaths	Houses Destroyed	Houses Damaged	Directly affected	Evacuated	Education centers
1996	18			199	12,104		1
2000	26	8	34		106,446	76079	
2001	13						
2002	14	1		487	74,450	18800	
2006	78	12	38		668,032		
2007	1						
2009	2				51,007		
2011	11				8,245	767	
2014	1		3		45		
2016	6	2					
2017	1			758	10,643		
2018	1			1	26,540	555	
2019	1				19,118	258	

Source: NCDM Cambodia Disaster Damage & Loss Information System (CamDi). http://camdi.ncdm.gov.kh/DesInventar/profiletab.jsp

51. It appears that the major cause of flooding in Kampot is river flooding following heavy rains.

Figure 9: Flooding in Kampot

Source: Egis, 2021

5. Extreme weather events and storm surge

52. Wind and tidal data are difficult to source from Cambodian ports and the wind data that is available for Kampot is incomplete. The following appraisal of data for Kampot is derived from wind data from Duong Dung in Vietnam to the south-east and Trat Airport in Thailand to the north-west.

53. The wind regime of Kampot province can be summarized as: Southwest monsoon winds during a 9-10 month wet season typically of 15 to 20 km/hr with a 30-40% probability of stronger winds in June and a slightly lower probability of stronger winds in the other months of the wet season (somewhere between 20-40%); a short period of light winds in the transition between seasons; a shorter dry season dominated by north-easterly winds of 15-20 km/hr and a 20-30% probability of winds over 20 km/hr.

54. The passage of Typhoons across the Gulf of Thailand is rare with only 2 records. In 1997, Typhoon Linda passes along Cambodia's southern coast and damaged 81 fishing boats on Pou Lo Wei Island and affected hundreds of families[18]. Fortunately, Kampot city is protected from large typhoon generated waves generated in the Gulf of Thailand by Phuc Quoc Island that is located 20 km to the southwest. Modeling carried out for an ADB report indicated that during the wet season, southwest monsoon winds generate waves of around 0.3 to 0.5 m offshore at Kampot. During monsoon storm events waves of up to 1m can impact the shore.

55. During a typhoon, the combined effect of low pressure and high winds result in higher than normal water levels. The ADB report also modeled the impact of a tropical storm of the size of Typhoon Linda passing to the south of Phu Quoc. The model projected waves of 1.2-1.4 m and a storm surge of 0.7 to 0.8 m at Kampot as the typhoon passed to the south of Phu Quoc and the wind direction turned southeast.[19]

6. Droughts hazard susceptibility

56. Extended periods of drought are now a large concern for human welfare and food security. When coupled with other climatic factors, such as higher temperatures and wind events or unsustainable agricultural and development patterns, droughts can result in land degradation and, if unchecked, in increases in desert land areas or desertification. The heavy reliance of Cambodian farmers on subsistence farming means that delays in the onset of monsoon rainfall have significant negative impacts on rice production. Droughts in Cambodia are caused by the failure of the monsoon rains and are often linked to the El Niño-Southern Oscillation (ENSO). El Niño events are often correlated with droughts over Southeast Asia and the opposite phase, a La Niña event, is associated with above-normal rainfall and sometimes extreme flood events.

57. El Niño weather patterns produce a twofold impact; higher-than-average temperatures and reduced monsoon rains that tend to start later in the season. Kampot Province was not identified as being drought prone in an assessment of drought vulnerability carried out in 2008 by

[18] NCDM 2008. Stategic National Action Plan for Disaster Risk Reduction 2008~2013. National Committee for Disaster Management. Phnom Penh.
[19] Refer footnote 18.

the NCDM which rated the province as a low priority in terms of drought[20]. The initial Survey of Cambodian Rural Households carried out as part of the Formulation of the NAPA ranked Kampot Province as the 11th highest province out of 21.[21] Impacts from droughts are recorded for Kampot Province in the NCDM disaster database for 1997, 2002, 2003, 2004, 2005, 2006, 2014, and 2016. [22] The NCDM database only lists damage to crops as impacts of the droughts.

58. The CSIRO study presented maps of drought indicators across Cambodia for the period 1980-2000. The modeled baseline data indicated that three-month droughts occurred ten times over the 20-year period. The average duration of droughts in Kampot is five months.[23]

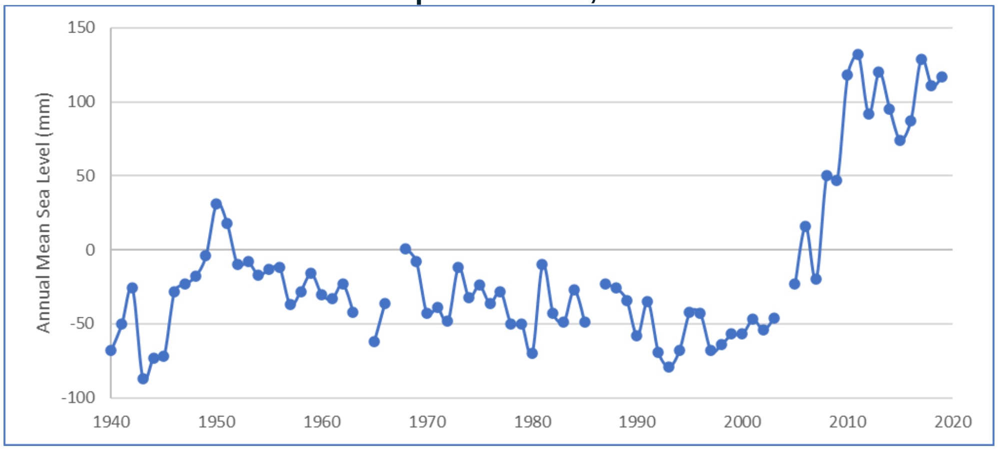
7. Sea Level Rise

59. An assessment of Koh Kong and Kampot Provinces by the International Union for Conservation of Nature (IUCN) described how storm surges related to a sea-level rise of 20cm in the past 30 years are already causing inundation of crop areas by saltwater and damage to infrastructure (particularly roads) constructed at the edge of the sea.[24]

60. Historical sea level data for Cambodia is difficult to access and the nearest available source of long term sea level data from tidal gauges is Ko Lak, Prachuap Khiri Khan, Thailand, 350 km on the other side of the Gulf of Thailand. The average yearly sea level from the tidal gauge at Ko Lak in Figure 10 shows that sea level has displayed a rise in the order of 150 mm since 2002. This trend of recent rises has been seen in all of the other ports around the Gulf of Thailand and has been related to region-wide vertical co-seismic displacements and post-seismic velocities caused by the 2004 Mw9.2 Sumatra-Andaman earthquake.[25]

[20] NCDM 2008. Strategic National Action Plan for Disaster Risk Reduction 2008~2013. Phnom Penh.
[21] MoE 2005. Vulnerability and Adaptation to Climate Hazards and to Climate Change: A Survey of Rural Cambodian Households. MoE, Phnom Penh.
[22] NCDM Cambodia Disaster Damage & Loss Information System (CamDi). http://camdi.ncdm.gov.kh/DesInventar/profiletab.jsp
[23] Katzfey, J.; Jiao, X.; Suppiah, R.; Hoffmann, P.; Nguyen, K. C. & Poun, S. 2013, 'Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia', Technical report, CSIRO, Australia.
[24] Bobenrieth, M.E., Kong, S., Kim Sreng, K. and Robert Mather, R. 2011. Vulnerability and Capacity Assessment of Koh Kong and Kampot Provinces, Cambodia, International Union for Conservation of Nature and Natural Resources IUCN Gland, Switzerland, 36pp.
[25] Trisirisatayawonga, I., Naeijeb, M., Simonsb, W. and Fenoglio-Marcc, L. 2011. Sea level change in the Gulf of Thailand from GPS-corrected tide gauge data and multi-satellite altimetry. Global and Planetary Change 76, 137–151.

Figure 10 : Annual Mean Sea Level in millimeters above the Thailand National Datum at Ko Lak Tidal Station Prachuap Khiri Khan, Thailand from 1941 to 2010.



Source: Permanent Service for Mean Sea Level (PSMSL). https://www.psmsl.org/data/obtaining/rlr.annual.data/174.rlrdata. Accessed 22/10/2020

8. Community perceptions of recent climate change

61. A comprehensive city survey across the urban Sangkats in in the Project Taget Area in Kampot has been conducted in December 2019. The survey undertaken by the transaction technical assistance facility sought the opinion of specific vulnerable groups such as people with lower incomes (ID-poor), Elders, Female-Headed Households (FHH), and indigenous people (IP), on key features related to climate change (flooding/ drought/ hot weather) through focus group discussion meetings, shown in Table 4.

8.1. Flooding

62. Two groups, the ID poor and FHH had experienced damaging inhouse flooding of more than 20cm that they attributed to not enough drains. Two groups, the ID poor and the Indigenous, thought that rainfall had increased in the last ten years. All groups thought that flooding had gotten worse in the last ten years. Two groups, the FHH, and Indigenous groups thought wet season flooding would impact the proposed project.

8.2. Drought

63. Two groups (Elders and FHH) thought that droughts had become longer in the last 20 years. Three groups (ID poor, Elders and Indigenous) thought that drought had impacted their income. The ID poor thought it had a small impact on health. The other groups thought their income had been moderately impacted with reduced income from crops or an agricultural business. It appears that the community in Kampot has close links with the wider agricultural sector and households are affected by the loss of crops during droughts.

8.3. Hot weather

64. All groups thought that hot weather had worsened health issues for members of their household. Three groups (Elders, FHH and Indigenous) thought there are more extremely hot days and more consecutive hot days together compared to 20 years ago.

Table 4: Results of Social Survey on opinion of specific vulnerable groups on key features related to climate change (flooding/ drought/ hot weather).

Group Number participants (total (men/women)	ID-Poor	Elders 11(1/10)	F HH	IP
Flooding				
Do you think flooding in the wet season will impact the proposed project components?	No	No	Yes	Yes
If yes, why?			Slow project implementation	Slow project implementation
Have you experienced flooding in your house?	Yes	No	Yes	No
If yes, what was level of floodwater: (a) around the house but not inside, (b) inside the house but not deep, (c) more than 20 cm deep in the house?	(c)		(c)	
If yes, what was the cause (a) not enough drains, (b) blocked drains, (c) too much water for the existing drains, (d) sea level rise, (e) other	(a)		(a)	
Have you experienced damage to your house from flooding?	Yes	No	Yes	No
Do you think that rainfall has increased in the last ten years?	Yes	No	No	Yes
Do you think that flooding has gotten worse in the last ten years?	Yes	Yes	Yes	Yes
Drought				
Has your household income been affected by drought?	Yes	Yes	No	Yes
How? (a) Household members with less work, (b) reduced income from crops or an agricultural Business, (c) other	(c) Health Problems	(b)		(b)
Did the drought have (a) a large impact, (b) a moderate impact, (c) a small impact?	(c)	(b)		(b)
Do you think that droughts have become longer in the last 20 years?	No	Yes	Yes	No
Hot weather				

Group Number participants (total (men/women)	ID-Poor	Elders 11(1/10)	F HH	IP
Have any members of your household had health issues that are made worse by hot weather?	Yes	Yes	Yes	Yes
Do you think that there are more extremely hot days now compared to 20 years ago?	No	Yes	Yes	Yes
Do you think that there are more consecutive hot days together compared to 20 years ago?	No	Yes	Yes	Yes
NOTES: ID-poor = lower incomes, F HH = Female Headed Households, IP = Indigenous people				

Source: Egis, 2021

IV. FUTURE PROJECTIONS

65. There has been very little effort into updating climate change projections for Cambodia in the last 5 years. Generally, climate modeling has been based on older generations of climate models released under CMIP3 and using the IPCC3 Special Report on Emissions Scenarios (SRES) CO_2 scenarios. Climate change modeling reports that present data for Cambodia are summarized in Table 5. The Second National Communication released in 2015, did not provide any recent modeling results and relied on projections from earlier reports. The Climate Futures program of the CSIRO funded by Ausaid used 6 CMIP5 GCM models and Representative Concentration Pathways (RCP) to create climate projections for Cambodia and Vietnam. The study produced downscaled projections from a Regional Climate Model with a resolution of 10 km, with six model runs based on inputs from each of the 6 GCMs. The CSIRO reports present maps of the average value of the projections from the six RCM runs. Because of the higher resolution of the CSIRO RCM, where possible the results of the for RCP8.5 for the 20 year period centered on 2055 are used for projections in this CRVA.

66. To provide more information on the range of individual GCM projections, results from the Royal Netherlands Meteorological Institute (KNMI) Climate Explorer Website are also presented. The Climate Explorer Website supported by the World Meteorological Organization, presents data from the latest CMIP6 models. The data consists of projections from a 13 ensemble of GCMs and is at the resolution of the original models with no downscaling (2.5° x 2.5° grid). Data was downloaded and compared to baseline of 2000 – 2020.

67. A discussion of the selection of projections to use for the design of project infrastructure is presented in section IV. 6 below.

Table 5: Climate Change Modeling used to Develop Projections in this Report.

Report	Year Released	Model generation	No. Models	CO_2 future Scenario	Baseline
Second National Communication	2015	CMIP3	2	SRES A2	2002

Report	Year Released	Model generation	No. Models	CO_2 future Scenario	Baseline
Climate Futures Program, CSIRO (Ausaid)	2013	CMIP5	6	RPC8.5	1975-2005
KNMI. Climate Explorer (www.climexp.knmi.nl).	2021	CMIP6	13	SSP2 RCP4.5 SSP5 RCP8.5	2000-2020
SRES = CO_2 scenarios developed for the IPCC3 Special Report on Emissions Scenarios RCP = CO_2 Representative Concentration Pathways developed for IPCC5 SSP = Shared Socioeconomic Pathways CMIP = Climate Model Intercomparison Project carried out for IPCC3, IPCC5 or IPCC6					

Source: Egis, 2021.

1. Temperature

68. Climate change models are very consistent in projecting an increase in temperature across Cambodia in the future. The projected temperature change for Kampot from CMIP6 GCMs is shown in Table 6. The table shows the median and range of a 13 ensemble of GCM's projections of mean annual temperature anomalies relative to the mean climate of 2000-2020 under the two scenarios for three 20 year time periods. Average annual temperature for Kampot is projected to increase by 0.6 °C by 2030, by 1.4 °C by 2050 and by 3.4°C by the end of the century under RCP8.5. Projections for 2050 under RCP 4.5 are slightly less out to 2050, but the difference is larger by the end of the century.

Table 6: Range of Projected Mean Annual Temperature Change (°C) for the 2.5° x 2.5° cell containing Kampot Compared to the 2000-2020 model average under the SSP2 RCP4.5 and SSP5 RCP8.5 Scenarios from 13 Model Ensemble.

20 yr period	2030			2050			2090		
Scenario	Min	Av	Max	Min	Av	Max	Min	Av	Max
SSP2 RCP4.5	0.1	0.5	0.8	0.6	1.1	1.6	0.9	1.7	2.9
SSP5 RCP8.5	0.2	0.6	0.8	0.8	1.4	2.2	2.2	3.4	5.5

Source. KNMI. Climate Explorer (www.climexp.knmi.nl).

69. The projected change in seasonal temperature for Kampot for the period centered on 2055 compared to the period 1975-2005 under RCP8.5 is shown in Table 7. Temperature changes are projected to be relatively even across the year under RCP8.5.

Table 7: Projected Seasonal Temperature Change (°C) for Kampot for the period centered on 2055 under RCP 8.5 compared to the period 1975-2005.

Parameter	Value
Mean Annual Temperature (°C)	1.8
April-May Temperature (°C)	1.8
June-September Temperature (°C)	1.75
October-November Temperature (°C)	1.75
December-March Temperature (°C)	1.8

Source. Katzfey, J., Jiao, X., Suppiah, R., Hoffmann, P., Nguyen, K. C. and Poun, S, Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia, 2013.

2. Number of hot days

70. The UNDP report defines a hot day threshold as the temperature exceeding 10% of days or nights during the period 1970-1999. The report presents projected changes in the number of hot days in the region around Kampot of 22 days by 2060 from an ensemble of 15 models (Model range is 15-59 days) under the SRES A2 scenario. However, modeling carried out by the CSIRO presents projections of the number of days above 35°C, which is a more realistic measure of potential heat stress conditions. The CSIRO modeling indicates that the number of days above 35°C is projected to increase from 2-3 days per year to over ten days per year by 2050 under RCP8.5 and that the number of consecutive hot days will increase from 8 to over 10.[26]

3. Rainfall

71. The projected change in rainfall from climate models is much more variable than it is for temperature. The Second National Communication states that under the A2 scenario, annual rainfall for Cambodia in 2100 would increase between 3% and 35% from current rainfall (2015), depending on location, while under SRES B1 the increase would be smaller. The projected annual rainfall change for Kampot from an ensemble of 10 CMIP6 GCMs is shown in Table 8. The average projection for annual rainfall from the GCMs used in this study is for an increase by 2030 but little change into the future. With regards to the range of outputs, some models project a decrease, -4% by 2030, -3% for 2050 and -6% for 2090, while others project an increase of up to 8% by the end of the century. The results for RCP4.5 are generally lower.

Table 8: Range of Projected Mean Annual Precipitation Change (%) for the 2.5° x 2.5° cell containing Kampot Compared to the 2000-2020 average under different Scenarios from 10 Model Ensemble.

Year	Scenario	Min	25th	Av	75th	Max
2030	SSP2 RCP4.5	-1	0	3	4	6
	SSP5 RCP8.5	-4	1	6	8	8
2050	SSP2 RCP4.5	-3	-2	-1	2	5
	SSP5 RCP8.5	-1	0	1	4	6
2090	SSP2 RCP4.5	-4	-3	0	3	8
	SSP5 RCP8.5	-6	-4	0	4	6

Source. KNMI. Climate Explorer (www.climexp.knmi.nl).

4. Extreme weather events and flooding

72. Typhoons making landfall on the coast of Vietnam often impact Cambodia as a tropical depression and can bring widespread heavy rainfall and subsequent flooding. The MRC State of the Basin Report found no increasing or decreasing trend in the number of tropical storms over the last ten years[27]. However, there is a growing level of consistency between global climate

[26] Katzfey, J. et al, 2013. Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia.
[27] The Mekong River Commission 2019. State of the Basin Report 2018. Vientiane Lao PDR.

models that on a global basis, the frequency of tropical cyclones is likely to decrease by the end of the 21st century. A CSIRO report found that the majority of GCMs project that there will be a decrease in tropical cyclone formation off the coast of Vietnam. This is consistent with a previous study by Chand et al. 2016 [28]. There is also a general agreement between models that the trade-off to the decrease in frequency is an increase in the intensity of wind speeds of 1.3 m/s [29], and an increase in rainfall rates of the order of 20% within 100 km of the cyclone center [30]. Studies of the northwest Pacific region off the coast of Vietnam project an increase in typhoon strength of around 5% by 2050[31]. This indicates that extreme rainfall events that result from tropical depressions crossing Cambodia will decrease in frequency, but each event will bring more rain. This increased strength will also occur for any typhoons that pass over southern Vietnam and reform in the Gulf of Thailand as Linda did in 1997.

73. Table 9 shows the projected increase in extreme rainfall events from two sources; the KNMI website, and the CSIRO study. Both results are based on outputs from CMIP5 GCM data. The KNMI website presents GCM data in 2.5° x 2.5° pixels, outputs from 10 models shown to be suitable for the region were assessed. The CSIRO study used 6 CMIP5 models as an input to a 10 km x 10km pixel Regional Climate Model. The KNMI data showed that climate models produced a wide range of projected changes and the average projection was for a change of 8%. The average of the ensemble used in the CSIRO study is lower than the KNMI data. These projections are consistent with the projected changes in rainfall that will result from tropical depressions crossing into Cambodia from typhoons landing in Vietnam. For the 5 day extreme events, the CSIRO study projected a decrease in 5 day events of 2.5 mm, which is not consistent with the projections for increased tropical storm intensity. Additionally, the coastal location of Kampot indicates that increased wet season monsoons could be expected to result in larger rainfall from extreme events.

Table 9: Projected Change in Extreme Rainfall Parameters (mm) for Kampot for the period centered on 2055 under RCP 8.5 compared to the period 1975-2005.

Parameter	BL	25th	Av	75th
Maximum 1-day rainfall (mm), KNMI, RCP4.5	130 mm	-41	3 (3%)	56
Maximum 1-day rainfall (mm), KNMI, RCP8.5	120 mm*	-45	10 (8%)	66
Maximum 1-day rainfall (mm), CSIRO, RCP8.5	160 mm		2.5 (1.6%)	
Maximum 5-day rainfall (mm), CSIRO, RCP8.5	250 mm		-2.5 (1%)	

NOTES: Both are based on CMIP5 models. The KNMI website presents GCM data in 2.5° x 2.5° pixels
The CSIRO study used CMIP5 models as an input to a 10 km x 10km pixel Regional Climate Model.
BL = Average of the model outputs for the baseline runs (1975-2005).
* Different ensemble of models available for each RCP

Source: KNMI. Climate Explorer (www.climexp.knmi.nl) and Katzfey, J. et al, Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia, 2013.

[28] Chand, S.; Tory, K.; Ye, H. & Walsh, K. 2016. 'Projected increase in El Niño-driven tropical cyclone frequency in the Pacific', Nature Climate Change 7.
[29] Kang, N.-Y., and J.B. Elsner. 2015. Trade-off between intensity and frequency of global tropical cyclones. Nature Climate Change.
[30] Knutson, T.R., McBride, J.L., Chan, J., Emanuel, K., Holland, G., Landsea, C., Held, I., Kossin, J.P., Srivastava, A.K., and Sugi, M., 2010. Tropical cyclones and climate change: Nature Geoscience, v. 3, p. 157-163.
[31] For detailed review see Walsh et al. 2016 Tropical cyclones and climate change. Wiley Interdisciplinary Reviews-Climate Change, 7 (1), pp. 65 – 89.

74. Given the high variability of the modeling results for projected rainfall change for Kampot, more detailed projected changes that were published for nearby Rach Gia on the west coast of Vietnam were sourced and are presented in Table 10. The extreme daily rainfall total for Rach Gia is similar to Kampot and both cities are influenced by the same climate drivers. The table expresses the 1-day total extreme rainfall with the current baseline represented by the analysis of the historical daily rainfall record for Rach Gia station from 1 January 1979 to 31 December 2007. The 5, 10 and 100 year return periods also are presented for the 2030 and 2050 future projections. Results are presented as extreme daily rainfall (in mm) and the percentage change from the baseline values. The percentile values arise from using a 12-GCM ensemble.

75. For the 25th percentile, 75% of the models agree the extreme will be larger than the given value. Likewise, for the 75th-percentile, 75% of the models agree the extreme will be smaller than the given value, i.e. the extreme value in 2050 under the A2-mid scenario, for a ten year return period will be between 210 and 228 mm, corresponding to an increase of between 7.6 and 15.7%. The modeling indicates that by 2050, events with a five-year return interval will increase in intensity by 8% (B2) to 9 % (A2) and that a 1 in a 100 extreme rainfall event will increase in intensity by 10 – 11 % (B2 and A2 respectively).

Table 10: Absolute Value (mm) and Percentage Projected Change in extreme daily rainfall intensity for different return periods for Rach Gia, Vietnam, for 2030 and 2050, for two emission scenarios (A2 and B2) specifying 25th, 50th and 75th percentile results

Return period	Five year			Ten year			100 year		
Percentile	25th	50th	75th	25th	50th	75th	25th	50th	75th
Current (mm)	164	164	164	194	194	194	292	292	292
2030									
A2-mid (mm)	170	173	179	203	206	212	304	310	323
% change	3.3	5.0	9.1	4.4	6.0	9.4	3.8	6.1	10.3
B2-mid (mm)	170	173	180	203	206	213	304	311	324
% change	3.5	5.2	9.5	4.6	6.2	9.9	4.0	6.4	10.8
2050									
A2-mid (mm)	174	179	192	210	215	228	313	325	348
% change	6.1%	9.2%	16.7%	8.1%	11.0%	17.3%	6.9%	11.1%	19.0%
B2-mid (mm)	173	178	189	208	213	224	311	322	343
% change	5.5%	8.3%	15.2%	7.4%	10.0%	15.7%	6.3%	10.1%	17.2%

Source. ADB, Climate Change Impact and Adaptation Study in the Mekong Delta: Climate Change Vulnerability and Risk Assessment Study for Ca Mau and Kien Giang Provinces, Vietnam - Final Report, 2011.

76. The high variability of the climate change information output from individual GCMs makes it difficult to provide enough information to devise climate change parameters for different future CO_2 scenarios. The role of tropical depressions formed from the remnants of Typhoons in extreme rainfall in Cambodia indicates that projected changes to the frequency and intensity of Typhoons will also apply to extreme rainfall in Kampot. Based on the consistency of the projected change in 1-day extreme rainfall by 2050 from the GCMs and the statistical downscaling, it is recommended

that each component of rainfall Intensity, Duration and Frequency (IDF) tables can be adjusted by the projected change as a percentage, i.e., 9% to determine projected rainfall conditions in 2050. The phased nature of the investments means that it is possible to iteratively review and update the allowances used for the design of subsequent phases, should changes be shown to be increasing faster than expected, or based on updated projections of change in heavy rainfall.

5. Droughts hazard susceptibility

77. The 2nd National Communication projected an increase in frequency and length of droughts across Cambodia. The Mekong River Commission state of the Basin Report for 2019 concluded that droughts could potentially increase across the Basin in the future due to the projected increase in temperatures and changes in rainfall patterns[32]. However, The CSIRO modeling projected little change in both the frequency and duration of droughts in Kampot. The results of the survey and the NCDM reports and database indicate that droughts currently have impacts on the community in Kampot due to the strong links with the agricultural sector and that that impacts from droughts will continue with at least the same frequency.

6. Sea Level Rise

78. Sea Level Rise (SLR) scenarios for the west coast of Vietnam under the low, medium and high scenarios are outlined in Table 11. By the end of the 21st century, sea level is projected to rise to 63 cm (low scenario), 70 cm (medium scenario), and 88 cm (high scenario) compared with 1980-1999. These figures are also broadly consistent with more recent estimate of global sea-level rise to the end of the century. Extrapolating the trend indicates a rise of 23.5 cm by 2040. Additionally, the sea level has already risen by 15 cm since 2004.

79. The recommended sea level rise from the 1980-1999 baseline to use for hydrological modeling for the period centered on 2040 is the high CO_2 scenario A1F1 plus the seismic displacements, which produces a total projected sea level rise of 38.5 cm.

Table 11: Projected Sea Level Rise for the West Coast of Vietnam compared to 1980 – 1999 baseline using downscaling from PRECIS for three emission scenarios.

Emission Scenario	2020 – 2039 (cm)	2040 – 2059 (cm)	2060 – 2079 (cm)	2080 – 2099 (cm)
Low (B1)	15	28	45	63
Medium (B2)	15	30	49	70
High (A1F1)	16	32	57	88

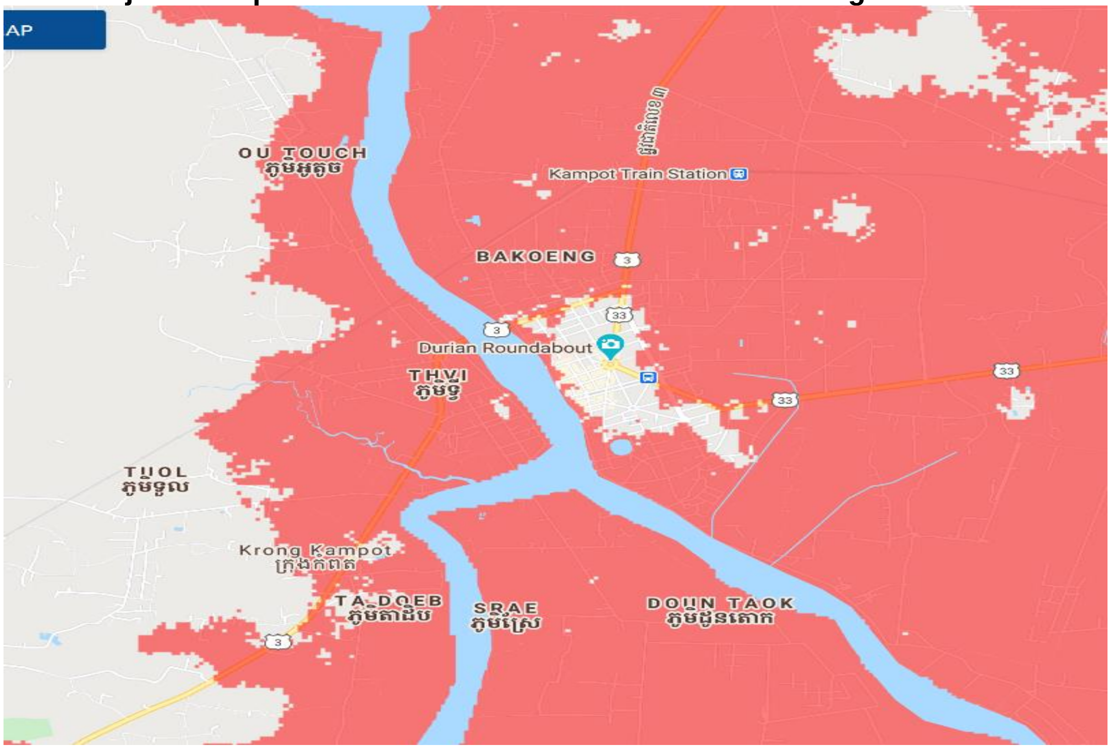
Source, ADB, Climate Risks in the Mekong Delta: Ca Mau and Kien Giang Provinces of Viet Nam, 2013.

80. The projections of Kopp et al 2017 are for slightly higher sea levels out to 2050 and for projections to be much higher than IPCC AR5 levels towards the later part of the century. To account for the local sea level rise trend, the projections of Kopp et al 2017 were used to derive

[32] 32 *The Mekong River Commission 2019. State of the Basin Report 2018. Vientiane Lao PDR.*

Figure 11. The flood height was developed from “A global reanalysis of storm surges and extreme sea levels.”[33]

Figure 11: Projected Exposure to Sea Level combined with Flooding for 2040 under RCP8.5



Note uses the median output from an ensemble of climate models for RCP8.5, global sea level projections from Kopp et al. 2017 (not adjusted for local conditions), flooding from Global flood database: Muis et al. 2016[34].
Source :climatecentral.org.(https://coastal.climatecentral.org/map/14/104.1995/10.6083/?theme=sea_level_rise&map_type=year&contiguous=true&elevation_model=best_available&forecast_year=2040&pathway=rcp85&percentile=p50&return_level=return_level_10&slr_model=kopp_2017).

81. The map presented in Figure 11 is based on the current elevation and does not include flood protection measures that could be proposed in the future. The second stage of the Climate Vulnerability and Adaptation Assessment Project made preliminary identification of adaptation options for Kampot.[35] The considered adaptation options included in the Southern flood protection and development project consist of, in ranked order:

- Construction of levees/floodwalls and bank protection along the banks of the Kampong Bay River opposite Fish Island (phase 3)
- New ring road / levee, riverbank and flood protection to northern part of Fish island (phase 1)
- Construction of an outer ring road further south on Fish Island and bridges to link with transport corridors to the east and west, plus additional levees/floodwalls and bank protection (phase 4)

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[33] *Muis, et al. (2016). A global reanalysis of storm surges and extreme sea levels. Nature Communications, 7(1).*
[34] Refer footnote 33.
[35] NIRAS. 2020. Climate Vulnerability and Adaptation Assessment Project.

- Construction of tide gates and pump stations downstream of the city to control incoming tides, and sea level rise (phase 5).

V. ASSESSMENT OF VULNERABILITY TO CLIMATE AND NATURAL HAZARDS

1. Identification of risk hazard zones and implications for future spatial development strategy

82. The review of vulnerability indicates that flooding is the most important hazard that will impact Kampot by 2040. Kampot is largely flooded by the river during heavy rainfall storm events. Flooding is mainly related to the river overflowing above the riverbanks and in the meanders upstream of the city. As sea level rises, the base level of the Teuk Chhou River will also rise, increasing the likelihood of flooding during high tide events. An additional hazard is a storm surge from a typhoon in the Gulf of Thailand extending up the Teuk Chhou River. Since typhoons produce heavy rainfall, storm surge will occur at the same time as river flooding and, if it coincides with a high tide will significantly increase the height and extent of flooding through the city.

83. An assessment of drought vulnerability carried out in 2008 by the NCDM rated the area around Kampot as a low priority in terms of drought. And other drought assessments have shown that communes other than Kampot City received more severe impacts.[36] There are no reports on low flows in the River due to drought but While drought will continue to impact Kampot into the future, the hazards presented to the proposed infrastructure is minimal.

84. An additional hazard is heat stress due to high air temperatures, particularly if consecutive hot days occur. Both the number of hot days and the number of consecutive hot days in a heatwave is projected to increase by 2040.[37]

2. Exposure

2.1. Current exposure

85. Exposure to heat stress is experienced across the city. However, poor households will be more likely to be impacted if they have no access to air-conditioning. The survey of specific vulnerable groups found that members of all the groups stated that hot weather had worsened health issues for members of their household. Increased heat stress will present a challenge for the city’s population and will have implications for the bioreaction speed in the design of any Wastewater or Fecal sludge Treatment Plant. However, the project sewage infrastructure will not be impacted by the increased number of hot days.

86. Drought is more likely to impact rural areas where reliance on income from agriculture is higher. However, the survey of specific vulnerable groups found that members of three of the groups stated that their income had been moderately impacted by drought. Drought could impact home gardens if there is limited access to water or if the cost of water for use in a garden is

[36] International Environment and Disaster Management (IEDM). 2005. Drought Management Considerations for Climate Change Adaptation: Focus on the Mekong Region. Oxfam Cambodia. Phnom Penh.

[37] Katzfey, J.; Jiao, X.; Suppiah, R.; Hoffmann, P.; Nguyen, K. C. & Poun, S. 2013. 'Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia', Technical report, CSIRO, Australia.

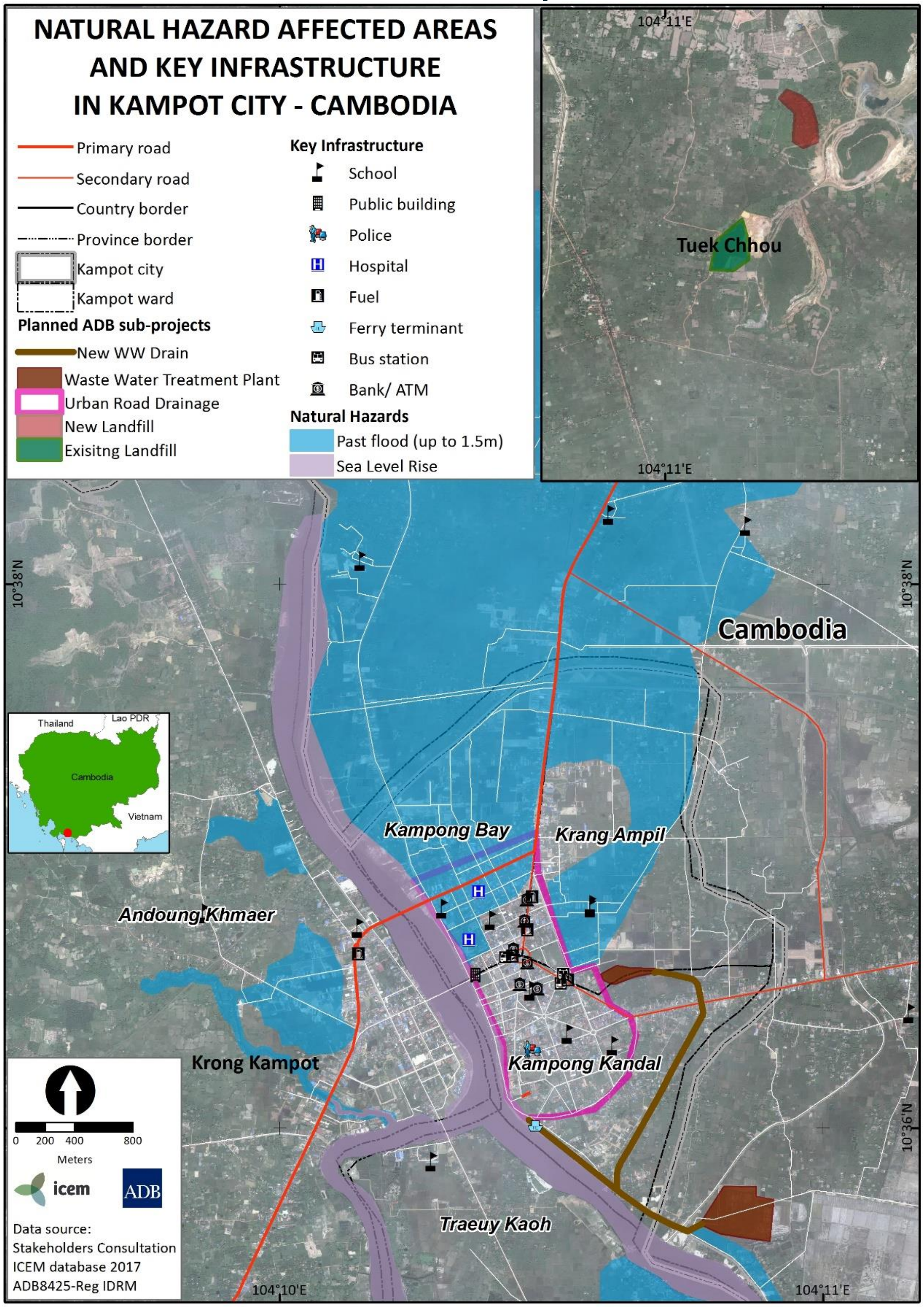
prohibitive. Drought will also put stress on water supply which will have implications for flow in sewage lines and the WWTP.

87. Through the Comprehensive City Survey, it is estimated that 47% of the population regularly experiences flooding following intense rainfall. The current extent of the recorded flooding in and around Kampot is shown in Figure 13. The European Commission's Copernicus's based maximum water coverage did not identify flooding within the urbanized center of Kampot City during the period 1984-2019. However, extensive flooding has occurred in the lower delta and on the low elevation, coastal is to the southeast of the city. A study carried out for the 'CAM8425 Second Greater Mekong Subregion Corridor Towns Development Project, Kampot and Sihanoukville', identified flooded areas from stakeholder meetings. The resultant map shown in Figure 13 indicates that much of the northern sections of the city are already susceptible to flooding.

Figure 12: Maximum Recorded Extent of Satellite Sensed Water for the period 1984-2019.

Source: Pekel, J-F., Cottam, A., Gorelick, N., Belward, A.S. 2016. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418-422 (2016). https://global-surface-water.appspot.com/download accessed 19/11/2020.

Figure 13: Flood Prone Areas in Kampot City Identified from Stakeholder Investigations carried out in 2017 by ICEM



Ministry of Public Works and Transport. 2017. Final Consultants Report; CAM8425 Second Greater Mekong Subregion Corridor Towns Development Project, Kampot and Sihanoukville. MPWT, Phomh Penh

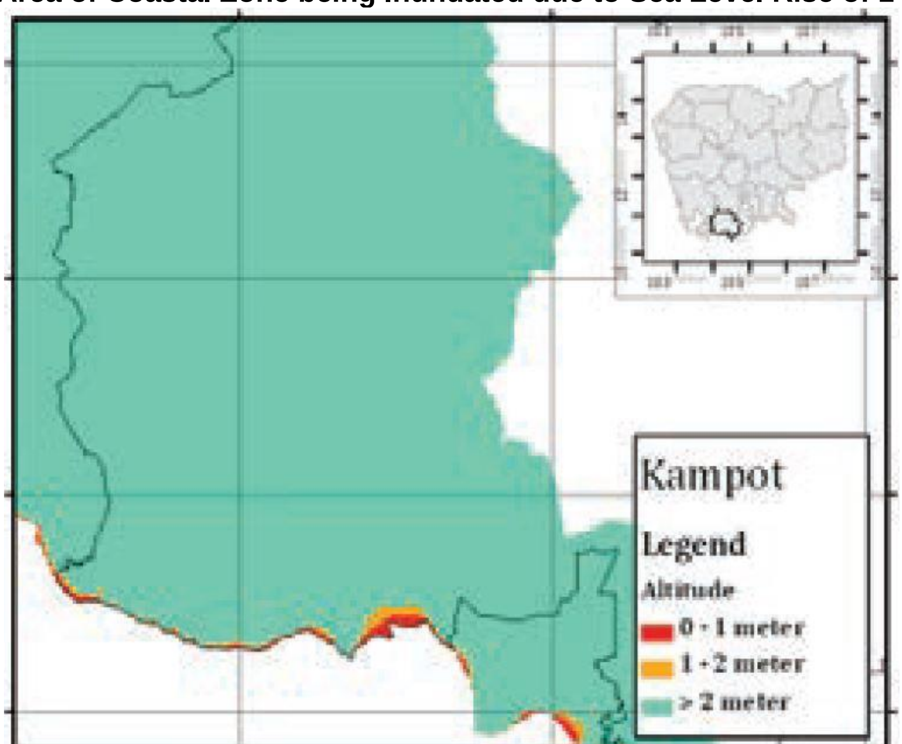
2.2. Future exposure

88. It is difficult to map the extent of future exposure to climate change hazards. There is the potential for droughts to increase, though this is not clearly indicated in climate modeling. Spatial exposure to drought will remain the same as at present. The number of hot days is projected to increase, but the exposure will remain the same unless incomes across the city are improved to the extent that air-conditioner ownership increases.

89. Exposure of Kampot to flooding is from river flooding, and the projected larger rainfall events will increase the depth and extent of the current problems if business as usual is continued.

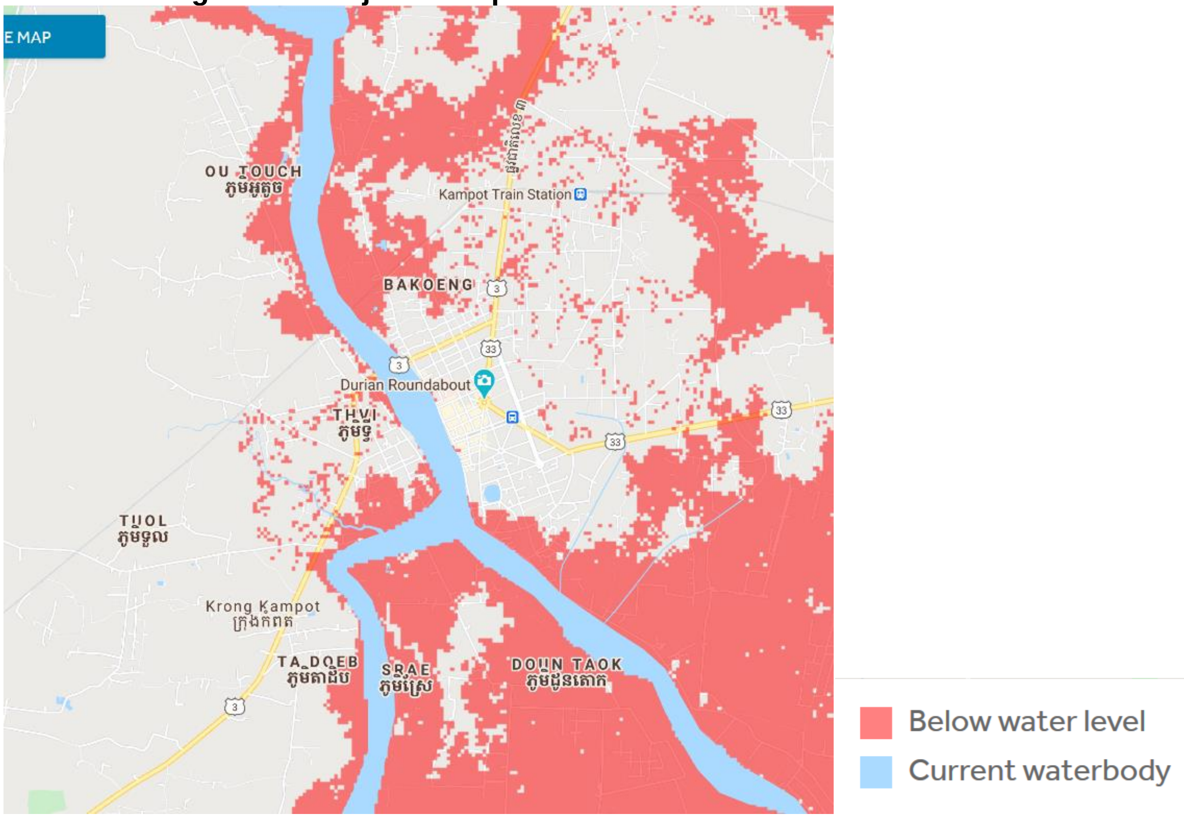
90. Exposure of coastal cities to sea level rise is explored in the Second National Communication, as shown in Figure 14. The report investigated the area of land that would be inundated under sea level rises of 1 m and 2 m. The map indicates that coastal areas to the east of the city will be severely affected, while sea level inundation will be less on the coastline to the west of the city. The city is not identified as being exposed to future sea level rises. However, mapping from the Climate Central sea-level mapping web site (Figure 15), projects that part of the city will be exposed to sea level rise under the RCP8.5 scenario.

Figure 14: Area of Coastal Zone being Inundated due to Sea Level Rise of 1 m and 2 m.



GSSD 2015. Cambodia's Second National Communication under the United Nations Framework Convention on Climate Change. General Secretariat, National Council for Sustainable Development/Ministry of Environment, Kingdom of Cambodia, Phnom Penh.

Figure 15: Projected Exposure to Sea Level for 2040 under RCP8.5



Note uses the median output from an ensemble of climate models for RCP8.5, global sea-level projections from Kopp et al. 2017 (not adjusted for local conditions).
Source climatecentral.org.
https://coastal.climatecentral.org/map/14/104.1995/10.6083/?theme=sea_level_rise&map_type=year&contiguous=true&elevation_model=best_available&forecast_year=2040&pathway=rcp85&percentile=p50&return_level=return_level_1&slr_model=kopp_2017.[38]

91. Because Kampot City is located 5 km upstream from the coast, the major impact from storm surge will be inundation rather than direct damage from storm waves. As the sea level rises the extent of the penetration of storm surge into the city will increase. Additionally, flooding that will accompany the storm will be unable to flow out the river mouth, increasing the extent of inundation across the city. The Climate Central sea-level mapping web site provides the capacity to combine sea level rise and flooding to map combined flooding. The resultant projected flooding under the RCP8.5 scenario is shown in Figure 11. The red areas (below water level) are those that would be inundated based on the current DEM and do not allow for any changes to proposed dikes or other flood protections. The map was constructed from projections of sea level rise plus the added height of a local moderate flood, defined as flood level that has a 10% annual chance of being exceeded. Two options for sea level projections are available on the web site, CMIP5 projections unadjusted for local conditions, and the revised projections of Kopp et al 2017.

[38] Kopp, R.; DeConto, R.; Bader, D.; Hay, C.; Horton, R.; Kulp, S.; Oppenheimer, M.; Pollard, D. & Strauss, B. (2017), 'Evolving understanding of Antarctic ice-sheet physics and ambiguity in probabilistic sea-level projections: Ambiguity in Sea-Level Projections', Earth's Future 5.

2.3. Identification of exposed project infrastructure

92. The numerous flood protection measures that are proposed makes it likely that, if they are funded, flooding across Kampot will be considerably reduced. For the purposes of this assessment of the adaptations needed for the installation of sewage pipes, the business-as-usual scenario is based on estimates of the combined flooding and sea level rise without flood mitigation projects. Based on the potential for increased flood depth across the city due to the combination of sea-level rise, storm surge, and larger rainfall events, a larger part of the proposed network will be exposed to flooding by 2040. The amount exposed is shown in Table 12.

Table 12: Infrastructure Exposed to Flooding

Infrastructure Component	Total	flood spots reported from the field	Sea level rise study
Gravity wastewater lines	7,500 m	337 m	3,910 m

Source: Egis, 2021

2.4. Sensitivity assessment

93. Sensitivity is the degree to which a system is directly or indirectly affected by a particular climate stimulus, such as changes in seasonal temperature or precipitation. An analysis of various sensitivity indicators of the exposed elements will give an indication of the degree of impact (the higher the sensitivity of the system, the higher the expected impacts). In the absence of quantitative information to measure direct or indirect damages, the degree of impact may be assessed qualitatively.

2.5. Sensitivity to flooding

94. The socio-economic condition of Kampot contributes to the sensitivity of the community to climate change impact. Some areas of the city are flooded locally due to a defect in the stormwater drainage system, but the main source of flooding is river flooding. Flooding of parts of the city is not uncommon in Kampot so the community is relatively resilient and has developed mechanisms to endure and recover from floods. However, some parts of the city are more prone to flooding and as the exposure to floods increases across the city there will be some areas that experience more frequent or deeper flooding under the business-as-usual scenario.

95. Project infrastructure such as pipes that cross drains will be sensitive to inundation and damage due to moving floodwater.

2.6. Sensitivity to drought

96. Risks and uncertainties that are often associated with the pronounced contrast between the wet and dry season are embedded in the practice of agriculture, and there is considerable experience of coping and risk management strategies among Cambodian people working in this sector. However, in the face of climate change, the magnitude and frequency of stresses and

shocks are changing and, therefore, the sensitivity of farmers to drought is increasing.[39] The perception in the community is that droughts do have an impact through reduced income from crops or agricultural businesses. Drought will also put stress on water supply which will have implications for flow in sewage lines and the WWTP. The proposed production and consumption projections already incorporate climate change assumptions.

97. While drought will continue to impact the community of Kampot into the future, the sensitivity of the proposed infrastructure to drought is minimal.

2.7. Sensitivity to Extreme Heat Events

98. Extreme heat events will have increasing impacts on the community of Kampot into the future. However, the sensitivity of the proposed infrastructure to 10 hot days per year is minimal.

3. Adaptive capacity assessment

99. Current vulnerability is a result of past adaptation to climatic variability; thus, potential vulnerability is a function of current vulnerability and current adaptive capacity. The challenges in operationalizing the country's policy and strategic directions (outlined in Section III.2), into tangible outcomes at the municipal and commune level means that at the local level, adaptive capacity is often limited.

100. The Climate Vulnerability and Adaptation Assessment concluded that the skills in the municipality and the provincial departments are inadequate when it comes to planning, implementing and managing climate change adaptation measures, so improved resourcing for sustainable city/town level master planning is highly needed. Also, very limited support is available within the urban planning sector for engineering climate change adaptive design consultancy services.[40]

101. Six (6) factors were used to assess the capacity of the Kampot municipal officials to efficiently reduce some of the impacts of climate change. These are: 1.) economic wealth; 2.) technology; 3.) Institutional; 4.) Infrastructure; 5.) information; and 6.) social capital. For each of the six factors, the capacity of the municipal officials was assessed against the criteria presented in an "Ability of the Local Government Unit to Deal with the Impact of Hazards" table (see appendix 3). The results of the assessment presented in Table 13 indicate that because of past experience with flooding, the Kampot municipality has a medium-high capacity to respond to extreme events. As a result, Kampot has the capacity to respond to any impacts to infrastructure that result from flood events. However, there appears to be a limited understanding of the potential increase in

[39] Phaloeun, C., Kimngoy, C. and Bopreang, K. 2015. Drought Conditions and Management Strategies in Cambodia. Chapter 4 National Reports; Cambodia. In Tsegai, D. and Ardakanian, R. (Eds). 2015. Proceedings of the Regional Workshop on Capacity Development to Support National Drought Management Policies for Asia-Pacific Countries, 6-9 May 2014, Hanoi, VietNam. UN-Water Decade Programme on Capacity Development (UNW-DPC). Geneva, Switzerland.

[40] MPWT. 2019. Climate Vulnerability and Adaptation Assessment Project - Final Report, Volume 1. Egis.

the extent of flooding across the city due to climate change. The full description of the adaptative capacity factors is presented in Appendix 1.

Table 13: Assessment of Adaptive Capacity of Kampot City Officials.

Adaptive Capacity Factor	Capacity Assessment	Description
Economic Wealth	Medium (3)	Enough financial resources for assistance to some affected sectors Most people in the area have access to resources to respond Some reliance on international aid for flood recovery Limited understanding of Climate Change impacts
Technology	Medium (3)	There is some equipment available for use and facilities to communicate directly with the people/sector affected Not adequate for extreme events Some limitations due to technical capacity
Institutional	Medium (3)	Municipal officers and community leaders are well-aware of hazards and can respond in the event of an occurrence Relevant processes, procedures and legislations are passed at the National level and there are existing processes and regulations to control the situation at the local level but implementing relevant legislation could be improved Limited capacity to adapt to projected future changes
Infrastructure	Medium (3)	There are some infrastructure, transport facilities and necessary equipment that can be used to respond to a hazard but not enough to accommodate the projected impact Facilities and equipment are available but not enough Flood mitigation and early warning infrastructure is inadequate
Information	Medium-High (4)	Municipal Officials and stakeholders are well-aware of the hazard Communication strategies are in place, and there is an early warning system but it needs improvement
Social Capital	Medium-High (4)	There is political willingness to allocate resources to build adaptive capacity of the Municipal officers There are specific agencies, community groups and NGOs with the mandate and skills to focus on the specific sector/area during the occurrence of hazards There are trained emergency response teams for this sector/ area There is limited understanding or knowledge to deal with climate change impacts

4. Risk assessment

102. The purpose of risk assessment, in the context of climate change, is to identify risks that may be induced or exacerbated by climate change and to evaluate their effects and likelihood. This procedure also allows the climate change risks and subsequent adaptive responses to be prioritized with confidence and compared equitably with other risks, resource availability and cost issues (including works) that the local authority faces. The major climate change risk to infrastructure in Kampot is flooding as a result of the combination of sea-level rise, storm surge and increased rainfall during extreme events so the risk assessment is carried out for flooding. The assessment of risk is carried out in a three-step process:

Step 1: Assess the likelihood of hazard scenario
Step 2: Assess the consequence of hazard occurring
Step 3: Evaluate the risk

4.1. Likelihood of hazard scenario

103. For each time step in the planning horizon, the likelihood (or probability) of flooding impacting project infrastructure is assessed. Assessment is based on the current likelihood and the projected climate change. A scale of 1-6 was used, with L1 = Rare and L6 = Certain, based on the Table of Likelihood Descriptors presented in Appendix 2. The calculated likelihood of impacts from flooding hazards for each element of infrastructure is presented in Table 14.

4.1. Consequences of the hazard occurring

104. In this step, the level of the impact (consequence) on the land, built environment and people for the flooding hazard is assessed. The assessment presented in Table 14, is formed from a combination of inputs; the adaptive capacity assessment, the GIS analysis is showing the number of km or the number of components that are exposed, and the sensitivity analysis. The consequences are categorized using the Descriptors of Consequence Table presented in Appendix 3, with C1 = Negligible and C6 = Extreme.

Table 14: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Wastewater Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Gravity lines (7.5 km)	Erosion by moving floodwaters Undercutting or damage of canal crossings	L4 Likely	C2 Minor	Pipes are installed underground No major crossings

4.2. Evaluation of risk

105. The results from the analysis of the likelihood and consequence are used to calculate the risk of each hazard scenario. Risk (R) is calculated as a function of the likelihood of a hazard impacting an infrastructure element, a community, or an ecosystem (L) and the consequences of that impact, (C).

$$R = L * C$$

106. Verbal descriptors can be applied to the calculated risk of each hazard scenario using Table 15. This makes it easier to quickly compare the impacts of climate change on each project component. For example, an activity that is likely to occur (4) but only has moderate (3) consequence has a risk of Moderate. It should be included in planning but given lower priority.

Table 15: Verbal Descriptors of Calculated Climate Change Risks.

		Consequence					
		C1	C2	C3	C4	C5	C6
Likelihood	L1	Low	Low	Low	Low	Low	Low
	L2	Low	Low	Low	Moderate	Moderate	Moderate
	L3	Low	Low	Moderate	Moderate	Moderate	High
	L4	Low	Moderate	Moderate	High	High	High
	L5	Low	Moderate	Moderate	High	High	Extreme
	L6	Low	Moderate	High	High	Extreme	Extreme

107. The assessed likelihood and consequences of impacts of increased flooding due to the projected climate change for each of the elements of the project components presented above are used to calculate the risks shown in Table 16.

Table 16: Calculated Risk from Flooding Hazard for the Infrastructure Element of The Project Components.

	Risk Calculation		
Infrastructure Elements	**Likelihood**	**Consequence**	**Risk**
Gravity lines (7.5 km)	L4 Likely	C2 Minor	8 Moderate

108. The calculated risk for project components is rated as moderate.

109. The risk from inundation during flood events is moderate (8). This risk is due to the potential for erosion from moving floodwaters to damage the gravity and pressure lines, particularly where they pass over drainage lines.

VI. ADAPTATION

1. Contribution of project components to adaptation

110. By assisting the Kampot municipality to develop climate change sensitive planning, the project has been designed to decrease the vulnerability of Kampot to the impacts of Climate Change, to improve the resilience of the community, and to improve the adaptive capacity of the Municipal Officials and the community.

111. The provision of properly treated wastewater will decrease the vulnerability of the city by decreasing the number of households exposed to wastewater during flooding events. It will also increase the resilience of the population by improving the ability of households to recover from floods by reducing the impact of diseases from floodwaters on the community and the health system.

112. The project also contributes to Cambodia's international commitments, as outlined in Table 17. Cambodia is a signatory to the Paris Agreement, and the project contributes to climate change commitments by supporting Priority Outcomes of the Cambodia Climate Change Strategic Plan 2014 – 2023. Project components also contribute to international Sendai Framework Disaster Risk Reduction commitments by supporting Priority Area Objectives of the National Disaster Risk Reduction and Management Plan 2011-2028. Additionally, the project contributes to Cambodia's international commitments to achieving the United Nations Sustainable Development Goals by supporting Strategic Goals of Cambodia's Rectangular Strategy for Growth, Employment, Equity and Efficiency: Building the Foundation Toward Realizing the Cambodia Vision 2050 Phase IV.

Table 17: Contribution of Project Components to International Commitments

Infrastructure Component	Cambodia Climate Change Strategic Plan 2014 – 2023 Priority Outcomes/Outputs	Strategic National Action Plan for Disaster Risk Reduction 2008 ~ 2013 Priority Area Objectives	Rectangular Strategy - Phase 4 Strategic Goals
Master Plans	• Urban infrastructure planning and development of climate proofed.	• Hazard risk information is used in land-use planning and zoning programs to prioritize adaptation measures. • Hazard risk information used in building design.	• Climate-resilient infrastructure master plan for urban areas supports clean water network master plan. • Climate-resilient technologies Incorporated into ecosystem management and socio-economic development.
Wastewater	• Wastewater management climate-proofed through integrated measures. • Climate resilience promoted	• Hazard information is used in the installation and access to sanitation facilities.	• Climate-resilient infrastructure master plan for clean water network developed and implemented.

Infrastructure Component	Cambodia Climate Change Strategic Plan 2014 – 2023 Priority Outcomes/Outputs	Strategic National Action Plan for Disaster Risk Reduction 2008 ~ 2013 Priority Area Objectives	Rectangular Strategy - Phase 4 Strategic Goals
			• Wastewater management strengthened using climate-friendly technologies.

2. Proposed adaptation measures to cope with climate change impacts

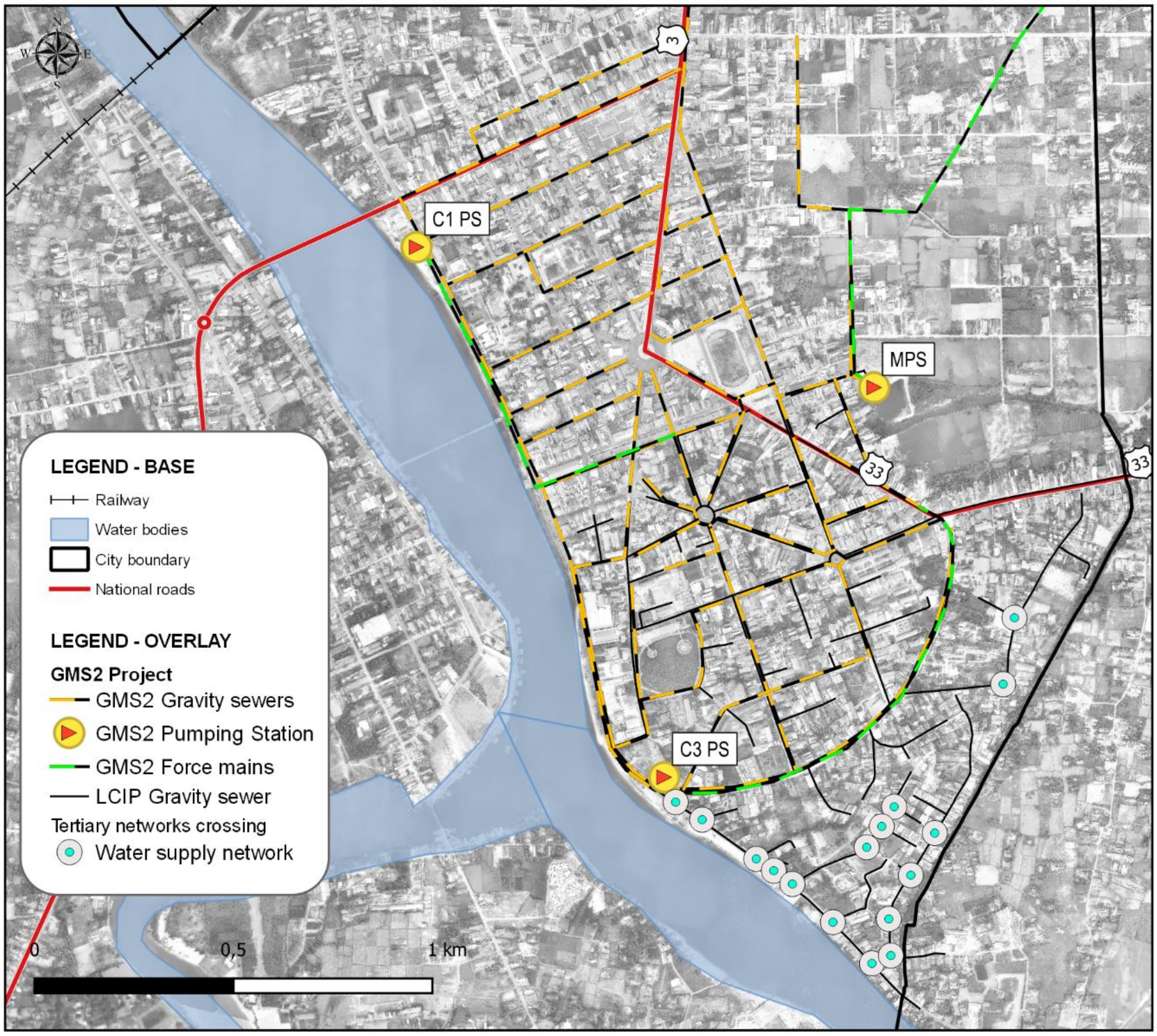
113. The largest risks identified in the risk assessment are related to the potential for increased flooding due to the projected increase in extreme rainfall events combined with sea-level rise and further compounded by storm surge. Therefore, adaptation measures are related to strategies to decrease the impacts of flooding. The major adaptation is a reappraisal of the extent of the City that will be exposed to flooding. Infrastructure design will assume that the entire City could potentially be impacted by floods. The adaptation options for specific infrastructure components are developed below.

114. The short-term components of the wastewater infrastructure are focused on urban areas. The pipes will be laid along road corridors, and protection from flooding will be provided by impervious surfaces such as the road and pavement surfaces.

115. Where pipelines cross other infrastructure, they may require protection from floods when drains are overtopped during extreme flood events. The protection of pipelines from higher flood levels will be carried out as part of the design of the crossings, and all crossings will be considered to be exposed to flooding.

116. A map of the third-party network crossing location is given below. The crossing with pressure lines (i.e. water supply network) does not present technical implementation difficulties. The lines can be crossed at different depths. The water supply network depth is unknown. The points on the map below have not to be seen as network incompatibility points but as an indication of feasible crossings.

Figure 16: Third-party network crossing points



Source: Egis, 2021

117. An education campaign backed up by legislation will be used to improve onsite management of existing septic tanks and improve the protection of tanks from localized flooding during higher rainfall events.

3. Assessment of maladaptation risks associated with proposed adaptation measures

118.2 Maladaptation refers to situations where climate funding or development funding may support initiatives that would negatively affect exposure and/or the sensitivity of society and ecosystems to climate-related stressors. It is driven by neglect of either the future impacts of climate change or the main drivers of the system’s vulnerability. Maladaptation to climate change is a relatively recent consideration in development and there are a number of ways to measure maladaptation. It should be noted that maladaptation is relative, as the balance of the positive

and negative effects of the initiative itself must be compared to the effects of other broader scale national and local adaptation and mitigation initiatives.

119. One important form of maladaptation is committing the MA to expensive solutions that do not adequately confer resilience to the community. One potential cause of this type of maladaptation is where the proposed adaptations are insufficient for the projected climate change impacts, requiring expensive retrofits of larger or more suitable infrastructure. In order to reduce the likelihood of this, it is advisable to adequately cater to impacts within the likely range of projected climate change. However, as this project is made up of short-, medium- and long-term phases, there is the capacity to re-assess the performance of infrastructure and make adjustments for later phases. By designing infrastructure to cater to the most likely projected climate change for the near or medium term, and reassessing the success of flood management projects, the suitability of infrastructure protections for the long term can be determined.

120. The same maladaptation of committing the MA to expensive inadequate infrastructure can be caused by committing to the installation of oversized infrastructure that results in higher construction and maintenance costs. The staged approach with reassessment means that there is no need to commit to the largest sized infrastructure protection measures possible. During the review phase, adjustments to the design can be made to respond to any climate trends and to new understanding of projected climate changes based on the most recent climate change science that is available at the time.

121. Another potential maladaptation is that a project it may commit capital and institutions to trajectories that are difficult to change in the future. However, by connecting to the existing WWTP and network, the provision of comprehensive sewage to the community as part of a phased installation of wastewater removal and treatment increases the resilience of the City and has a positive CO_2 balance.

4. Climate change adaptation costs

122. The cost of climate proofing the project components are presented in Table 18. The design of the network includes protection at crossing points and this cost is included in the total cost estimate.

123. While the planning and provision of adequate wastewater service should be part of any city's infrastructure, the provision of a climate proof wastewater treatment master plan and associated pipe works will decrease the sensitivity of Kampot City to climate change by improving the ability of households to recover from flood event and decreasing the number of households exposed to wastewater when flooding occurs. As shown in section VI.1 above, the project contributes to Cambodia's international commitments and supports Priority Outcomes of the Cambodia Climate Change Strategic Plan 2014 – 2023. Therefore, a proportion of the costs of the whole project can be considered to be a climate change adaptation, which is calculated as 30% of the total cost which is $1,225,051.

Table 18: Proposed Adaptation Measures and Costs for Each Project Component

Infrastructure Component	Proposed Adaptation Measures	Target Climate Risk	Estimated Adaptation Costs ($)
Network	No extra costs as the design provide adequate protection	Increased exposure of infrastructure at crossings	-
	Provision of properly treated wastewater	Exposure of households to wastewater during Flood events	30% of total cost $1,225,051

5. Prioritization of measures

124. The present socio-economic condition of the city increases the community's sensitivity to hazards. And while the National Government has made steps to develop policies and infrastructure to manage climate change hazards and disaster risks (section III.2), there are still issues with implementation and technical capacity at the subnational level. However, based on the risk assessment (section VI.5), climate-induced hazards are expected to have moderate impacts on the project infrastructure. Additionally, the project is designed to increase the resilience of the city to climate change and disasters. Therefore, all infrastructure is expected to be potentially exposed to flooding and all of the necessary adaptions are incorporated into the design.

VII. MITIGATION

125. Mitigation measures are actions that are taken to slow the process of global climate change by lowering greenhouse gas emissions or enhancing the “sinks” that accumulate and store these gases (such as the oceans, forests, and soil).

1. Contribution of project components to climate change

126. The project will contribute to CO_2 emissions as infrastructure materials are made, transported, and installed. The increased connection of the community to the network and professionally managed treatment of wastewater will contribute to reducing emissions of N_2O and CH_4. Any reduction in the use of septic tanks as a result of connection to mains will also result in a reduction in emissions, e.g., no GHGs emitted during transport to empty tanks and more efficient sewage treatment process resulting in less GHG emissions.

127. Additionally, the cost of the emissions is offset by the contributions of the project towards international commitments; Sustainable Development Goals through the Rectangular Strategy - Phase 4 Strategic Goals, to Paris Agreement, targets through the Cambodia Climate Change Strategic Plan 2014 - 2023 Priority Outcomes, and to the Sendai Framework commitments through the Strategic National Action Plan for Disaster Risk Reduction 2008 – 2013 Priority Area Objectives.

128. The Cambodian Government has a number of national strategies to reduce greenhouse gas emissions, and where possible these will be incorporated into the project. The CCCSP has a strategic objective to promote low-carbon planning and technologies to support sustainable development. This includes the use of more sustainable urban transport options and tree planting in public spaces.[41] However, there are no specific mitigations that can be costed.

[41] Ministry of Environment. 2016. Climate Change Action Plan 2016-2018. Phnom Penh.

APPENDICES

Appendix 1. Adaptive Capacity Assessment Table

The capacity of the local government and the local community to adapt to each hazard is assessed using the following table:

Factor	Adaptive Capacity Level/Score				
	High (5)	**Medium High (4)**	**Medium (3)**	**Medium Low (2)**	**Low (1)**
Economic Wealth	▪ Have adequate and available financial resources for assistance to all affected sector ▪ The people in the affected areas have their own resources to respond to a hazard	▪ Have enough financial resources for assistance to some affected sectors ▪ The people in the area have access to resources to respond to a hazard	▪ With limited financial resources for assistance for priority affected sectors ▪ The people in the area have limited access to resources to respond to a hazard	▪ Have limited financial resources for assistance to affected sectors ▪ Affected people have very limited access to resources to respond to a hazard	▪ No available financial resources for assistance to the affected sector ▪ Affected people don't have their own resources to respond to a hazard
Technology	▪ There is equipment available for use and facilities to communicate directly with the people/sector affected	▪ There are some equipment available for use and facilities to communicate directly with the people/sector affected	▪ Limited equipment and facilities for assistance and communication	▪ Very limited equipment and facilities for assistance	▪ Very few equipments and facilities for use and communication with affected people/sector is difficult
Institutional	▪ LGU and community leaders are aware and could effectively manage a quick response in the event of a hazard occurrence ▪ There are existing processes and regulations to control the situation ▪ Relevant legislations are in place to respond to a certain hazard	▪ LGU and community leaders are aware and can respond in the event of a hazardous occurrence ▪ There are processes and regulations but not yet fully implemented nor tested	▪ LGU and community leaders are aware but management set-up to respond to a hazard is non-existent. ▪ Relevant processes, procedures, and legislations are passed but implementing guidelines still have to be formulated	▪ Few LGU officials and leaders are aware of the roles and functions during but a quick response team to quickly respond during an occurrence of a hazard is yet to be formed ▪ Draft process, procedures, and relevant legislations still has to be passed	▪ LGU officials are not fully aware of a hazard or disaster that may occur ▪ There are no definite processes and regulations to control the situation and respond to a certain hazard.
Infrastructure	▪ There is more than adequate transport, water infrastructure,	▪ There is enough transport, water infrastructure, energy	▪ There are some infrastructure, transport facilities and necessary	▪ Infrastructures are available, but there are no facilities that	▪ Necessary infrastructures and facilities necessary to

Factor	Adaptive Capacity Level/Score				
	High (5)	**Medium High (4)**	**Medium (3)**	**Medium Low (2)**	**Low (1)**
	sanitation, energy supply and management and medical services that can be used to respond to a hazard ▪ These facilities and infrastructures are strong enough to withstand a projected hazard and located in safe areas	supply and medical service, etc. that can be used to respond to a hazard ▪ Facilities and equipment are available but not enough	equipment that can be used to respond to a hazard but not enough to accommodate a projected impact of a hazard ▪ Infrastructure and facilities still have to be retrofitted to ensure its safety and strength during a hazard	can be used to respond to a hazard ▪ Transport services in some possibly affected areas are not available	respond to a hazard still has to be constructed ▪ Existing infrastructures and facilities are not within the standard to withstand a projected impact of a hazard
Information	▪ LGU and stakeholders in the area/sector are well aware of the hazard and its potential impact on them ▪ Communication facilities and procedures are in place to respond in the occurrence of a hazard ▪ Early warning system in place and drills have been conducted	▪ LGU and some stakeholders are aware of the hazard and its potential impact on them ▪ There is an early warning system in place	▪ Some degree of awareness of LGU and stakeholders ▪ Communication facilities are in place, but procedures are not yet in place ▪ Draft early warning system available	▪ Limited awareness of LGUs and stakeholders due to lack of IEC program	▪ LGU officials and affected communities are not yet fully aware of the hazards and their potential impact ▪ No early warning system yet
Social Capital	▪ There is political willingness to allocate resources to build adaptive capacity of the LGU ▪ There are specific agencies, community groups and/or NGOs that have the mandate and skills to focus on the specific	▪ There is some degree of willingness of the leaders to allocate funds to build the adaptive capacity of the LGU ▪ Some agencies are and NGOs are available and have skills to assist specific	▪ LGU have political willingness but still has to be convinced to allocate resources to build adaptive capacity of LGUs ▪ There are specific agencies and NGOs with a mandate to assist affected	▪ LGU officials still have to be convinced to allocate resources to build the adaptive capacity of LGUs ▪ There are a limited number of agencies and NGOs with mandate and skills to assists the	▪ LGU officials still have to be oriented on adaptive capacity building ▪ Specific agencies still have to have a clear mandate and plans to assist affected communities

Factor	Adaptive Capacity Level/Score				
	High (5)	Medium High (4)	Medium (3)	Medium Low (2)	Low (1)
	sector/area during the occurrence of hazards ▪ There are trained emergency response teams for this sector/ area	sectors during the occurrence of hazard ▪ There is a team with basic skills for emergency response	communities but still lack skills to respond ▪ The team have been organized for emergency response	occurrence of hazards ▪ Team for emergency response still to be organized	▪ No NGOs with mandate and skills to help the specific sector in times of climate hazards ▪ No policies or orders yet for the creation of the team for emergency response

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Appendix 2. Table of Likelihood Descriptors

Category	Description	Expectance	Recurrence Interval	Probability
L6	Certain	Expected to occur in most circumstances.	Expected to occur several times per year.	Has a greater than 90% chance of occurring in a year.
L5	Very Likely	Will probably occur in most circumstances.	Will probably occur about once per year.	Has a 60–90% chance of occurring in a year.
L4	Likely	Will probably occur at some time	Will probably arise once in 5 years	Has a 40–60% chance of occurring in 5 years.
L3	Possible	May occur at some time.	May arise once in 10 years	Has a 20–40% chance of occurring in 10 years.
L2	Unlikely	May occur at some time but is considered unlikely.	May arise once in 10 to 20 years.	Has a 10–20% chance of occurring in the future.
L1	Rare	Could occur in exceptional circumstances.	Unlikely during the next 20 years.	Could occur in exceptional circumstances (i.e. less than 10% chance of occurring by 2040).

Appendix 3. Descriptors of Consequence Table

1. In the second step of the risk calculation, the level of the impact (consequence) on the land, built environment and people for each hazard scenario is assessed. The assessment is formed from a combination of inputs; the GIS analysis showing the number of km or the number of components that are exposed, the estimate of the degree of impact, the sensitivity analysis, and the adaptive capacity assessment. The assessment is informed by questions such as:

a) Is the effect of the hazard a brief inconvenience (e.g., road flooding) or high cost (e.g., flooding of many houses, or several days inundation)?
b) Are assets easily relocatable (e.g., concrete slab-on-ground houses, is there access to alternative sites).
c) Are there particular environmental issues to be considered (e.g., undermining of septic tanks or erosion or waterlogging of effluent disposal fields, causing water pollution)?
d) Are there particular social issues that need to be considered (e.g., housing occupied by people who have limited ability to recover from financial losses, or cultural ties and rights to an area)?
e) Is the effect of the hazard continuous (e.g., coastal erosion) or intermittent (e.g., flooding)?

The consequences are then categorized using the Descriptors of Consequence Table presented below.

Consequence	Category	Description
C6	Extreme	Major irreversible impact requiring complete replacement.
C5	Major	Significant impact, long term, requiring substantial repair/replacement of long sections/whole components.
C4	Severe	Strong impacts, requiring substantial repair/replacement of some sections/components.
C3	Moderate	Low-Medium impacts, requiring repairs to some whole sections/components of infrastructure.
C2	Minor	Low impact, localized repairs to short sections/components
C1	Negligible	Insignificant impact, minor repairs to small sections