Climate Risk and Vulnerability Assessment

Project Number: 53199-001
October 2021

Cambodia: Livable Cities Investment Project
Poipet

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 Sub-region Corridor Towns Development Project Phase 1. (Currently under implementation).
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 concentration pathway	–	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 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-wet 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 ground water 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 South East 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. 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 Poipet for implementation in the Short-Term (2020-2025) includes

(i) Wastewater: (a) Wastewater treatment plant for the initially connected population, with some provision for extensions for the longer term; (b) pumping stations to create a transfer chain to the WWTP when areas to be serviced requires, and gravity flows cannot be achieved because of distance and topography, and; (c) the construction of sewer pipes designed primarily for the selected existing built-up areas with some capacity for extensions for future growth.

(ii) Stormwater: Extension of the street drainage to cover all of the existing built-up areas near the border and integrating coverage with the GMS1[1] drainage construction. This will include approximately 41 km of primary drainage.

(iii) Solid Waste Management: (a) Improvement of the existing door-to-door collection system in the urban area; (b) Centralized collection points in rural Sangkat; (c) Conversion of the current dumpsite into a transfer station; (d) New landfill site; (e) Pre-sorting plant and a composting plant, and: (f) Training on O&M contract management, landfilling / Composting / pre-sorting technical management.

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:

(i) Wastewater: (a) Staged extension of the network, gravity sewers, pumping stations, and force mains to follow the urban expansion: (b) Improvements to the provision of household plumbing and on-site containment and treatment in Rural Areas

(ii) Storm Water: Extend the primary drainage network to serve built-up areas to the north, some connected to the GMS 1 drainage, and some directed to the west border river, and a major new drainage channel approximately 20 to 25km long flowing south towards the river.

(iii) Solid Waste Management: Extensions to the landfill and composting sites.

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

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 5 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.

14. Poipet is located on the western border of Banteay Meanchey province on the western border with Thailand. The City is sited on the flood plain of the Ou Chhrov River that flows from Thailand and drains into Tonle Sap. The region consists generally of the typical plain wet area of central Cambodia, with rice fields and other agricultural plantations. Agricultural land use represents the biggest portion of the city.

15. Mean average temperatures range from 25° to 30°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 Poipet projected to increase by 0.7 °C by 2030, by 1.5 °C by 2050 and by 3.8°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 Poipet is projected to change from 25-30 to over 50 days per year by 2050 and the number of consecutive hot days will increase from <5 to over 25.

17. 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 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.

18. When there are heavy rains in the central part of the country, runoff floods areas along smaller rivers and parts of the provinces around the Tonle Sap Lake. Banteay Meanchey Province is basically upstream of Tonle Sap and can flood over large areas due to the flat terrain. However,

reports of the severity of flooding in the area around Poipet indicate that widespread river flooding is not a large problem within the city. The major cause of flooding in Poipet is thought to be due to inadequate drainage that is unable to deal with intense rainfall events exacerbated by obstruction of flows due to poor road design or other anthropogenic activities and interventions. The exposure of Poipet to flood hazard is limited to areas where to superposition of these factors occurs.

19. The flat terrain of Poipet means that when designing storm water infrastructure, it is difficult to produce enough fall to generate flow in the drains so any increase in the design event size results in extreme increases in the required cross sectional area. Therefore, selection of a large increase in extreme rainfall event size just in case to allow for climate change, risks maladaptation by committing the municipal administration (MA) to large expensive infrastructure and added costs for relocation. The phased nature of the project means that short term and near term infrastructure planned to be installed in phase 1-2 can be designed to cope with projected climate change in the near term. The long term phase (2030-2040) of the project incorporates revision of the performance of phase 1-2 infrastructure, revision of urban growth and development and importantly revision of any evident trends in rainfall and a reassessment of climate change projections based on the most recent scientific understanding.

20. Modeling studies project that extreme rainfall in 1-day events will increase by 5 – 6 mm (5 - 6%). Therefor a value of 5% is used for the projected increase in extreme rainfall event size due to climate change. Sensitivity analysis carried out during the design of the drainage for Poipet indicated that to cater to an increase in rainfall of 5% would require drains to be 10% larger, with an ever-increasing size needed for higher design rainfalls. Using the median projected increase due to climate change means that it is still economically feasible to develop a climate change proof design based on a 1 in 5 year event. These design parameters result in infrastructure that fits within the envelope of the available space provided by the road reserve and along the existing canal negates the need for households to be relocated and minimized impacts on primary structures.

21. Droughts caused by failure of the monsoon rains are common across Cambodia and extended periods are a large concern. Delays in the onset of monsoon rainfall have significant negative impacts on rice production for subsistence farmers. El Niño events with higher-than-average temperatures and reduced monsoon rains starting later in the season 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. Banteay Meanchey Province is vulnerable to drought and the average duration of droughts in is 5.5 - 6 months. An assessment of drought carried out in 2003 by the National Committee for Disaster Management (NCDM) rated the area immediately around Poipet as a low priority in terms of drought. It is projected that there will be no change in the average duration of droughts and a small decrease in the frequency of short 3-month long droughts.

22. 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 quarter

of participants had experienced flooding in the last 10years that they attributed to inadequate drainage, three quarters thought that flooding had gotten worse in this time, all 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, thought there were more extremely hot days and more consecutive hot days compared to 20 years ago and that hot weather had worsened health issues for members of their household.

23. The review of risks indicates that localized flooding is the most important hazard that will impact Poipet by 2040. Drought will continue to impact Banteay Meanchey into the future, but the hazards presented to project infrastructure are minimal. Heat stress due to high air temperatures may become an additional hazard, particularly if consecutive hot days occur.

24. In regard to future exposure to climate change hazards: exposure to drought will remain the same as at present, exposure to heat stress will remain the same unless incomes across the city are improved to the extent that air-conditioner ownership increases and exposure to flooding is from localized flooding due to problems with drainage and the current extent of the problems are not mapped. Larger rainfall events may increase the depth and extent of the current problems if business as usual is continued.

25. The capacity of the Poipet municipality to deal with the impacts of extreme events was assessed as medium to medium low and any impacts to infrastructure that result from flood events will be exacerbated by a limited capacity to respond to the impacts.

26. 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 generally rated as Low or Moderate.

27. The largest risks identified in the risk assessment are related to the potential for increased localized flooding due to the projected increase in extreme rainfall events of 5%. Therefore, adaptation measures are related to strategies to decrease these impacts. The major adaptation is a reappraisal of the projected extreme rainfall size used in the design of the drainage infrastructure.

28. Each component of the project contributes to improving the capacity of Poipet to adapt to climate change. Properly treated wastewater, a functioning drainage system and efficient waste management will increase the resilience of the population by improving health and wellbeing, improving the ability of the community to recover from typhoons and other disasters, and will minimize health risks during localized flooding events. Therefore, a proportion of the costs of the installation of the infrastructure are considered to be climate change adaptation. Some components of the project will require specific adaptations to make each element climate change resilient. The proposed adaptation measures and the associated costs are summarized in the Table below.

29. The larger extreme event size means that localized flooding will continue to occur and will increase in extent in areas not serviced by drainage lines. Therefore the wastewater treatment plant will require an onsite rainwater management plan designed for extreme rainfall 5% above current events.

30. Similarly, the landfill site will also require flood water management designed to manage rainfall events 5% higher than at present.

31. The overall cost of climate change adaptations for the project is calculated as $18.07 million.

Table 1: Summary Adaptation Costs

Infrastructure Component	Calculated Risk	Proposed Adaptation Measures	Estimated Adaptation Costs ($)
Wastewater WWTP	8 Moderate	Increase capacity of stormwater management system Increased drainage capacity	5% increase in size of stormwater lagoon: $2,441 2% increase in CAPEX for drainage $1,000
		30% of remaining total construction cost (less mitigation costs)	$11,900,250
Stormwater Box Culverts	8 Moderate	Increase size of drainage network	2% increase in CAPEX $345,384
		30% of remaining total construction cost	$4,929,980
Solid Waste Landfill	8 Moderate	Increase capacity of stormwater management system	2% increase in CAPEX for drainage $1,000
		30% of remaining total construction cost (less mitigation costs)	$887,570

32. The waste management project components, including composting of organic waste; controlled wastewater treatment; GHG capture; recycling and waste minimization are greenhouse gas emission reduction strategies. In particular emissions of the more potent greenhouse gases Methane (CH_4) and Nitrous oxide (N_2O) from anaerobic decomposition will be captured and converted to CO_2. It is expected to cost $2,375,076 to develop a composting plant and $198,535 to install a landfill gas (LFG) collection system and a gas flare unit. Additionally, emissions of CO_2 and pollutants from burning rubbish will also be reduced.

33. The proposed installation of solar PV systems at the wastewater treatment plant and at the solid waste management site will contribute to climate change mitigation and will provide an important demonstration of the use of renewable energy. It is expected to cost $362,500 to install

solar panels at the two sites. Additionally, greening of the tourist areas and in other areas where appropriate, provides mitigation through CO_2 sequestration.

Infrastructure Component	Proposed Mitigation Measures	Estimated avoided GHG Emissions	Estimated Mitigation Costs (US)
Wastewater	Use of solar power thru PV modules	46,035 kg CO_2e/yr	$148,500
Solid Waste	LFG collection and flue	31,661 kg CO_2e/yr	$198,535
	Composting Plant	4,388 – 6,827 kg CO_2e/yr	$2,375,076
	Use of solar power thru PV modules	10,658 kg CO_2e/yr	$214,000

34. 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. General mitigation strategies will be used as part of the overall project strategy where possible such as the use of biofuels, light vehicle technologies, electric vehicles. The project will contribute to mitigation by promoting the use of solar operation at the infrastructure site.

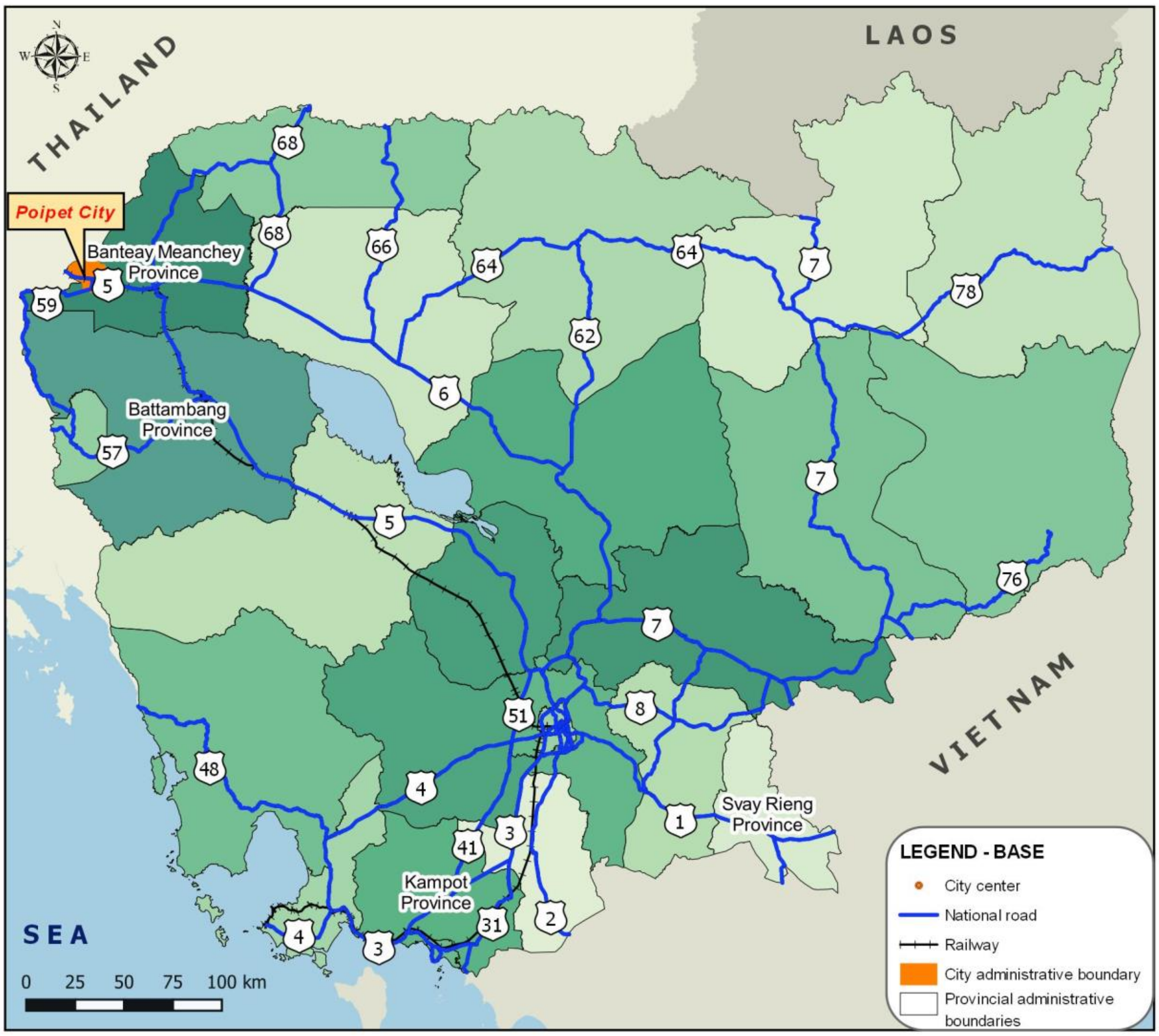
35. The total cost for the proposed mitigations is $2,936,111.

I. INTRODUCTION

1. Study area description

1. Banteay Meanchey province is located in the Northwest of the country on the border with Thailand. It is bordered by Battambang Province to the South, Siem Reap to the east, and Odar Meanchey to the North. It is 6,679 km2, most of which is relatively flat low land with scattered hills up to 100 m a.s.l. and uplands over 100 m in the North. Eastern Banteay Meanchey is located on the upper reaches of the central plains area that is hydrologically dominated by Tonle Sap and subject to the annual flooding that occurs across central Cambodia. The Sisophon River which is a major tributary of Tonle Sap flows drains the province. The region consists generally of the typical plain wet area of Cambodia, with rice fields and other agricultural plantations.

Figure 1: Site Location



Source: Egis, 2021

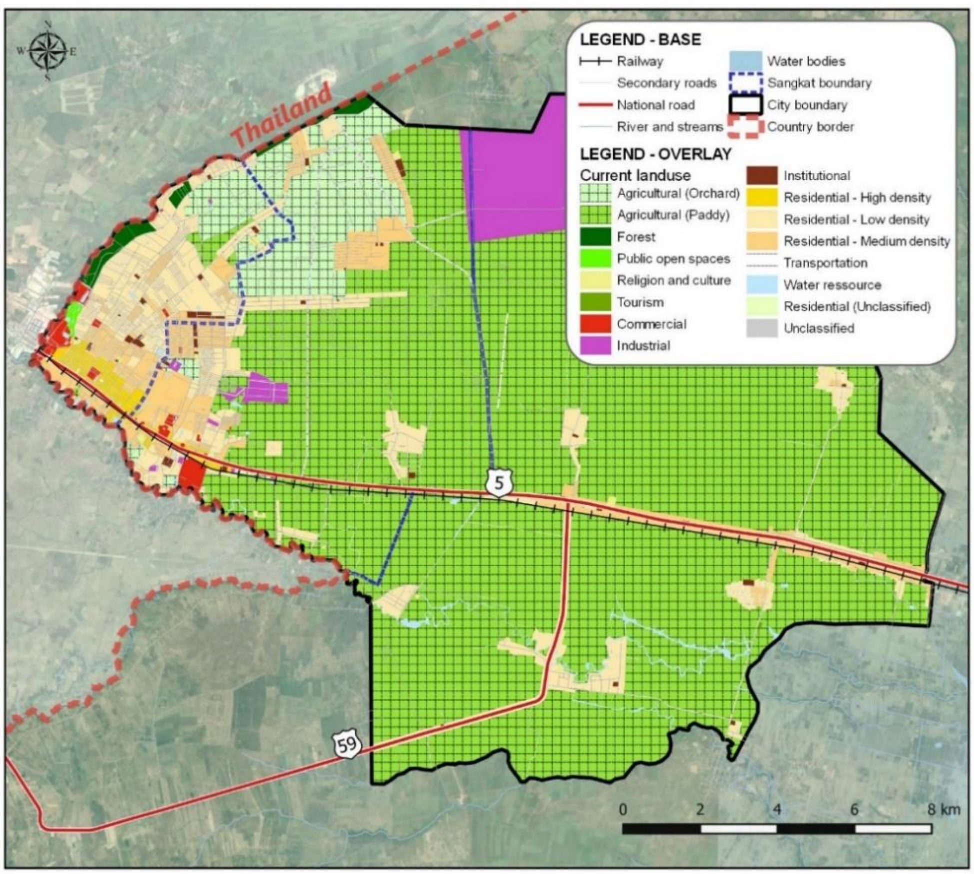
2. Poipet is located on the western border of Banteay Meanchey province and is an international border gate between Cambodia and Thailand on one of the country's busiest highways, National Road No 5, which links Phnom Penh and Bangkok. Its counterpart across the border is Aranya Prathet, Thailand.

3. The region consists generally of the typical plain wet area of Central Cambodia, with rice fields and other agricultural plantations. Widespread flooding typical of Central Cambodia occurs in the wet season.

4. Poipet is located on flat terrain of the flood plain of the Ou Chhrov River that flows from Thailand through the Province joining with the Sisophon River, a major tributary to Tonle Sap. The Cambodian upstream part of the Ou Chhrov River serves as the south-eastern border limit between Poipet and Thailand. The Ou Stueng Bot river is located in the western border of the city center. The border checkpoint crosses this river. The Ou Stueng Bot River flows from the north to the south into the Ou Chhrov River.

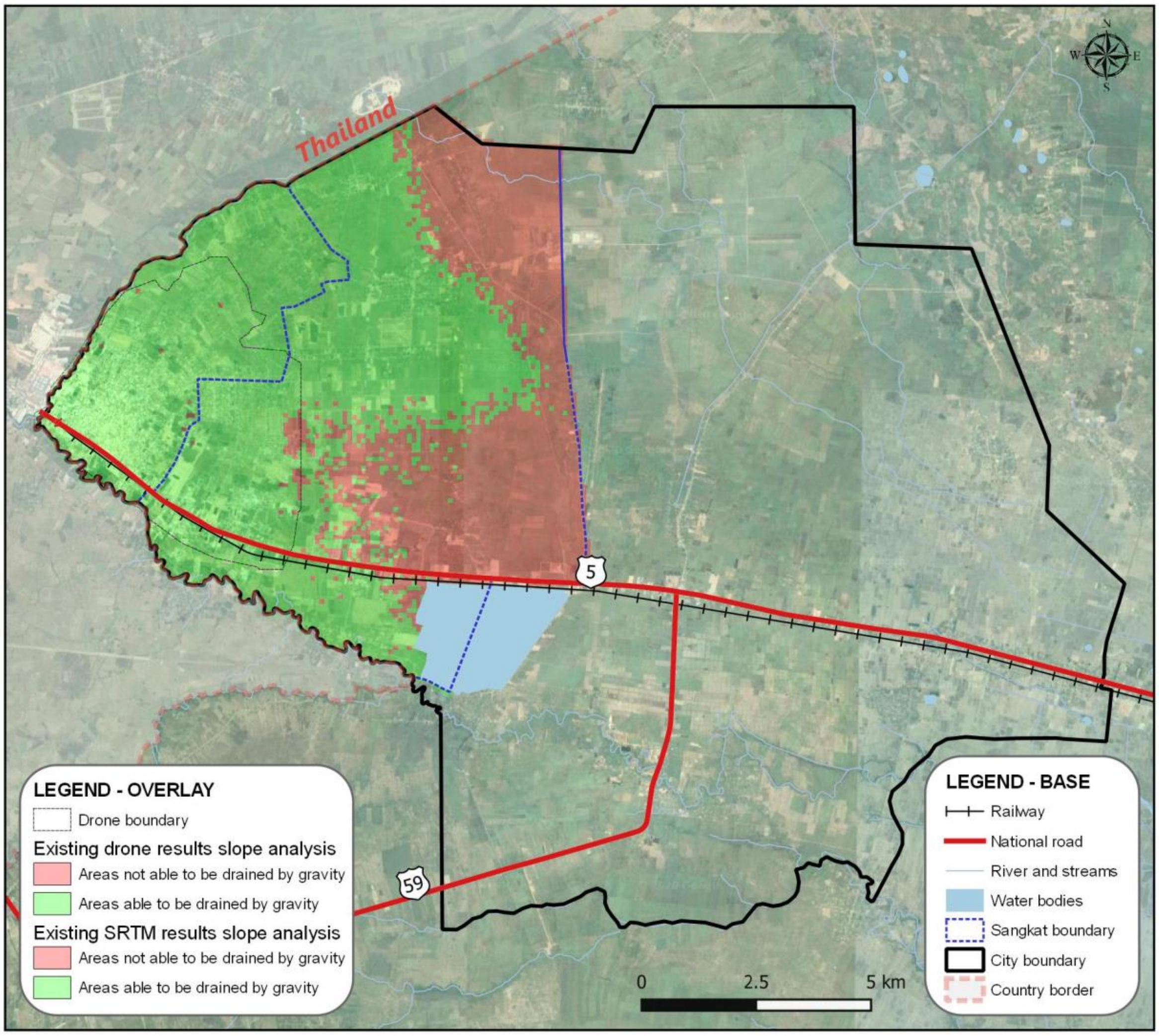
5. The current land use of the province is shown in Figure 2 below. Agricultural land use represents the biggest portion of the city, 21.4km2 or 77%. There are no extensive natural forests or mountainous areas and elevations across the City are below 20 m asl and the topography is characterized by slight slopes. A small area of forest covering 1% of the total land use is located within the city area.

Figure 2: Current Land Use of Poipet City



Source: Egis, 2021

Figure 3: Schematic Representation of the Areas of Poipet suitable to Gravity Drainage (green areas)



Source: Egis, 2021

2. Project description

6. 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]

7. 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

[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.*

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.

8. 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.

9. 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 future cost associated to the climate change impact.

10. The project components under output 2 are:

(i) Improved wastewater management systems (pumping stations, network and treatment plant);

(ii) Improved drainage systems to manage stormwater flows, and;

(iii) Improved SWM systems (including landfill, waste collection & recycling, and transportation vehicles, an upgrade of environmental protection measures and activities to promote waste reduction).

11. 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 Poipet is set out for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined below.

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

2.1. Short-term (2020-2025)

Wastewater

12. There is, at present no sewer and no wastewater treatment plant in Poipet and wastewater flows directly to the environment through combined sewers and road drains, or indirectly via canals into the open water. The assessment of the fecal and non-fecal waste disposal chain, both in rural and urban areas, suggests that 91% of fecal waste is not managed safely. Within the town center, wastewater is not being adequately evacuated from urban areas and remains stagnant in urban areas. Because of the expected growth of the urban population and the increase of the number of commercial establishments, a sewerage system needs to be developed to meet the present and future requirements.

13. Based on the selected scenario for the master plan, a wastewater treatment plant (WWTP) centralized will serve the built-up area of Poipet and its extension in the medium and long term horizon (however, the areas part of Nimit Sangkat are not included). LCIP targets the creation of connection to wastewater network for a major part (75%) of the population located in urban areas. Long-term capacity (up to horizon 2040) is considered for the design of proposed infrastructures.

14. At the end of master plan study stage, it was suggested to start the implementation with:

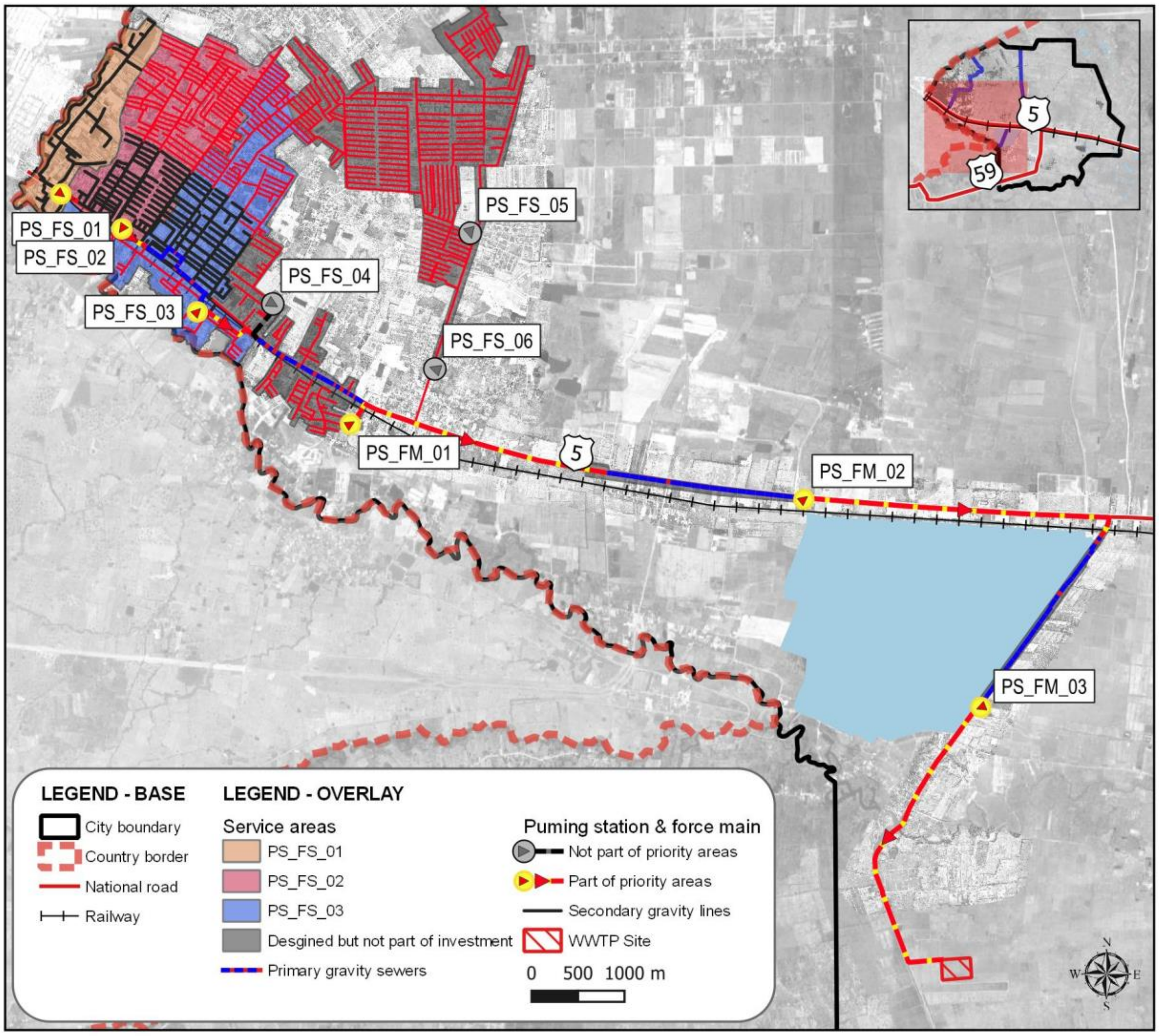
(i) Construction of a wastewater treatment plant;

(ii) Construction of pumping stations to create a transfer chain to the WWTP when areas to be serviced requires, and gravity flows cannot be achieved because of distance and topography, and;

(iii) Construction of sewer pipes designed primarily for the selected existing built-up areas with some capacity for extensions for future growth.

15. The proposed priority infrastructure and the relationship with longer term infrastructure is shown in Figure 4. To fit the budget requirement, part of the infrastructure designed (shown in red/grey) has not been integrated into the final investment proposed.

Figure 4: Proposed Infrastructure showing Priority and Long Term Infrastructure.



Source: Egis, 2021

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

Table 2: Wastewater – Investment Horizon and Design Capacity

Item	LCIP – investment horizon	Design Capacity
Sewer Network	2025 – short term or priority area	2040
Pumping Stations & Force mains		Equipment 2030 Civil works 2040
WWTP		2030

Table 3: Summary Table of Investment in Poipet (wastewater)

Investment Area	Components
Pumping stations	6 PS
Networks	55.6 km of gravity lines, 11 km of force mains
Connection points for SEZ and long term areas	5
Wastewater Treatment Pant	Activated Sludge (9,576 m^3/day)

Stormwater

17. Urban flooding is a recurring problem for the city center of Poipet (surrounding the market) because of the inadequate existing drainage. Some relief will be provided by the infrastructure under construction as part of the GMS 1 program; new box-culverts lines between the national road and Ou Chhrov River (close to the city center). However, other streets and upstream areas not incorporated in the GMS 1 project (northeast of the city center) in the built-up area will continue to experience floods.

18. Construction of new buildings such as hotels, shopping malls, casinos, and parking areas will continue to cover the natural land with concrete, steel, and asphalt structures. Runoff rates will increase from these impermeable surfaces and cause more localized flooding on streets and around buildings in low-lying areas.

19. Poipet currently has a sizeable stormwater drainage system. However, recurrent floods are reported by inhabitants and local authorities. This is due to a lack of an existing global strategy for the development planification of stormwater/wastewater drainage networks. There are inconsistencies in the concept/design of the existing drainage networks (pipelines are connected to the existing system in the wrong direction, other pipelines are not connected to the existing primary drainage system). Main stormwater channels are operating correctly, but their capacity is not sufficient to ensure proper drainage of the city center. Common issues in the urban area are, a high level of filling, obstructions by solid waste, grid obstruction by locals to reduce odor nuisance, lack of inlets, unconnected independent drainage.

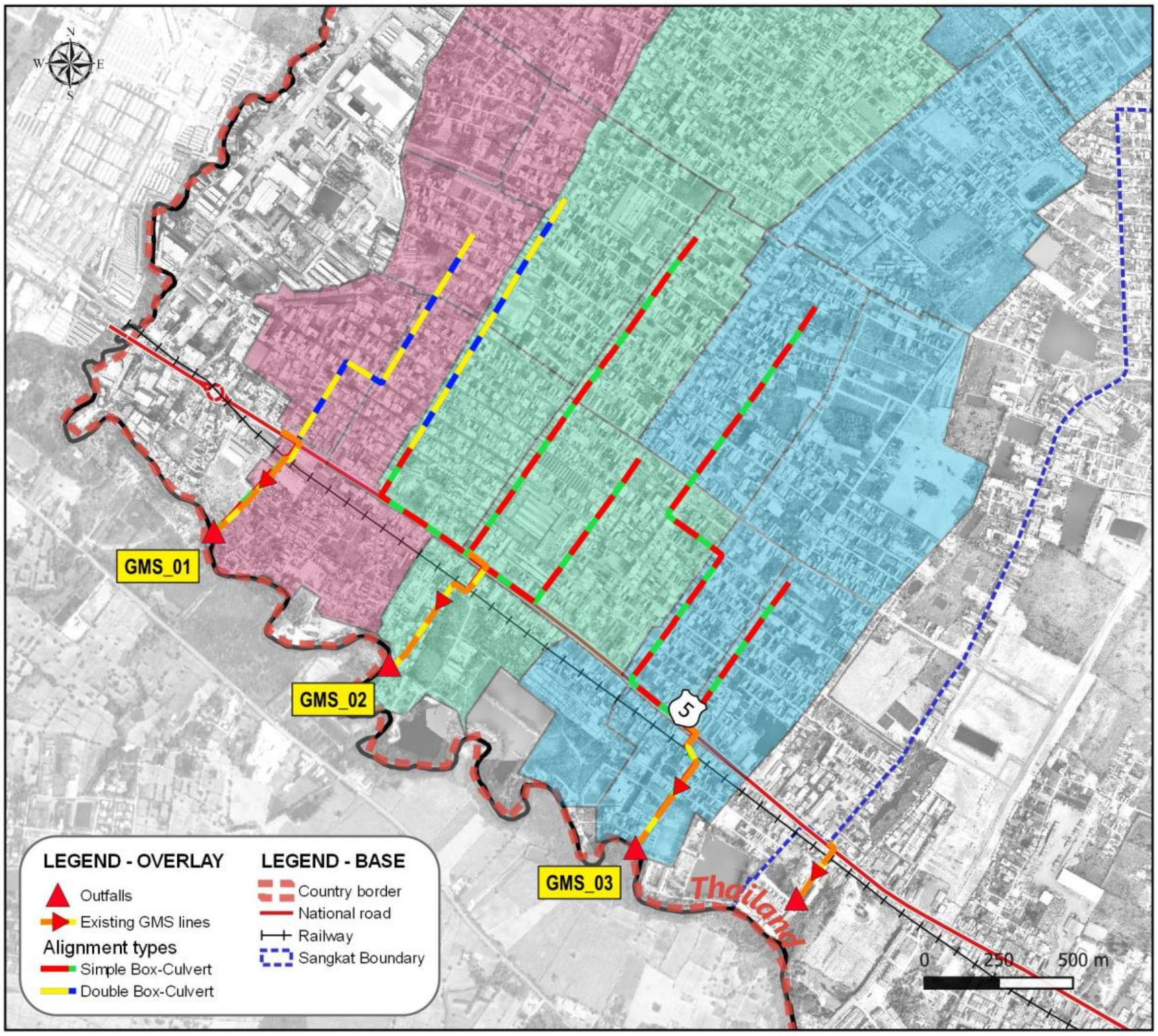
20. All of the alignments in Poipet are proposed to be box-culverts. Because the urban tissue is dense, there is no space available to build open-channels with sufficient capacities regarding the runoff peaks modeled.

21. Regarding the limited land availability and allowable width on the road, it was proposed to multiply outfalls to avoid excessive drain widths. From this perspective, the proposed stormwater network divides the study area into 54 main catchments that flow through 9 outfalls drain into two watercourses: Ou Chhrov and Ou Steoung Bot.

22. The short term proposed program of works shown in Figure 5 is to extend street drainage to cover all of the existing built-up areas near the border and integrating coverage with the GMS1 drainage construction. It is not proposed to reuse/rehabilitate existing lines. The existing secondary drainage network needs to be re-connected to the proposed drainage lines to get a

consistent strategy for the whole drainage network. Secondary network connections will be studied during the detailed engineering design based on a detailed topographical survey. The proposed drainage network follows the natural topography and discharges at low points of the road. As much as possible, the few existing cross-drains will be reused to limit the cost of road cutting and reinstatement.

Figure 5: Proposed Urban Drainage Network



Source: Egis, 2021

Table 4: Summary Table of Investment in Poipet (stormwater)

Investment Area	Components
Box culvert	7.126 km

Solid Waste Management

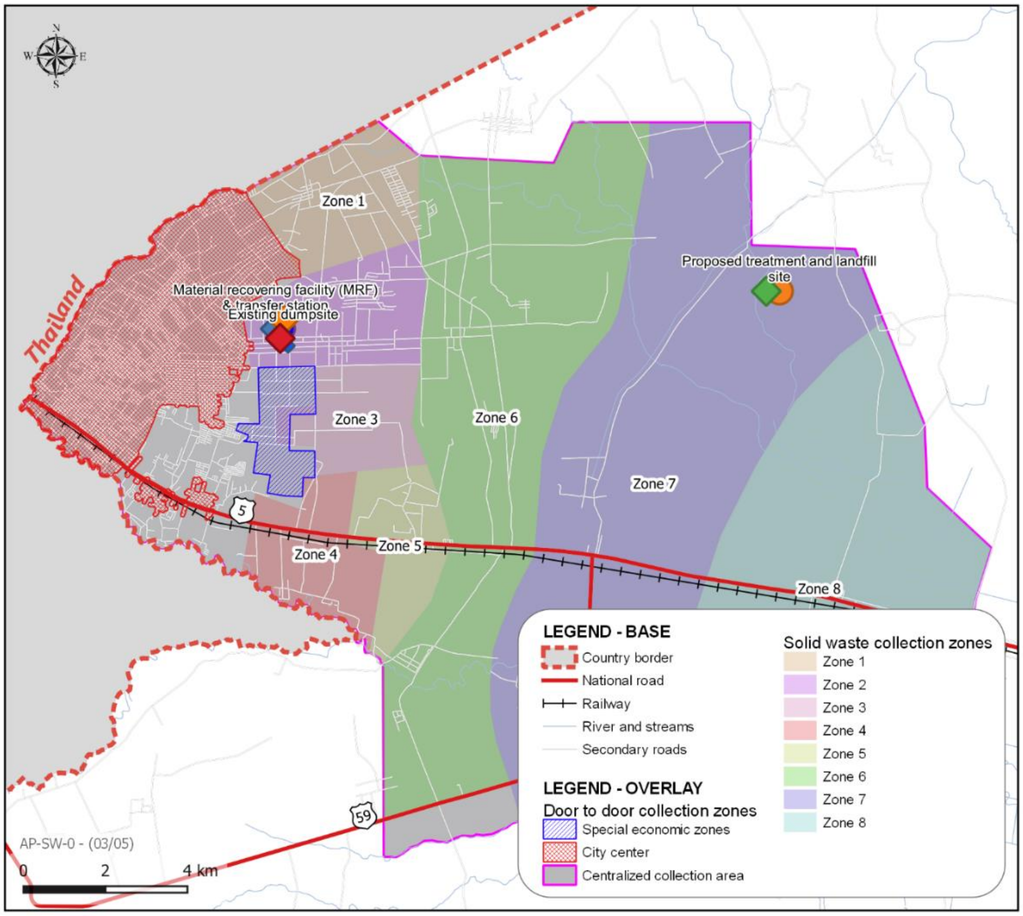
23. The current solid waste management (SWM) presents severe deficiency in the collection, recovering and disposal of the solid waste generated in Poipet city. It is estimated that 88% of the solid waste generated in Poipet is unsafely managed. The household collection coverage is only approximatively 16%. A large portion of the municipal solid waste (MSW) is also left uncollected and is dumped directly in the nearby natural environment and/or burnt. It is necessary to improve the collection for the whole city.

24. Because of the expected growth of the urban population and the increase of the number of commercial establishments, a strong solid waste management is required to address the present and future needs.

25. In terms of collection, door to door collection is preferred in the city center while centralized collection is suggested in rural areas until these areas are sufficiently developed to allow for door-to-door collection. Source segregation at markets, with a dedicated centralized collection point, would be an opportunity to increase the sorting of bio-waste and therefore the potential for compost production.

26. In terms of treatment, priority is to build a transfer station and a landfill to dispose properly the residual waste. Then it is recommended to invest on the pre-sorting plant to reduce waste landfilled and to employ scavengers working currently in poor conditions as sorting operators. Finally, a composting plant is proposed to divert part of the biowaste from landfilling.

Figure 6: Proposed Priority SWM Projects for the Short Term



Source: Egis, 2021

Table 5: Solid Waste Management Sub-Components – Technical Options and Design Capacity

Item	Options	Design Capacity
Collection		
Rural area collection	Centralized collection points	
Urban area collection	Door to door collection	
Market biowaste collection	Centralized collection points with segregation at source	
Treatment		
Sorting plant	Sheltered sorting line, managed as an additional flow of the MRF	Designed for 2040
Composting plant	Windrow composting process	Designed for 2040
Landfill	Leachate management: combination of leachate recirculation and off-site treatment at WWTP	

Table 6: Summary Table of Investment in Poipet (SWM)

Investment Area	Components
Collection	18 compacting trucks
Treatment	1 sorting-plant and 1 composting plant
Disposal	1 controlled landfill

2.2. Medium term (2025-2030)

27. For the medium term it is proposed that master plans are reviewed and updated. It is expected that medium term infrastructure will include:

Wastewater

(i) Staged extension of the network, gravity sewers, pumping stations, and force mains to follow the urban expansion.

(ii) Improvements to the provision of household plumbing and on-site containment and treatment in Rural Areas

Storm Water

(i) Extend the primary drainage network to serve built-up areas to the north, some connected to the GMS 1 drainage, and some directed to the west border river, and a major new drainage channel approximately 20 to 25km long flowing south towards the river. The cost is estimated at $54 million for 44 km of primary drainage.

Solid Waste Management

(i) Extensions to the landfill and composting sites

2.3. Long term (2030-2040)

28. 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 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.

29. The proposed review will include the success of phase 1 and 2 drainage infrastructure in reducing flooding across the urban center, review of growth areas for extensions of sewerage and additional pumping stations pipes and house connections, review of the required number of additional collection trucks, cell requirements at the landfill and the operation of the waste sorting and composting sites. 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

30. Vulnerability per district can be assessed by examining exposure to climate change hazards, sectorial sensitivity and the capacity of the provincial and district 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.

31. The project is designed to facilitate long-term sustainable and economic growth in Poipet by developing strategies to improve urban infrastructure. Sector Master Plans identified infrastructure required to meet the future urban needs of Poipet for three planning stages; Short-Term (2020-2025), Medium-Term (2025-2030), and Long-Term (2030-2040) as outlined in section II2 above. However, this feasibility report presents an assessment of the proposed infrastructure that is proposed for the short term, i.e. the next 5 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

32. 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.

33. 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.

34. 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.

35. 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.

36. 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.

37. 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

38. 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

[5] UNDRR (2019). Disaster Risk Reduction in Cambodia: Status Report 2019. Bangkok, Thailand, United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific

awareness of climate change, improve the national capacity, enhance community resilience, and reduce national GHG emissions.

39. 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

40. 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.

41. 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).

42. 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.

43. 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.

44. 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.

45. 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

46. 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.

47. 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.

48. 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.

[6] Royal Government of Cambodia No.182ANK.BK Sub-decree on Functions, and Structure of Municipal Administration http://ncdd.gov.kh/wp-content/uploads/2020/03/SUB-DECREE-182-ANK.BK-ON-FUNCTIONS-AND-STRUCTURE-OF-MUNICIPAL-ADMINISTRATIONS.pdf

4. Challenges

49. 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 community level. Coupled with limited technical capacity and finances, political interference, and absence of functional implementation structures across these levels, effective CCA is limited.

50. The Rectangular strategy acknowledges that there is a lack of consideration for enterprise or factory locations in accordance with the master plan of urban planning and land management when planning and constructing infrastructure.

51. 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 improved7. A World Bank review in 2017 found that lack 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

52. 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.

53. Specifically, this is related to the ability of Poipet municipality to raise more income through the formulation and agreement of the wastewater and the solid waste tariffs roadmaps and a lack of capacity to carry out regular maintenance and monitoring and inventory.

54. The capacity of the Municipal Authority 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.

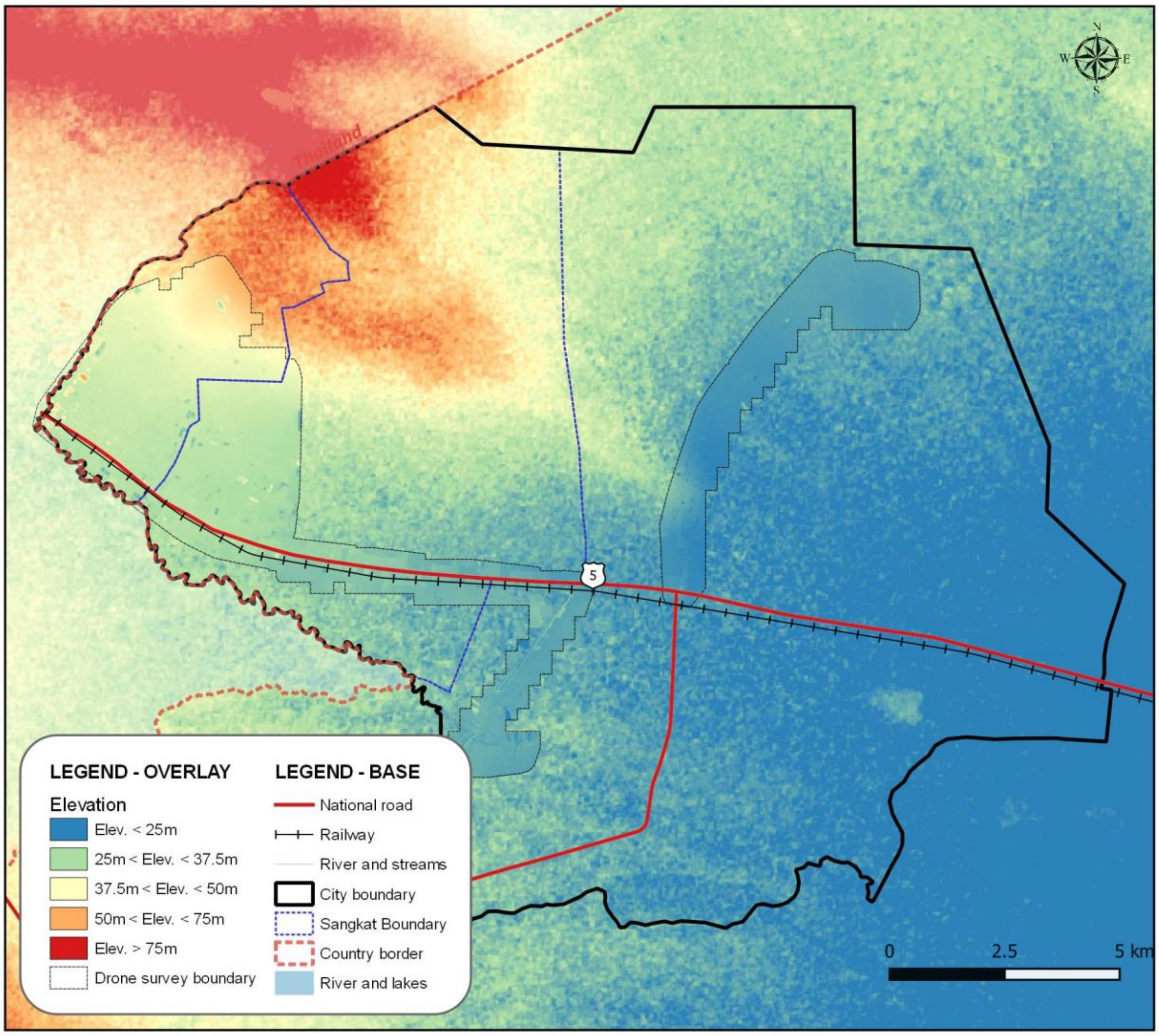
[8] World Bank & GFDRR, 2017. Disaster Risk Finance Country Diagnostic Note: Cambodia, s.l.: World Bank.

III. RISKS BASED ON CURRENT CLIMATE VARIABILITY

1. Geophysical setting and earthquake/volcano hazards

55. Poipet is located on flat terrain of the flood plain of the Sisophon River that flows from Thailand and forms the south-eastern border of poipet. Elevations across the city are below 20 m above sea level (ASL) and widespread flooding typical of Central Cambodia occurs in the wet season. The area is geologically stable and not considered to be at high risk of earthquakes.

Figure 7 Raw DTM Elevation Data



Source: Egis, 2021

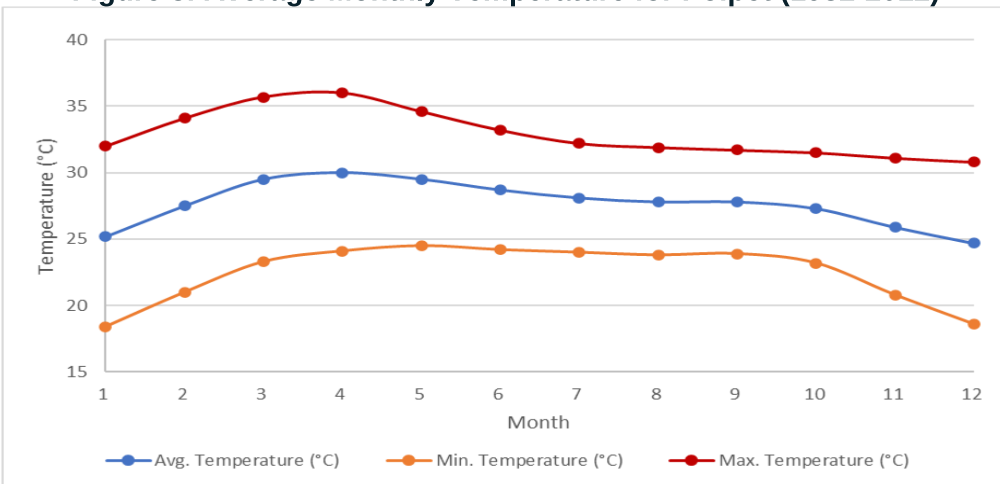
2. Temperature

56. 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. Temperatures then taper back towards the long-term mean for the remainder of the wet season. The mean maximum temperature is 28°C and the mean minimum temperature is 22°C. Average monthly

temperature is shown in Figure 8. Monthly maximum temperatures above 32°C are common before the start of the rainy season and may rise to more than 38°C.

57. 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). [9]

Figure 8: Average Monthly Temperature for Poipet (1982-2012)



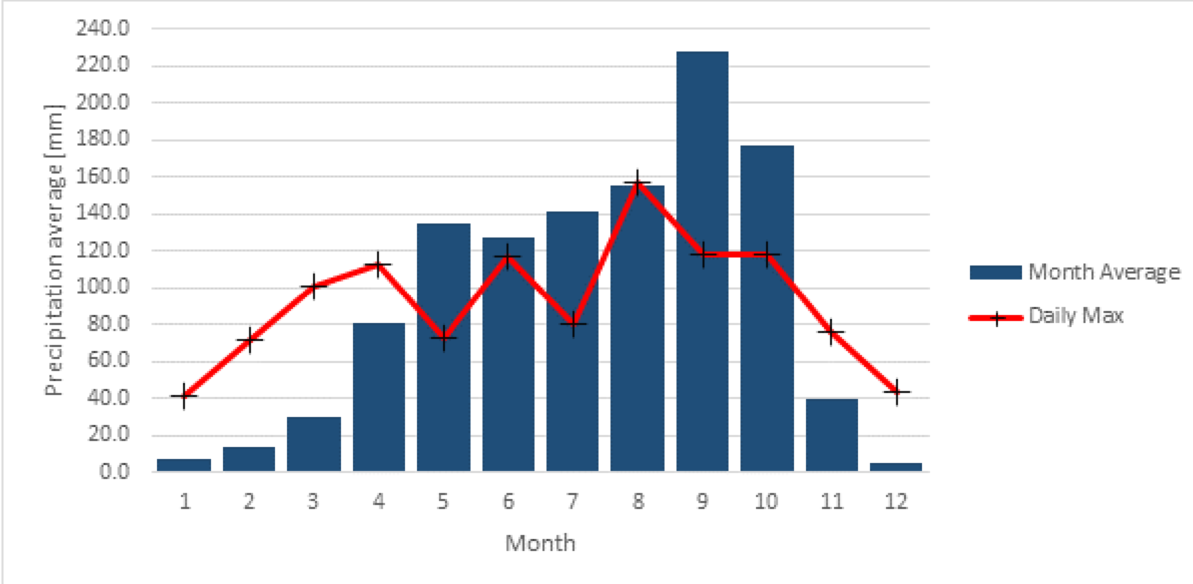
Source: Climatedata.org

3. Rainfall

58. Poipet's climate is tropical monsoon characterized by a rainy season from May to October which accounts for 90% of annual precipitation and a dry season, from November to April. The average monthly rainfall for Poipet, shown in Figure 9, ranges from 7.3 mm in February to 227.7 mm in September, while extreme rainfall events can occur that exceed monthly totals in a single day. Yearly precipitation from 1985 to 2018 is shown in Figure 10. The average annual rainfall varied between 619 mm in 2014 and 1,476 mm in 2011. There has been a (not statistically significant) increasing trend of 11.3 mm per decade.

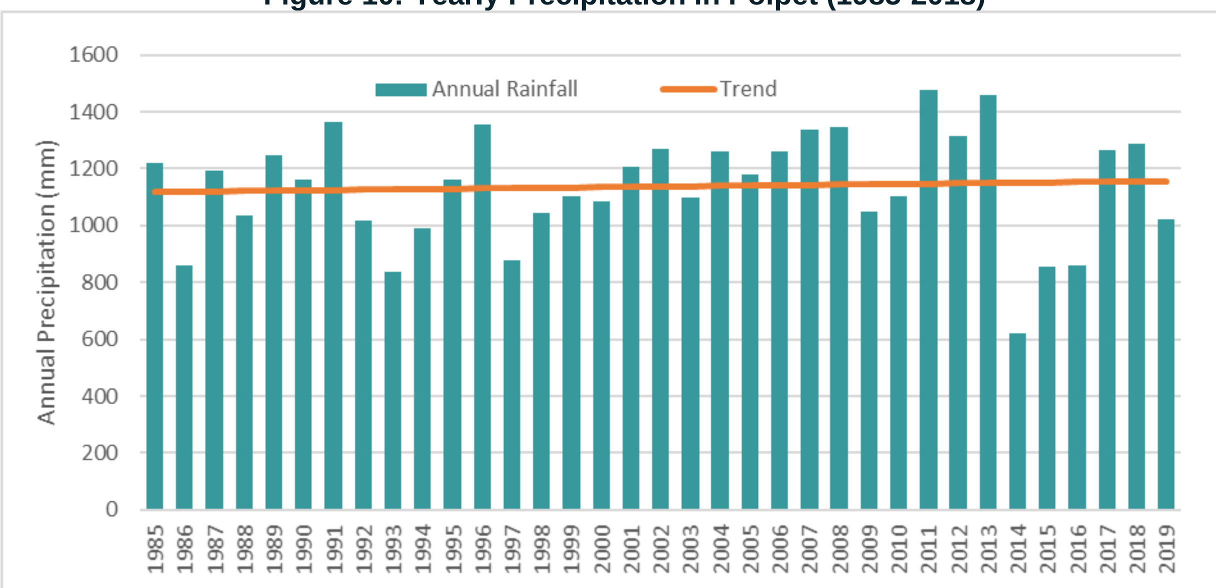
[9] GSNCSD/MoE. 2020. Cambodia's Updated Nationally Determined Contribution (NDC). The General Secretariat of the National Council for Sustainable Development/Ministry of Environment, the Kingdom of Cambodia. Phnom Penh.

Figure 9: Monthly Average Precipitation and Daily Maximum Precipitation (Sisophon)



Source: MOWRAM 1985-2018

Figure 10: Yearly Precipitation in Poipet (1985-2018)



Source: Data from MOWRAM.

4. Extreme weather events and flooding/storm surge hazards

59. 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 northwest and south; Battambang, Kampong Chnnang, Kampong Speu, Kampong Thom, Kampot, Kandal, Pursat and Rattanakiri.[10] Flooding in southeastern and central

[10] 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

Cambodia occurs between early July and early October due to increased water levels in the Mekong River and Tonle Sap basins (that together cover 80% of the country). Widespread flooding across Cambodia covering many provinces occurred in 1991, 1996, 2000, 2011 2013 and 2019. At the time, the 2000 floods were considered to be the worst to hit Cambodia in 70 years,[11] until more damaging floods occurred in 2011 and then again in 2013.[12]

60. 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 saw widespread flooding across Cambodia.

61. When there are heavy rains in the central part of the country, runoff floods areas along smaller rivers and parts of the provinces around Tonle Sap Lake. Bantey Meanchey Province is basically upstream of Tonle Sap and can flood over large areas due to the flat terrain. MPWT's in-house software used for determining the magnitude of flood risk, the Flood Risk Management Interface (FRMI), classifies NR5 as being at low risk of flooding with the only source of flood risk related to large area flooding.[13]

62. Previous studies into the vulnerability of Banteay Meanchey Province to flooding have found that the province is vulnerable to flooding.[14] The initial Survey of Rural Cambodian Households carried out as part of the Formulation of the 1st National Adaptation Program of Action to Climate Change (NAPA) found that Banteay Meanchey was vulnerable to flooding and ranked the province as the 6th highest province out of 21.[15] However, reports of the severity of flooding in the area around Poipet indicate that widespread river flooding is not a large problem within the City. The last large extent flood event has been reported by local press and dated from September 28th, 2019, when a 2km section of NR5 (national road no. 5) was closed. However, this large flood was caused by the collapse of Okayan Dam in Thailand.

63. 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 Poipet as low priority in terms of flooding[16]. Banteay Meanchay was impacted by flooding in 2010, 2011. 2012, and 2013. The impacts from these 4 years on Poipet City listed in the NCDM database are shown in Table 7. [17]

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[11] NCDM, 2011. Summary Annual Report on Disaster Events in Cambodia from 2000-2010. Phnom Penh.

[12] Vice-President of the National Committee for Disaster Management (NCDM). 2013. Update on the current flood situation affecting the country, (18th October, 2013). Reported in Floodlist; https://floodlist.com/asia/cambodia-floods-recede.

[13] Ministry of Rural Development. 2018. Project Climate and Disaster Risk Assessment for CAM 42334 Cambodia: Rural Roads Improvement Project III. Phnom Penh

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

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

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

[17] Cambodia Disaster Damage & Loss Information System (CamDi). http://camdi.ncdm.gov.kh. Accessed 14 April 2021.

Table 7: Combined Impacts of Flooding on Poipet in 2000 and 2011-2013.

Profile	Number
Records	< 23
Deaths	< 3 - 4
Houses Destroyed	1 - <3
No People Indirectly affected	<1400

Source: Cambodia Disaster Damage & Loss Information System (CamDi)

64. It appears that flooding due to river/streams overtopping their banks or an extension of the flooding of Tonle Sap is not a major issue for Poipet. The major cause of flooding in Poipet is inadequate drainage being unable to deal with intense rainfall events. A situation that is exacerbated by obstruction of flows due to poor road design or other anthropogenic activities and interventions.

5. Droughts and land degradation/salinity hazard susceptibility

65. 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 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.

66. El Niño weather patterns produce a twofold impact; higher-than-average temperatures and reduced monsoon rains that tend to start later in the season. Droughts are common across Cambodia with widespread droughts occurring in 1995, 1996, 1998 and 2002, 2003, 2004, 2009, 2012, 2015, 2016, and 2019. In 2015, Cambodia experienced its worst drought in 50 years with an estimated 2.5 million people affected across 25 provinces.[18]

67. The CSIRO study presented maps of drought indicators across Cambodia for the period 1980-2000. [19] The modelled baseline data indicated that three month droughts occurred 10-12 times over the 20 year period. The average duration of droughts in Poipet is 5.5 to 6 months.

68. Banteay Meanchey Province is generally presented as being susceptible to drought and is listed as impacted in many of the reported droughts listed above. The initial Survey of Rural Cambodian Households carried out as part of the Formulation of the NAPA found that Banteay Meanchey was vulnerable to drought and ranked the province as the 3th highest province out of 21[20]. However, an assessment of drought vulnerability within the province carried out in 2008 by

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

[19] 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.

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

the NCDM rated the area immediately around Poipet as low priority in terms of drought[21] and the Province was not listed as drought effected by the NCDM in the period between 2000 and 2019.[22]

6. Community perceptions of recent climate change

69. A comprehensive city survey across the Urban Sangkats in Poipet was conducted in December 2019. The subjects to be surveyed include household (HH) and commercial & Institutions (C&I) in the target location. 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 8.

6.1. Flooding

70. One group, the ID poor, had experienced flooding around the house but not inside that they attributed to blocked drains and damage from flooding. No groups thought that rainfall had increased in the last 10 years. Three groups thought that flooding has gotten worse in the last 10 years. The other group, the ID poor thought it had not. No groups thought wet season flooding would impact the proposed project.

6.2. Drought

71.1 Three groups (Elders, FHH and Indigenous) thought that droughts have become longer in the last 20 years. All groups thought that drought had impacted their income, with reduced income from crops or an agricultural business. The ID poor thought it had a large impact. The other groups thought their income had been moderately impacted.

6.3. Hot weather

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

Table 8: 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 11(5/6)	Elders 12(3/9)	F HH 10(7/3)	IP 4(4/0)
Flooding				
Do you think flooding in the wet season will impact the proposed project components?	No	No	No	No
If yes, why?				
Have you experienced flooding in your house?	Yes	No	No	No
If yes, what was level of flood water:	(a)			

[21] NCDM 2008. Stategic National Action Plan for Disaster Risk Reduction 2008~2013. Phnom Penh.
[22] Cambodia Disaster Damage & Loss Information System (CamDi). http://camdi.ncdm.gov.kh. Accessed 14 April 2021.

Group Number participants (total (men/women)	ID-Poor 11(5/6)	Elders 12(3/9)	F HH 10(7/3)	IP 4(4/0)
(a) around the house but not inside, (b) inside the house but not deep, (c) more than 20 cm deep in the house?				
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	(b)			
Have you experienced damage to your house from flooding?	Yes	No	No	No
Do you think that rainfall has increased in the last 10 years?	No	No	No	No
Do you think that flooding has gotten worse in the last 10 years?	No	Yes	Yes	Yes
Drought				
Has your household income been affected by drought?	Yes	Yes	Yes	Yes
How? (a) Household members with less work, (b) reduced income from crops or an agricultural Business, (c) other	(b)	(b)	(b)	(b)
Did the drought have (a) a large impact, (b) a moderate impact, (c) a small impact?	(a)	(b)	(b)	(b)
Do you think that droughts have become longer in the last 20 years?	No	Yes	Yes	Yes
Hot weather				
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
NOTES: ID-poor = lower incomes, F HH = Female Headed Households, IP = Indigenous people				

Source: Egis, 2021

IV. FUTURE PROJECTIONS

73. 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) CO2 scenarios. Climate change modeling reports that present data for Cambodia are summarized in Table 9. 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.

74. 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.

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

Table 9: Climate Change Modelling Discussed in this Report.

Report	Year Released	Model generation	No. Models	CO_2 future Scenario	Baseline
Second National Communication	2015	CMIP3	2	SRES A2	2002
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 = CO2 scenarios developed for the IPCC3 Special Report on Emissions Scenarios RCP = CO2 Representative Concentration Pathways developed for IPCC5 SSP = Shared Socioeconomic Pathways developed for IPCC6 CMIP = Climate Model Intercomparison Project carried out for IPCC3, IPCC5 or IPCC6 CSIRO = Australian Commonwealth Scientific and Industrial Research Organisation KNMI = Royal Netherlands Meteorological Institute					

Source: Egis, 2021

1. Temperature

2 Climate change models are very consistent in projecting an increase in temperature across Cambodia in the future. The projected temperature change for Poipet from CMIP6 GCMs is shown in Table 10. 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 Poipet is projected to increase by 0.7 °C by 2030, by 1.5 °C by 2050 and by 3.8°C by the end of the century under RCP8.5. Projections for 2050 under RCP 4.5 are slightly less, with the difference much larger by the end of the century.

Table 10: Range of Projected Mean Annual Temperature Change (°C) for the 5° x 2.5° cell containing Poipet Compared to the 2000-2020 model average under the SSP2 RCP4.5 and SSP5 RCP8.5 Scenarios from 13 Model Ensemble.

Decade	2030			2050			2090		
Scenario	Min	Av	Max	Min	Av	Max	Min	Av	Max
SSP2 RCP4.5	0.2	0.6	0.9	0.7	1.2	1.8	0.9	2.0	3.4
SSP5 RCP8.5	0.2	0.7	1.0	0.6	1.5	2.5	2.2	3.8	6.3

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

3 The projected change in seasonal temperature for Poipet from the CSIRO RCM downscaling for the period centered on 2055 compared to the period 1975-2005 under RCP8.5 is shown in Table 11. Temperature changes are projected to be relatively even across the year under RCP8.5.

Table 11: Projected Seasonal Temperature Change (°C) for Poipet for the period centered on 2055 under RCP 8.5 compared to the period 1975-2005.

Parameter	Value
Mean Annual Temperature (°C)	2.1
April-May Temperature (°C)	1.8
June-September Temperature (°C)	2
October-November Temperature (°C)	2
December-March Temperature (°C)	2.1

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.

76. **Number of Hot Days.** Modeling carried out by the CSIRO presents projections of the number of days above 35°C which is a measure of potential heat stress conditions. The CSIRO modeling indicates that the number of days above 35°C is projected to increase from 25-30 days per year to over 50 days per year by 2050 under RCP8.5 and that the number of consecutive hot days will increase from <5 to over 25.[23]

2. Rainfall

77. 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 Poipet from an ensemble of 10 CMIP6 GCMs is shown in Table 12. The median

[23] Katzfey, J. et al, 2013. Climate change projections for Mondulkiri and Koh Kong Provinces in Cambodia.

projection for annual rainfall from the GCMs used in this study is for little change into the future. The projections for RCP4.5 are lower than for RCP8.5 with negative median projections from 2050 onwards under RCP4.5. With regards to the range of outputs, some models project a small decrease under most scenarios, while others project an increase.

Table 12: Range of Projected Mean Annual Precipitation Change (%) for the 5° x 2.5° cell containing Poipet Compared to the 2000-2020 average under different Scenarios from 10 Model Ensemble.

Year	Scenario	Min	25th	Av	75th	Max
2030	SSP2 RCP4.5	-3	-1	1	5	7
	SSP5 RCP8.5	1	2	2	5	8
2050	SSP2 RCP4.5	-3	-2	-1	1	6
	SSP5 RCP8.5	-3	0	3	5	9
2090	SSP2 RCP4.5	-4	-3	-1	2	10
	SSP5 RCP8.5	-7	1	2	5	6

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

3. Extreme weather events and flooding

78. Typhoons making landfall on the coast of Vietnam often impact Cambodia as a tropical depression and can bring widespread heavy rainfall and subsequent flooding. There is a growing level of consistency between global climate 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 [24]. There is also a general agreement between models that the trade off to the decrease in frequency is an increase in intensity of wind speeds of 1.3 m/s [25], and an increase in rainfall rates of the order of 20% within 100 km of the cyclone center [26]. This indicates that extreme rainfall events that result from tropical depressions crossing Cambodia will decrease in frequency, but each event will bring more rain.

79. Table 13 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. Poipet is located on the boundary of two cells in the E/W direction, so the results were averaged for the two cells. The CSIRO study used CMIP5 models as an input to a 10 km x 10km pixel Regional Climate Model. Both studies found that 1 day extreme events are projected to increase in the future. The KNMI GCM data showed that climate models produced a wide range of projected changes. The mean projection of the change in mm from the ensemble used in the CSIRO study is similar to the KNMI data. The CSIRO median projection equates to 4%, while the KNMI median equates to 6%. For the 5 day extreme events, the CSIRO study projected an decrease in 5 day events of 10 mm. This is

[24] 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.
[25] Kang, N.-Y., and J.B. Elsner. 2015. Trade-off between intensity and frequency of global tropical cyclones. Nature Climate Change.
[26] 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.

inconsistent with the projected changes in rainfall that will result from more intense tropical depression. However, because Poipet is on the western border of Cambodia, the models may reflect decreased decay of events as they pass across the country.

Table 13: Projected Change in Extreme Rainfall Parameters (mm) for Poipet for the period centered on 2055 under RCP 8.5 compared to the period 1975-2005.

Parameter	Value			
	BL	25th	Median	75th
Maximum 1-day rainfall (mm), KNMI, RCP4.5	90 mm	-30	5 (6%)	36
Maximum 1-day rainfall (mm), KNMI, RCP8.5	93* mm	-16	5 (5%)	59
Maximum 1-day rainfall (mm), CSIRO, RCP8.5	130 mm	-8	5 (4%)	69
Maximum 5-day rainfall (mm), CSIRO, RCP8.5	180 mm		-10	

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).
* A different ensemble of models available

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.

80. The MRC State of the Basin Report found no clear trend in the extent of flooding across the Mekong River Basin including Tonle Sap over the last ten years. However, the economic costs of flooding have shown an increase. The report also found no increasing or decreasing trend in the number of tropical storms over the same period[27]. The MRC basin-wide assessments of climate impact on flood behavior suggests that flooded areas might increase by between 4.6% and 27.3% by 2060 for floods of all return intervals.

4. Droughts and land degradation/salinity hazard susceptibility

81. The Mekong River Commission state of the Basin Report concluded that droughts could potentially increase across the basin in the future due to the projected increase in temperatures and changes in rainfall patterns.[28] The CSIRO modelling showed no change in the projected average duration of drought for the 20-year period centered on 2055 under RCP 8.5[29]. Additionally, their modelling projected a small decrease in the frequency of short 3 month long agricultural droughts which affect rice cultivation in Cambodia.

[27] The Mekong River Commission 2019. State of the Basin Report 2018. Vientiane Lao PDR.
[28] Refer footnote 27.
[29] *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.

5. Selection of projections of extreme rainfall event increase for design of climate proof project infrastructure

82. In designing drainage for a city that is located on very flat terrain, one difficulty is allowing for enough fall to generate gravity flow and developing adequate drainage cross sectional area to cater to projected water volumes. A number of scenarios that considered the merits of designing the stormwater system for Poipet using a 1 in 2-year return frequency compared to a 1 in 5 year return period was conducted as part of the sector master planning stage.[30] The design storm intensity based on a 1 in 5 year return period is equivalent to a total rainfall of 108mm in one day. The one-day total rainfall for a 1 in 2-year event is 5% lower (79 mm). The comparison found a considerable difference in costs for infrastructure depending on which scenario was used. An additional consideration is that the new lines are connected to existing lines (GMS1) and so pipe sizing needs to be compatible with their capacities.

83. As there has been no clear trend in the number of storms or the size of extreme rainfall in recent decades across the Mekong River basin, it does not appear to be likely that there will be a large change in extreme event size in the next 10 to 20 years. Analysis of rainfall data from 1985-2019 indicates a (not statistically significant) increasing trend of 11.3 mm per decade the in maximum yearly rainfall. Projections for increases in typhoon intensity in the future are for an increase of 20% by the end of the century and this indicates that extreme rainfall events will increase in the future. The median projections from the modeling are for an increase of 4-5% between the baseline (2000 - 2020) and the modeled period (2045 - 2065) under the RCP8.5. Under RCP4.5, the median model projection is for a similar sized change.

84. Given the existing increasing trend and using the average projected change of the two data sources, 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. 5% to determine projected rainfall conditions in 2040. The phased nature of the investment means that allowances for extreme rainfall can be reviewed during subsequent phases based on updated climate projections, and the performance of drainage infrastructure from phase 1.

85. An additional impact of designing for a larger design storm intensity is that as the size of the cross sectional area increases, the amount of space required for the infrastructure also expands. Figure 11 shows critical open channel drainage infrastructure in Poipet with the corridor of impact. The available space provided by the road reserve and along the existing canal will be completely taken up by the recommended design (1 in 5-year event size 5% larger due to climate change). The design of the project has been carried out in an effort to reduce the displacement of landowners, under the proposed design, across Poipet there is no need for households to be relocated or have primary structures impacted, but 8 households will lose a proportion of their privately owned residential land.[31] Using the median projected increase due to climate change means that it is still economically feasible to develop a climate change proof design based on a 1 in 5 year event.

[30] Sector master plan prepared under TA 9554-REG:Southeast Asia Urban Services Facility
[31] Refer to the basic resettlement plan for further details.

Figure 11: Detail of Available Road Reserve for Box Culvert Stormwater Infrastructure in Urban Areas

Source: Egis, 2021

V. ASSESSMENT OF VULNERABILITY TO CLIMATE AND NATURAL HAZARDS

1. Identification of risk hazard

86. The risk of flooding in western central Cambodia results from two source; flooding due to the annual flooding of Tonle Sap, and localized flooding due to heavy rainfall events and poor or obstructed drainage. Poipet is located well above the floodplain of Tonle Sap so flooding from the Lake is not a hazard. There are rivers along the western and southern edges of the city, but there are no reports of flooding of these rivers impacting Poipet City. Flooding in the surrounding rural area as a result of the Ou Kai Don Reservoir overflowing after heavy rainfall was reported in 2020.

87. Poipet currently has a sizeable stormwater drainage system. However, recurrent floods are reported by inhabitants and local authorities. This is due to a lack of an existing global strategy for the development planification of stormwater/wastewater drainage networks. There are inconsistencies in the concept/design of the existing drainage networks (pipelines are connected to the existing system in the wrong direction, other pipelines are not connected to the existing primary drainage system). In the city center, the main stormwater channels are connected correctly, but their capacity is not sufficient to ensure proper drainage. Common issues in the urban area are, a high level of filling, obstructions by solid waste, grid obstruction by locals to reduce odor nuisance, lack of inlets, unconnected independent drainage. The hazard assessment

indicates that while Poipet is not vulnerable to river flooding, localized flooding is the most important hazard that will impact Poipet by 2040.

88. An assessment of drought vulnerability carried out in 2008 by the NCDM rated the area around Poipet as low priority in terms of drought. And other drought assessments have shown that communes other than Poipet city received the more severe impacts[32]. While drought will continue to impact Poipet into the future, the hazards presented to the proposed infrastructure is minimal.

89. 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 heat wave is projected to increase by 2040.[33]

Picture 1: Flooding in Poipet

Source: Egis, 2021

[32] International Environment and Disaster Management (IEDM). 2005. Drought Management Considerations for Climate Change Adaptation: Focus on the Mekong Region. Oxfam Cambodia. Phnom Penh.
[33] 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.

Picture 2: Poipet Ou Kai Don Reservoir overflowing after heavy rainfall events (October 2020)

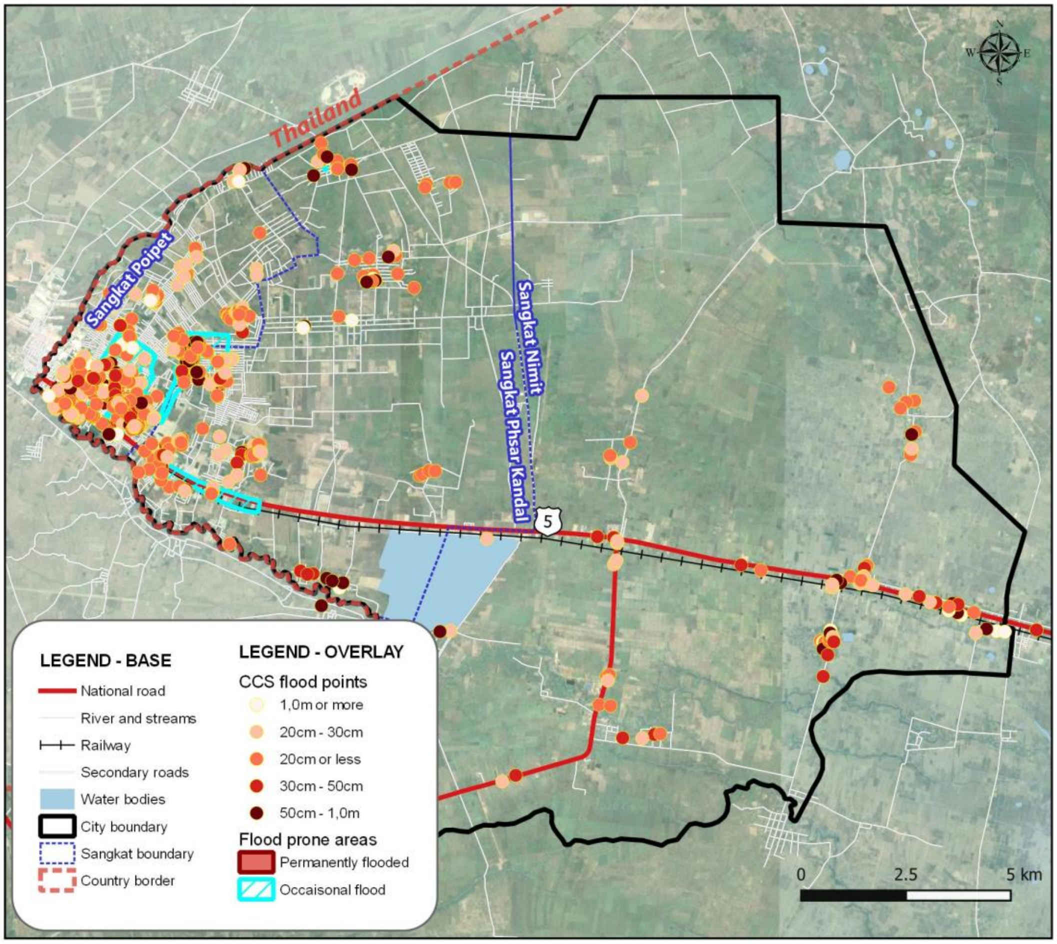
Source: National Television of Cambodia (TVK)

2. Exposure

2.1. Current exposure

90. As part of the survey of specific vulnerable groups undertaken by the transaction technical assistance project, participants were asked to identify flood prone areas in the city. Additionally, any flooding evident during field visits by project staff were also noted. The current extent of the recorded flooding in and around Poipet is shown in Figure 12. The map indicates that flooding is restricted to along roads and in urbanized areas.

Figure 12: Flood Prone Areas in Poipet City identified from CCS Focus Groups and Field Investigations



Source: Egis, 2021

91. 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 groups stated that hot weather had worsened health issues for members of their household.

92. 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 all 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 prohibitive.

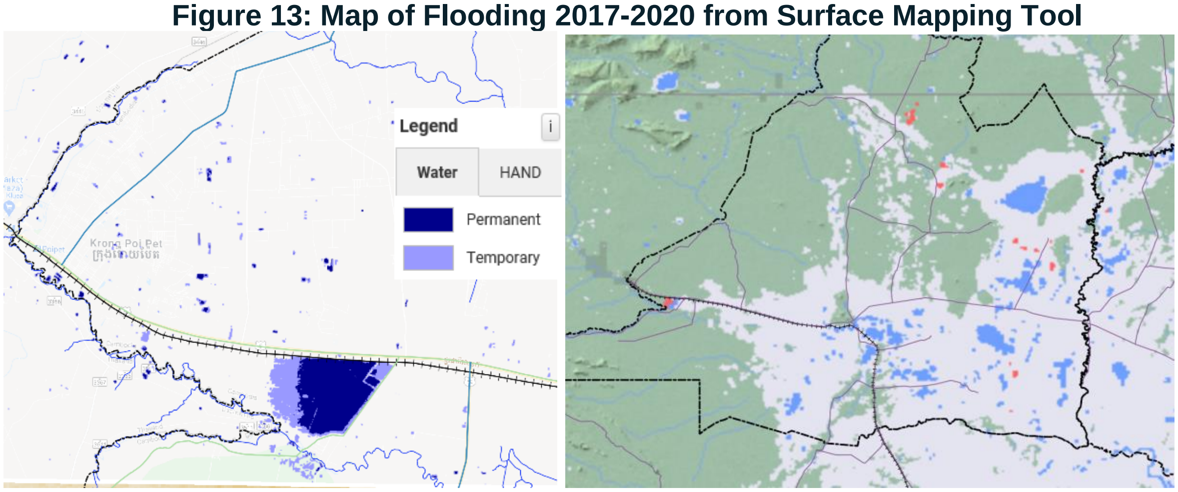
2.2. Future exposure

93. It is difficult to maps the extent of future exposure to climate change hazards. There is the potential for drought to increase, though this is not clearly indicated in the 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.

94. Exposure to flooding is from localized flooding due to problems with drainage and the current extent of the problems are not clearly mapped. It is possible that larger rainfall events will increase the depth and extent of the current problems if business as usual is continued.

95. Mapping from the USAID Surface Water Mapping Tool, a Landsat based online mapping tool presents maps of seasonally inundated land, wetlands, rice fields, fish ponds, or floods.[34] The map indicates that flooding has been experienced in the eastern part of the province, but that there are no indications of widespread flooding in Poipet between 2017 and the present. Similarly, the mapping carried out by the Global Flood Monitoring System (GFMS),[35] showed no widescale flooding within Poipet has been registered in satellite images. A recent flood map established by the within GMS Flood and Drought Risk Management and Mitigation Project for the flooding event that occurred on 17th October 2019 also did not show any flooding for Poipet. This indicates that exposure to flooding in the short to medium term is likely to be restricted to localized flooding.

Figure 13: Map of Flooding 2017-2020 from Surface Mapping Tool



Source: Egis, data from USAID Surface Water Mapping Tool. http://surface-water-servir.adpc.net/.

2.3. Identification of exposed project infrastructure

96. Under the climate change scenario extreme rainfall events are projected to be 5% larger. As a result, areas that have been identified as subject to localized flooding will become flooded more often. It is also possible that the areal extent will also increase due to the higher rainfall. However, it is difficult to predict the extent to which localized flooding will increase due to the highly variable nature of local conditions that lead to, or contribute to, any localized event. Additionally, efforts by local residents or the municipality to reduce flooding may be successful but may also merely move the impacts elsewhere. More rainfall also does not necessarily mean greater flood depths as overflows to adjacent drainage catchments could limit absolute flood levels in any one particular location. In order to map the exposure of project infrastructure, all areas in the city where flooding has been identified were mapped. On the basis of the increased rainfall intensity of 5%, it was assumed that the frequency of flooding would increase, and the depth may also increase. Infrastructure planned for these locations was identified and determined to be exposed to higher impacts due to climate change. All identified infrastructure was classed

[34] USAID Surface Water Mapping Tool. http://surface-water-servir.adpc.net/.
[35] University of Maryland Global Flood Monitoring System (GFMS), http://flood.umd.edu/.

as highly exposed to flooding regardless of the current depth. The summary presented in Table 13 shows the length of the sections or the number of individual elements of the infrastructure proposed for each component that are exposed to increased impacts due to the projected increase in localized flooding.

Table 14: Infrastructure Exposed to Increased Impacts from Floods.

Infrastructure Component	Impacted by flood spots reported from field	% Impacted by flood spots reported from field
Gravity stormwater lines	684 m	7%
Pressure wastewater lines	2977 m	31%
Gravity wastewater lines	8307 m	13%
Pumping station	0	0%
WWTP	Impacted	100%
Landfill and adjacent infrastructures	Not impacted	0%

3. Sensitivity assessment

97. 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, degree of impact may be assessed qualitatively. This report uses a simple qualitatively assessment of high, moderate or low, based on three components; i) the direct impacts in terms of number of fatalities, injuries and value of property damage, ii) the length of time that development processes will be impacted into the future, and iii) the costs of recovery.

3.1. Sensitivity to flooding

98. The socio-economic condition of Poipet contributes to sensitivity of the community to climate change impact. A number of anthropogenic activities and interventions have contributed to urban flooding. These are: i) Urbanization linked to economic development contributing to surface impermeability and increased runoff: ii) Rapid development of SEZs with a lack of regulation/enforcement with the same consequences: iii) Limited access to basic services, particularly a lack of waste management, which has resulted in blocked drainage: and iv) lack of maintenance of drainage lines. As a result, the community of Poipet shows some degree of sensitivity to flooding, particularly localized flooding due to blocked or poorly functioning drainage. One of the vulnerable groups, the ID poor, report flood damage to housing.

99. The existing drainage system of Poipet has more than 3.3 km of open channel network. These earth open-channel are used to drain stormwater from the dense urban areas toward rural areas/rivers. Project infrastructure such as pipes and pumping stations that cross these drains will be sensitive to inundation and damage due to moving floodwater from overflowing drains. Additionally, any embankments constructed for wastewater or solid waste management plants

will be subject to erosion during heavy rainfall events and possible undercutting from fast flowing floodwaters.

3.2. Sensitivity to drought *(land degradation/soil erosion)*

100. 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 is changing and, therefore, the sensitivity of farmers to drought is increasing[36]. The perception in the community is that drought do have an impact through reduced income from crops or agricultural businesses.

101. Extended droughts have the potential to require water restrictions in the city reducing influent volumes into the wastewater treatment plant (WWTP). This can have effects on wastewater treatment processes efficiency and associated operational costs. As influent flows decrease, there is less water to dilute contaminants potentially increasing pollution concentrations in downstream effluent.

102. The volume of inputs into the WWTP in the future will be influenced by a range of factors as the system is developed over the short and medium terms. The review proposed for the long term will need to consider the future requirements of wastewater treatment for Poipet city and this review will need to include a review of measured and projected changes in the frequency and intensity of droughts. While drought will continue to impact the community of Poipet into the future, the sensitivity of the proposed infrastructure to drought in the short and medium term is classified as low.

3.3. Sensitivity to extreme heat events

103. Extreme heat events will have increasing impacts on the community of Poipet into the future. There is the potential for increased temperature to have impacts on the WWTP and the solid waste management components. Warmer temperatures can increase the bacterial reaction rate which reduces the density of settled sludge. Higher temperatures can also increase the formation of N_2O during the denitrification processes. The preference for the lower technology Waste Stabilization Ponds system reduces these impacts.

104. The projected higher temperatures by 2050 are incorporated into the design of the WWTP. Hot days over 30°C already occur and the increase in the number of hot days from 30 to 50 is not expected to impact the WWTP. The projected increase in the number of consecutive hot days from <5 to over 25, combined with projected increases in evapotranspiration, will put added pressure on water supplies, particularly if the same source is used for irrigation. The proposed review of the master plan will need to include an assessment of issues related to water supply and potential impacts on the WWTP.

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[36] 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.

105. The sensitivity of the proposed infrastructure to the projected increase in hot days and longer periods of consecutive hot days for the short and medium term is classed as low, provided a review of water supply is included in the review proposed for 2030-2040.

4. Adaptive capacity assessment

106. 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.

107. A UNDRR report in 2019 found that while the country's policy and strategic directions lay a solid framework for coherence, efforts to operationalize these plans for tangible outcomes at the local government levels remains to be achieved.[37]

108. Reviews and lessons learned of other infrastructure development projects, such as GMS1,[38] GMS2,[39] and similar projects in Cambodia found that most of the MA employees lack skills in engineering design, asset management, financial systems, and the operation and maintenance of public services infrastructure (drainage, sewerage, and solid waste management). This lack of capacity highlights the need for capacity building related to the operation of project infrastructure as well as the capacity for planning sustainable and climate change resilient expansion of the services.

109. The capacity of the Poipet municipality to deal with the impacts of floods and droughts was assessed. Six (6) factors were used to assess the capacity of the Poipet 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 Poipet 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 15 indicate that Poipet municipality has only a medium low capacity to respond to extreme events. As a result, any impacts to infrastructure that result from flood events will be exacerbated by a limited capacity to respond to the impacts. The full description of the adaptative capacity factors is presented in Appendix 1.

Table 15: Assessment of Adaptive Capacity of Poipet City Officials

Adaptive Capacity Factor	Capacity Assessment	Description
Economic Wealth	Medium (3)	Resources limited to assistance for priority areas only Most people in the area have limited access to resources Reliant on international aid for flood recovery The Municipality has limited experience in devising and collecting tariffs

[37] UNDRR (2019). Disaster Risk Reduction in Cambodia: Status Report 2019. Bangkok, Thailand, United Nations Office for Disaster Risk Reduction (UNDRR), Regional Office for Asia and the Pacific

[38] ADB. Greater Mekong Subregion Southern Economic Corridor Towns Development Project

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

Adaptive Capacity Factor	Capacity Assessment	Description
Technology	Medium Low (2)	Limited equipment and facilities for assistance and limited communication Not adequate for extreme events Some limitations due to technical capacity
Institutional	Medium (3)	Officials and community leaders are aware but management set-up to respond to a hazard is non-existent. Relevant processes, procedures and legislations are passed at the National level but implementing guidelines still have to be formulated The relevant Ministries are tasked with providing assistance and capacity building
Infrastructure	Medium Low (2)	Infrastructures are available but there are no facilities that can be used to respond to a hazard Transport services in some possibly affected areas are not available No central disaster management center in the Municipality
Information	Medium Low (2)	Some degree of awareness of Municipal Officials and stakeholders Communication strategies are in place, but procedures are not yet in place
Social Capital	Medium-Low (2)	There is some degree of willingness of the leaders to allocate funds to build adaptive capacity of the Municipality Staff have been transferred from relevant ministries so should have some skills Some agencies and NGOs are available and have skills to assist specific sectors during occurrence of hazard There is a team with basic skills for emergency response

5. Risk assessment

110. 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 steps and scoring matrix are described in detail in Appendix 2.

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

5.1. Likelihood of hazard scenario

111. 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 Descriptors presented in Appendix 3. The calculated likelihood of impacts from flooding hazard for each element of infrastructure for each component is presented in Table 16.

5.2. Consequences of hazard occurring

112. In this step the level of the impact (consequence) on the land, built environment and people for the flooding hazard is assessed. The assessment is formed from a combination of inputs; the adaptive capacity assessment, the GIS analysis showing the number of km or the

number of components that are exposed, and the estimate of the degree of impact based on the sensitivity. The consequences are categorized using the Descriptors of Consequence Table presented in Appendix 2, with C1 = Negligible and C6 = Extreme. The calculated Consequences of impacts from flooding hazard for each element of infrastructure for each component is presented in Table 16. The details of the specific protection features mentioned in the Comments column are discussed in Chapter VI.

Table 16: 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 (56 km)	Erosion by moving floodwaters Undercutting or damage of bridge/canal crossings	3 Possible	2 Minor	Consequence is reduced as protection included in drainage rehabilitation (see discussion below) No significant environmental impacts identified aside from localized disturbance
Pumping Stations 6	Some may be exposed to minor drain flooding	3 Possible	2 Minor	Selected sites are currently flood free. Enclosure design should include protection from inundation
Pumping Mains (11 km)	Erosion by moving floodwaters Undercutting or damage of bridge/canal crossings	3 Possible	3 Moderate	Consequence is reduced as protection included in drainage and road bridge rehabilitation
WWTP	Increased localized flooding	4 Likely	2 Minor	Design should include management of localized rainfall at projected higher event size

Table 17: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Stormwater Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Box culverts (7.1 km)	City wide increase in the size of extreme events leading to increased amount of water required to be removed	4 Likely	2 Minor	Higher event size is incorporated in design

Table 18: Calculated Likelihood and Consequence of Impact from Flooding Hazard for the Infrastructure Element of the Solid Waste Management Component.

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
Landfill	Stormwater system could be overwhelmed	2 Unlikely	4 Severe	Design will incorporate future event size

Infrastructure Elements	Impacts	Likelihood	Consequence	Comments
	Leachate could be released			
Sorting Plant	Damage to building due to stronger wind events	1 rare	2 Minor	Built to national standards
Composting Plant	Localized flooding Leachate could be released	2 Unlikely	2 Minor	Design will incorporate future event size
Collection infrastructure	Localized flooding at collection site	2 Unlikely	2 Minor	Drainage improvements will minimize localized flooding

5.3. Evaluation of risk

113. 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).

$$R = L * C$$

114. Verbal descriptors can be applied to the calculated risk of each hazard scenario using Table 19. This makes it easier to quickly compare the impacts of climate change on each project component. For example, an activity which 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 19: 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

115. 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 20.

Table 20: Calculated Risk from Flooding Hazard for the Infrastructure Element of The Project Components.

Infrastructure Component	Infrastructure Elements	Risk Calculation		
		Likelihood	Consequence	Risk
Wastewater	Gravity lines (56 km)	3 Possible	2 Minor	6 Low
	Pumping Stations 6	3 Possible	3 Moderate	9 Moderate
	Pumping Mains (11 km)	3 Possible	2 Minor	6 Low
	WWTP	4 Likely	2 Minor	8 Moderate
Stormwater	Box culverts (7.1 km)	4 Likely	2 Minor	8 Moderate
Solid Waste	Landfill	2 Unlikely	4 Severe	8 Moderate
	Sorting Plant	1 rare	2 Minor	2 Low
	Composting Plant	2 Unlikely	2 Minor	4 Low
	Collection infrastructure	2 Unlikely	2 Minor	4 Low

116. The calculated risk for project components ranges from low to moderate. The highest calculated risks are (9 Moderate) the potential for minor flooding to inundate pumping stations on the wastewater lines, and (8 Moderate) the potential for localized flooding impacting the WWTP, the drainage box culverts, and the landfill site. The vulnerability of specific infrastructure elements of each component is discussed below.

6. Vulnerability of infrastructure

117. The projected increase in temperature and the number of hot days will potentially put added stress on project components. The smart city asset management system and improved institutional capacity will assist in managing these changes into the future.

6.1. Wastewater

118. The projected higher extreme event size means that higher localized flooding could impact infrastructure particularly pumping stations and where pipes have to cross drainage canals. The design of bridge crossings and pump housing will reduce this risk. Localized flooding at the proposed WWTP sites will become deeper with climate change under a business as usual scenario. The WWTP site is currently subject to flooding of up to 0.5 m. However, it is likely that as drainage canals around the site are rehabilitated and the onsite drainage designed as part of the treatment plant is constructed, localized flooding will be reduced.

6.2. Stormwater drainage

119. The projected increase in rainfall will result in a small increase in the amount of water that will need to be moved via the proposed drainage improvements which leads to the moderate risk assessment. The use of a designed rainfall event that takes the projected increase in extreme event size of 5% into account will reduce the risk. The current flooding that occurs in Poipet is related to poorly designed/maintained drains not to river flooding. Therefore, the proposed component including improvements to the overall connectivity and maintenance of the city's drainage system will improve the overall flow within the system and will minimize risks. Any flooding that occurs around water bodies will continue and may increase in area slightly, although this will be offset by increased evaporation due to the projected higher temperatures.

6.3. Solid waste management

120. Both the existing landfill site and the identified alternative location have been assessed as not subject to flooding. While this is not likely to change given the projected rainfall increase of 5%, there is a moderate risk of impact due to localized flooding overwhelming the stormwater management facilities leading to leachate leaving the site. The design of the new landfill will require a water management plan that will handle extreme events of the projected larger size.

6.4. Other infrastructure

121. Other infrastructure such as access roads and waste collection stations are also at risk from localized flooding. The proposed improvements to drainage will minimize this risk and the proposed reassessment of the master plan before commencement of later stages should identify any new impacts. Drainage for access roads incorporates increased extreme event size of 5%.

VI. ADAPTATION

1. Contribution of project components to adaptation

122. By assisting the Poipet municipality to develop climate change sensitive planning, the project has been designed to decrease the vulnerability of Poipet 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. Each component contributes to improving increase the capacity of Poipet to adapt to climate change in a number of ways as outlined below.

1.1. Wastewater

123. The provision of properly treated wastewater will decrease the vulnerability of the city by decreasing the number of households exposed to wastewater during localized 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. Additionally, proper treatment of wastewater onsite where sewage treatment is not available will increase the resilience of the population by minimizing health risks during localized flooding events.

1.2. Stormwater drainage

124. The current drainage system operates in effect as combined drainage and sewage system and is poorly maintained and unconnected. Rehabilitation and expansion of the drainage system will improve connectivity and increase the efficiency of the system. This will decrease the exposure of the city to flood hazards by reducing blockages that increase the extent and length of flood events. It will also decrease the vulnerability of Poipet to the impacts of climate change by minimizing flood damage through efficient and quick removal of floodwaters. Improvements to the system in the urban center and the provision of well-designed canals in the surrounding rural areas and the construction of well-designed outlets will also decrease the sensitivity of the community by reducing negative health impacts from wastewater contamination.

1.3. Solid waste management

125. Proper management and disposal of solid waste will increase the resilience of the population by improving the health and wellbeing by reducing exposure to unhealthy waste and minimize health risks during both flood events and drought. Ecological solid waste management will contribute to improved air quality and decrease the exposure of the community by removing waste blocking the drainage system that increase the extent and length of flood events. Provision of green spaces around the SWM sites offers a soft solution for adaptation and will contribute to mitigation.

1.4. Contribution to international/national climate change commitments

126. The project also contributes to Cambodia's international commitments as outlined in Table 21. 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 21: 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 transport infrastructure planning and development climate proofed.	• Hazard risk information 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 used in the installation and access of sanitation facilities.	• Climate resilient infrastructure master plan for clean water network developed and implemented. • Wastewater management strengthened using climate-friendly technologies.
Stormwater	• Water infrastructures developed and rehabilitated and climate proofed through introduction of new technologies.	• Hazard information used in the development, rehabilitation, and access of water infrastructures.	• Climate resilient integrated water infrastructure management plan developed and implemented.
Solid Waste	• Solid waste management climate-proofed through integrated measures.	• Hazard information used in the installation and access of sanitation facilities.	• Climate resilient integrated water infrastructure management plan developed and implemented. • Solid waste management plans strengthened using climate-friendly technologies.

2. Proposed adaptation measures to cope with climate change impacts

127. The largest risks identified in the risk assessment are related to the potential for increased localized flooding due to the projected increase in extreme rainfall events of 5%. Therefore, adaptation measures are related to strategies to decrease these impacts. The major adaptation is a reappraisal of the projected extreme rainfall size used in the design of the drainage infrastructure. Sensitivity assessment carried out during the design phase indicated that an

increase in extreme event size will lead to an increase in stormwater flows requiring drainage infrastructure to be 10% larger. Additionally, the improvements in the connectivity of the system and improvements to the canals will increase the efficiency and will minimize the extent and duration of localized flooding. The net result will be a reduction in the impacts of localized flooding across the serviced areas despite the increased size of rainfall events.

128. The larger extreme event size means that localized flooding will continue to occur and will increase in extent in the area not serviced by drainage lines. Therefore, the WWTP will need to be isolated from the surrounding area that is currently flood prone and will require higher embankments to ensure protection from external flood waters and internal water management designed to manage rainfall events 5% higher than at present.

129. Similarly, the landfill site will also require flood water management designed to manage rainfall events 5% higher than at present. The adaptation options for specific infrastructure components are developed below.

130. As part of the feasibility study, the transaction technical assistance also developed an institutional strengthening plan, which outlines capacity-building tasks for each sector, covering the following areas 1) Improvement of the Regulatory Framework, 2) Improvement of the Institutional Arrangements, 3) Provision of managerial and technical programs, 4) increasing global knowledge of the communities.

2.1. Stormwater drainage

131. The improvements to the drainage are in themselves a climate change adaptation. By improving and rehabilitating drains, the ability of Poipet city to recover from high rainfall events will be improved. The master plan sensitivity analysis allowed for the design to maximize the utilization of road and canal reserves while minimizing the need for land acquisition and relocation. The sensitivity analysis determined that to allow for an increase in extreme rainfall events of 5%, the average pipe/channel section would need to be increased by 10%. The sensitivity analysis also showed a considerable difference in costs for infrastructure depending on which return period was used. By allowing for a projection of climate change for the short term, with review before the implementation of the long term, the proposed infrastructure was able to be designed for a 1 in 5 year event. The implications for the potential for maladaptation due to different climate change projections are discussed below in section VI.4.

2.2. Wastewater

132. The short term components of the wastewater infrastructure are focused on the urban areas. Pipes will be laid along road corridors and protection from localized flooding will be provided by a road easement design that includes the installation of appropriate drains designed to cater to the projected larger extreme event size. The proposed pumping stations are not located in areas identified as being currently exposed to localized flooding and the design of the housing that already incorporates protection from inundation will be sufficient.

133. Where pipelines cross streams or drainage canals, they will require protection from floods when drains are overtopped during rare extreme flood events greater than the designed 1 in 5 year events. The protection of pipelines from higher flood levels will be carried out as part of the design of bridge crossings that should already provide protection from flooding.

134. 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.

135. To minimize impacts, the WWTP will be built with flood protection measures incorporated including perimeter barrier/topographic constraints. Additionally, road structures are scheduled to be developed on dykes for maintenance needs. Additional tree planting could be considered after site development to reduce the rainfall-runoff.

2.3. Solid waste

136. The solid waste facilities are not exposed to climate change impacts. However, the stormwater management system design for the landfill will be designed using the current extreme rainfall event size +5%, adding an extra 2% to the costs. The majority of the leachate will be recirculated back into the landfill mass, with the excess being sent off-site for treatment at the WWTP. The projected increase in extreme event rainfall of 5% is not expected to have a large impact on this process as the extra leachate produced will be within the designed capacity redundancy and excess leachate can be pumped back into the landfill.

3. Prioritization of measures

137. The present socio-economic condition of the city increases the community's sensitivity to hazards. And while the National Government has made steps to developed 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 low to moderate impacts on the project infrastructure. Additionally, the project is designed to increase the resilience of the city to climate change and disasters. Therefor all infrastructure is intended to be climate change proof and where vulnerabilities were identified, all of the necessary adaptions are incorporated into the design. The following section outlines the most critical adaptations that were incorporated.

4. Assessment of maladaptation risks associated with proposed measures

138. 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.

139. 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 infrastructure for the long term, there is no need to commit to the largest sized infrastructure possible. Additionally, the largest size for drainage infrastructure could be achieved while minimizing the relocation of households. The drainage plan in phase 1 is focused on improving drainage for the most urbanized areas, with drainage lines proposed for less urbanized areas at the medium phase. The long-term plan includes a review of the performance of phase 1 and 2 infrastructure, allowing for adjustments in the layout or sizing of any new infrastructure.

140. The proposed works for the urban infrastructure focuses on improving connectivity and performance of existing box culverts as a system, so sizing is related to the existing components. The proposed open channel drainage lines are similar to the existing canals that can be widened in the future if necessary. The WWTP is also designed with a staged approach and a review is proposed in the long term (2030-2040). At this stage, the amount of wastewater that needs to be treated will be reassessed, and the ability of the WWTP storm water management system to cater to extreme rainfall events can be assessed and redesigned based on the most up to date climate change projections. The solid waste treatment plant is proposed to be developed as a series of cells to be constructed at various stages with the function of each cell and ability to cope with leachate and rainfall quantities to assessed before the final design and construction of the next.

141. 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. In designing drainage for a city that is located on very flat terrain, one difficulty is allowing for enough fall to generate gravity flow and developing adequate drainage cross sectional area to cater to projected water volumes. Sensitivity analysis carried out during the design of the drainage for Poipet indicated that to cater to an increase in rainfall of 5% would require drains to be 10% larger, with an ever-increasing size needed for higher design rainfalls.

142. In many cities the higher standard for urban drainage pipes and channels of 1 in 5 year design is now used and it is considered an affordable balance between drainage infrastructure costs and reduced flood damage. Therefore, and as recommended in the national Road Design Standard (MPWT, 2003), the master plan recommended that the urban drainage of the city be design for a capacity for 1 in 5 year storm runoff. The use of the average of the outputs from an ensemble of climate change models has been shown to more adequately reproduce baseline climate statistics. Additionally, RCP8.5 is generally used as the business as usual case and RCP4.5 as the best case. Therefore, the current IDF curves are adjusted by 5% based the median extreme rainfall projected for 2040 from an ensemble of GCMs modelling RCP8.5.

143. The staged approach gives urban designers the chance to assess the performance of stage 1 infrastructure that has been designed to deal with a 1 in 5 year rainfall adjusted by 5% to allow for projected climate change. Additionally, the performance of the urban drainage infrastructure as a system in reducing localized flooding can be assessed. 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.

144. Potential maladaptation related to each project component is summarized in Table 22.

Table 22: Potential Maladaptation Measures for Each Project Component.

Component	Possible Maladaptation	Comment
Wastewater	May commit capital and institutions to trajectories that are difficult to change in the future	Design of proposed site taking into account planning for staged increase in capacity with review. Planned comprehensive sewage increases resilience and has positive CO_2 balance.
Stormwater	Insufficient for extreme events in the future	Design incorporates projected future extreme rainfall for the high CO_2 RCP8.5 scenario for 2060
	Over designed infrastructure committing MA to high financial burden	Design of proposed infrastructure taking into account planning for staged implementation with review.
Solid Waste	May commit capital and institutions to trajectories that are difficult to change in the future	Planned comprehensive waste management and recycling increases resilience and has positive CO_2 balance. LFG wells and collection infrastructure are designed with simple flue with the ability to move to power generation as institutional capacity increases.
	Insufficient for extreme events in the future	Ensuring proper drainage system at the landfill area including the increase of rainfall event by 5%
	Provision of disposal site catering to the business-as-usual habit of waste generation could inhibit the goal of waste minimization.	Provision of engineered sanitary landfill to address the problem of solid waste, recycling facilities and MFRs will provide a demonstration of best practice

5. Climate change adaptation costs

5.1. Direct Costs

145. The cost of climate proofing the project components are presented in Table 23. The sensitivity analysis carried out during the Master Plan stage determined the potential cost of incorporating climate change adaptations. This analysis determined that the average pipe/channel section would need to be increased which expanded the construction cost by 2% and this figure was used to determine extra costs to all drainage components of the infrastructure proposed for the feasibility stage. It should be noted that there have been substantial changes to stormwater infrastructure between the Master and Feasibility stages, however it is expected that the figure of 2% is still representative of the expected increase in cost for all drainage infrastructure. The total cost for the proposed adaptations is $382,688.

Table 23: Proposed Adaptation Measures and Costs for Each Project Component

Infrastructure Component	Proposed Adaptation Measures	Target Climate Risk	Estimated Adaptation Costs ($)
Wastewater	Increase capacity of stormwater management system	Extreme rainfall 5% larger	5% increase in size of stormwater lagoon $2,441 2% increase in CAPEX for drainage $1,000
Stormwater	Increase size of drainage network	Extreme rainfall 5% larger	2% increase in CAPEX $345,384
Solid Waste	Increase capacity of stormwater management system	Extreme rainfall 5% larger	2% increase in CAPEX for drainage $1,000

5.2. Proportional Costs

146. In many cases the proposed infrastructure is itself a climate change adaptation. 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. Improvements to the infrastructure to reduce the amount and length of localized flooding is a primary adaptation option to cope with the projected increase in localized flooding. Improving flood management will reduce standing water and reduce health impacts. The project will also produce flow on benefits of improvements to the functioning of all of the other urban infrastructure in the City. Successful completion of this project will increase resilience by reducing flooding in Poipet, but the proposed modifications to existing infrastructure are required now to reduce the localized flooding that currently occurs after heavy rain. Moreover, the options suggested for reducing the impact of higher intensity rainfall events on existing storm water drainage infrastructure, should be standard operating procedure for a good maintenance program. However, the improved connectivity, planning and maintenance capacity will improve the resilience of Poipet, and a proportion of the costs can be considered to contribute to climate change adaptation.

147. The provision of a WWTP and associated pipe works and pumping stations will decrease the vulnerability of Poipet city and improve the ability of households to recover, by decreasing the number of households exposed to wastewater during localized flooding events. However, the planning and provision of adequate wastewater service should be part of any city's infrastructure. Similarly, the provision of solid waste management infrastructure should be expected to be part of urban infrastructure. But the design and construction of a landfill that is climate change resilient is an important a climate change adaptation. The apportionment of costs of project infrastructure to climate change is presented in Table 24. As discussed above, the provision of adequate drainage system is an important adaptation so 30% of the cost are considered to be climate change adaptation. The provision of properly treated wastewater and solid waste management infrastructure are considered a Municipal responsibility, but by ensuring it is planned and by incorporating phased revisions and implementation, 30% of the costs are considered to contribute to climate change adaptation. The inclusion of the composting facility contributes to the cities GHG commitments and can be considered to be a climate change adaptation. The total cost of proportional adaptation is estimated at $18,067,624.

Table 24: Proportion of Each Activity Related to Climate Change and the Proportional Cost Towards Adaptation

Activity	Result	Proportion	Costs ($)
Wastewater			
Provision of properly treated wastewater	Decrease the sensitivity of the City and improve the ability of households to recover, by decreasing the number of households exposed to wastewater during localized flooding events	30%	$11,903,691
Stormwater			
Rehabilitation and expansion of the drainage system to improve connectivity and increase the efficiency of the system	Decrease the exposure of the City to flood hazards by reducing blockages	30%	$5,275,364
	Minimize flood damage through efficient and quick removal of floodwaters		
	Decrease the sensitivity of the community by reducing negative health impacts		
Construction of well-designed outlets	Minimize flood damage through efficient and quick removal of floodwaters Decrease the sensitivity of the community by reducing negative health impacts		
Provision of green spaces around the existing water bodies	Improve infiltration into groundwater, improve air quality and will contribute to mitigation		
Capacity building to use specialized equipment and to develop and carry out a maintenance program	This will make an immediate improvement to drainage functioning and will become progressively more important as heavy rainfall events become more likely		
Solid Waste Management			
Proper management and disposal of solid waste in landfill	Increase the resilience of the population by improving the health and wellbeing by reducing exposure to unhealthy waste	30%	$888,570
	Minimize health risks due to exposure during both flood events and drought		

Activity	Result	Proportion	Costs ($)
Removing waste blocking the drainage system	Decrease the extent and length of flood events		

VII. MITIGATION

1. Contribution of project components to climate change

148. The project will contribute to CO_2 emissions as infrastructure materials are made, transported, and installed. The operation of pumping stations for sewage collection, wastewater treatment and the treatment of solid waste will also contribute to CO_2 emissions. The transport of the landfill leachate to the WWTP will also produce CO_2. The compost process uses diesel fuel to manage the piles and transport materials. However, professionally managed treatment of wastewater and solid waste and the focus on recycling, LFG collection and development of a composting facility will all reduce emissions of N_2O and CH_4. Improved functioning of the Cities drainage network will reduce GHG emissions from stagnant water due to improved flows and connectivity. Additionally, the cost of the emissions are outweighed 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.

2. Proposed climate change mitigation measures

149. The Cambodian Government has a number of national strategies to reduce greenhouse gas emissions, and where possible these will be incorporated into the project. Some of the project components also contribute to lowering greenhouse gas emissions. 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[40]. General mitigation strategies will be used as part of the overall project strategy where possible such as the use of biofuels, light vehicle technologies, electric vehicles. The project will contribute to mitigation by promoting the use of solar operation at the infrastructure site.

150. The waste management project components, including LFG collection with a flare stack, composting of organic waste; controlled wastewater treatment; recycling and waste minimization are greenhouse gas emission reduction strategies. In particular emissions of the more potent greenhouse gases Methane (CH_4) and Nitrous oxide (N_2O) from anaerobic decomposition will be reduced. Emissions of CO_2 and pollutants from burning rubbish will be reduced. Trees that are planted as part of the development will act as a CO_2 sink.

151. Mitigation options for specific infrastructure components are developed below.

Wastewater

152. The equipment and utilities to be used in the WWTP will be energy efficient such as LED lights, high EER rating air conditioning units, machines, and others to ensure minimum electricity/power consumption. The power requirement for the utilities including building, lighting, automatic valves, lift system, and air conditioning including process cooling production for air blower is 52,560 kWh annually.

[40] Ministry of Environment. 2016. Climate Change Action Plan 2016-2018. Phnom Penh, Cambodia

153. Solar power through the use of photovoltaic modules could be used to compliment the power requirements of the WWTP. The WWTP process in Poipet required too much energy (764,532 kWh annually) to propose a reasonable PV panel solution. The photovoltaic modules will be placed on a metallic structure near the buildings in the WWTP to cover part of the non-process items energy consumption. The solar power is a 90 kWp system with a capacity to produce a total of 77,015 kWh annually. Due to the shift between solar radiation hours and WWTP energy need, only 54% of the power needs of the WWTP non-process equipment (i.e. 28,470 kWh annually) will be met by local solar production with the rest to be purchased from the electric grid. At this stage, the surplus photovoltaic electricity is not considered to be resold to Electricité Du Cambodge (EDC). However, further negotiations with EDC could provide a new source of revenue for the operator and reduce the burden of electricity consumption. The cost of implementation (panels supply, installation and metallic structure) is $148,500.

Solid Waste

154. The equipment and utilities to be used in the Sanitary Landfill will be energy efficient such as LED lights, high EER rating air conditioning units, machines, and others to ensure minimum electricity/power consumption. The power requirements for the utilities including building, lighting and air conditioning including process cooling production for air blower is 83,380 kWh annually. Leachate disposal equipment at the landfill requires an annual power of 35,040 kWh. At this stage the use of low emission trucks is not an option due to the high cost and lack of hydrogen infrastructure needed for the high power consumption for compactors.

155. Solar power through the use of photovoltaic modules could be used to compliment the power requirements of the Landfill building and Leachate Disposal. The photovoltaic modules will be placed on a metallic structure near the buildings of the new landfill. The solar power is a 130 kWp system with a capacity to produce a total of 118,420 kWh annually. Due to the shift between solar radiation hours and energy need, only 69% of the power needs of the Landfill non-process equipment (i.e. 60,000 kWh annually) and 77% of Leachate disposal (i.e. 26,980kWh annually) will be met by local solar production with the rest to be purchased from the electric grid. At this stage, the surplus photovoltaic electricity is not considered to be resold to Electricité Du Cambodge (EDC). However, further negotiations with EDC could provide a new source of revenue for the operator and reduce the burden of electricity consumption. The cost of implementation (panels supply, installation, and metallic structure) is $214,500.

156. Two further measures to reduce GHG emissions are integrated into the project:

(i) **LFG capture.** The sanitary landfill will have an LFG management system with LFG wells in the waste mass and a flare stack for direct combustion of the LFG. It is estimated that by 2040 up to 184 m^3 of methane will be captured from the landfill per hour. In the initial stage of the project, it is recommended that active venting with a flare stack be used for ease of operation with a view to installing electricity installation in the future. Both of these options will convert methane into CO_2. As methane produces 28 times more greenhouse warming than CO_2, the conversion of the estimated N_2O emissions to CO_2 equates to a reduction in greenhouse potential of 31,661 kg CO_2e.

(ii) **Composting Plant.** There are currently no existing composting options at the landfill. The design at the new SWM includes a windrow composting plant using green waste from parks and gardens that are shredded and mixed up with biowaste from markets. Well run composters emit little methane and N_2O, hence, this is part of the high methane generation potential part of the MSW which will not be landfilled and will be treated in such a way as to achieve almost 100% degradation with minimal extra atmospheric GHG emissions. Additionally, the use of the compost will contribute to carbon sequestration. It is difficult to calculate the CO_2 emission reductions until the exact design and size of the composting plant and the makeup and moisture content of the feedstock is determined but it is estimated that 3,793 t/y of material will be composted by 2025 saving about 3,700 kg of CO_2e.[41]

3. Prioritization of measures

157. All measures that are financially feasible will be incorporated.

4. Climate change mitigation costs

158. The cost of climate change mitigation incorporated into the project components are presented in Table 25. As the composting plant reduces emission of the more potent GHGs methane and nitrous oxide it can be considered a mitigation. Similarly, the LFG flue converts methane and nitrous oxide to CO2 and reducing overall GHG emissions. The total cost for the proposed mitigations is $2,936,111.

Table 25: Proposed Mitigation Measures and Costs for Each Project Component

Infrastructure Component	Proposed Mitigation Measures	Estimated avoided GHG Emissions	Estimated Mitigation Costs ($)
Wastewater	Use of solar power through PV modules	46,035 k CO_2e/yr	$148,500
Solid Waste	LFG collection and flue	31,661 kg CO_2e/yr	$198,535
	Composting Plant	4,388 – 6,827 kg CO_2e/yr	$2,375,076
	Use of solar power through PV modules	10,658 kg CO_2e/yr	$214,000

[41] Based on conversion rate presented in Biala, J. 2011. The benefits of using compost for mitigating climate change. Depatment of Environment, Climate Change and Water NSW. Sydney.

APPENDICES

Appendix 1. Adaptive Capacity Assessment Table

1. 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 affected sector ▪ Affected people don't have their own resources to respond to a hazard
Technology	▪ There are 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 equipment 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 response in the event of a hazard 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 has to be formulate	▪ Few LGU officials and leaders are aware of the roles and functions during but 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.

Factor	Adaptive Capacity Level/Score				
	High (5)	Medium High (4)	Medium (3)	Medium Low (2)	Low (1)
Infrastructure	▪ There is more than adequate transport, water infrastructure, 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	▪ There is enough transport, water infrastructure, energy supply and medical service, etc. that can be used to respond to a hazard ▪ Facilities and equipment are available but not enough	▪ There are some infrastructure, transport facilities and necessary 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 has to be retrofitted to ensure its safety and strength during a hazard	▪ Infrastructures are available but there are no facilities that can be used to respond to a hazard ▪ Transport services in some possibly affected areas are not available	▪ Necessary infrastructures and facilities necessary to respond to a hazard still has to be constructed ▪ Existing infrastructures and facilities are not within 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 to 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 to 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 its potential impact ▪ No early warning system yet
Social Capital	▪ There is political willingness to allocate resources to build adaptive capacity of the LGU	▪ There is some degree of willingness of the leaders to allocate funds to build	▪ LGU have political willingness but still has to be convinced to allocate resources to build	▪ LGU officials still has to be convinced to allocate resources to build adaptive capacity of LGUs	▪ LGU officials still has to be oriented on adaptive capacity building

Factor	Adaptive Capacity Level/Score				
	High (5)	**Medium High (4)**	**Medium (3)**	**Medium Low (2)**	**Low (1)**
	▪ There are specific agencies, community groups and/or NGOs that have the mandate and skills to focus on the specific sector/area during occurrence of hazards ▪ There are trained emergency response teams for this sector/ area	adaptive capacity of the LGU ▪ Some agencies are and NGOs are available and have skills to assist specific sectors during occurrence of hazard ▪ There is a team with basic skills for emergency response	adaptive capacity of LGUs ▪ There are specific agencies and NGOs with mandate to assist affected communities but still lack skills to respond ▪ Team have been organized for emergency response	▪ There are limited number of agencies and NGOs with mandate and skills to assists occurrence of hazards ▪ Team for emergency response still to be organized	▪ Specific agencies still has to have clear mandate and plans to assist affected communities ▪ No NGOs with mandate and skills to help specific sector in times of climate hazards ▪ No policies or orders yet for the creation of the team for emergency response

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)?

2. 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