Climate Change Assessment

Project No. 50099
May 2018

Cambodia: Fourth Greater Mekong Subregion Corridor Towns Development Project

Project Climate Risk Assessment and Management Reporting Template

I. Basic Project Information	
Project Title:	Fourth Greater Mekong Subregion Corridor Towns Development Project
Project Budget:	$88.5 million
Location:	Cambodia: Kampong Cham, Kratie and Stung Treng Towns
Sector:	Water and other urban infrastructure and services
Theme:	▪ Strategic planning ▪ Environmentally sustainable growth ▪ Inclusive economic growth ▪ Gender equity and mainstreaming ▪ Regional integration ▪ Improving resilience to climate change ▪ Key urban infrastructure ▪ Governance strengthening and capacity development
Brief Description:	The Fourth Greater Mekong Subregion Corridor Towns Development Project (Project) will support the Government of Cambodia in enhancing the competitiveness of three towns along the Central Economic Corridor in the Greater Mekong Subregion, namely, Kampong Cham, Kratie and Stung Treng.
Output 1:	Urban Environmental infrastructure improved **1.1** Kampong Cham Subproject: a sewerage system comprising a new 5,050 cubic meter per day (m^3/day) lagoon-based wastewater treatment plant (WWTP) with 137 km pipelines, 4,676 household connections and pump stations, 4.3 km drainage channel, and a controlled landfill[1] with a volume capacity of 900,000 cubic meter (m^3) and waste collection vehicles **1.2** Kratie Subproject: a sewerage system comprising a new 4,900 m^3/day lagoon-based WWTP with 143 km pipelines, 2,688 household connections and pump stations, 12 km drainage channel, a controlled landfill with a volume capacity of 433,500 m^3 and waste collection vehicles, and pedestrian walk rehabilitation with energy-efficient street lights **1.3** Stung Treng Subproject: a sewerage system comprising a new 3,800 m^3/day lagoon-based WWTP with 147 km pipelines, 2,253 household connections and pump stations, a controlled landfill with a volume capacity of 291,000 m^3 including collection vehicles, pedestrian walk pavement rehabilitation with street landscaping and energy-efficient street lights
Output 2:	Institutional capacities and national infrastructure for enhancing regional economic connectivity enhanced.
Outputs 1, the infrastructure component, is the focus of the climate risk and vulnerability assessment. All infrastructure sites, except those for the controlled landfills, experience flooding each year, either fully or partially. The sites for the lagoon-based wastewater treatment plants (WWTPs) in all three towns, trunk sewers in Kampong Cham, and an 80-m wide open channel in Kratie are most vulnerable to climate change, being routinely waterlogged during the rainy season.	

II. Summary of Climate Risk Screening and Assessment
A. Sensitivity of project component(s) to climate/weather conditions and sea level
Cambodia's tropical monsoon climate is characterized by a rainy season and a dry season. The rainy season, which lasts from May to early October, accounts for 90% of annual precipitation. The dry season, from November to April, brings drier and cooler air from November to March, and then

[1] A controlled landfill has lined cells, soil cover layers, minimum leachate and gas treatment to control pollution.

<table>
<tr><td colspan="2">hotter air in April and early May. The geographical incidence of extreme weather events, such as droughts and floods, varies and while floods affect lowlands areas, the geographical distribution of droughts is widespread. Storms occur more frequently between August and November, with the highest frequency in October. The country is rarely exposed to the full force of typhoons as it is surrounded by mountain chains, which dissipate a typhoon's force.
The main climate factors that could have adverse effects on design, construction and operation of the infrastructure components are rainfall, temperature and wind, their variability and associated risks. Flood caused by heavy rainfall is a major natural hazard in the Project area and intensity of which can further increase with climate change. Increase in temperatures and longer hotter and drier days may cause lowering of groundwater resulting in land/ground subsidence. Stronger winds could impact on vertical elements or sub-components.</td></tr>
<tr><td>Project component</td><td>Sensitivity to climate/weather conditions and sea level</td></tr>
<tr><td>1. Lagoon-based wastewater treatment system
1. Municipal solid waste-controlled landfill
2. Town center enhancement</td><td>1. Increase in rainfall intensity and frequency resulting in increased incidence of flood and extent, and/or lengthening waterlogged period in the rainy season.
2. Temperature increase could lead to lowering of the groundwater table resulting in ground/land subsidence
3. Intensity and frequency of extreme winds, affecting vertical elements or sub-components</td></tr>
<tr><td colspan="2">B. Climate Risk Screening</td></tr>
<tr><td colspan="2">A climate risk screening was undertaken for the Project, using the AWARE for Project tool. Based on the screening, the project was assigned a "medium" risk rating. Flood was identified as high risk; precipitation increase and water availability as medium risk; and temperature increase, precipitation decrease and other variables as low risk. (See Annex A)</td></tr>
<tr><td>Risk topic</td><td>Description of the risk</td></tr>
<tr><td>1. Rainfall increase and associated flooding
2. Temperature increase and longer duration of hotter and drier days resulting in the lowering of the groundwater table leading to subsidence
3. Increased extreme wind events.</td><td>1. Rainfall increase could cause:
(i) increased risk of direct flood damage to treatment plant, pumping, conveyance and outfall;
(ii) increased risk of combined sewer network overload and more frequent and larger combined sewer overflow and discharge of untreated wastewater;
(iii) hastened deterioration of pipelines due to ground saturation and increased ground movement;
(iv) lower performance of the WWTP with too much influent; and
(v) increased stormwater to manage at the landfill site and increased leachate production.
2. Temperature increase could cause:
(i) pipe corrosion from biological reactions associated with warmer water;
(ii) increased pollution load of wastewater or receiving waters leading to operating challenges;
(iii) ground subsidence affecting the structural integrity of pipelines;
(iv) power outages during hotter and drier days disrupting WWTP operations;</td></tr>
</table>

	(v) increased risk of fire/explosion at the landfill; and (vi) heat stress on vegetation at completed waste cells. 3. Extreme winds could cause: (i) damage to exposed/vertical structures such as pumping stations, water tower tanks; (ii) erosion of side slopes of active and completed waste cells at the landfill; and (iii) power outages, disrupting WWTP operations.
Climate Risk Classification: Medium. (See **Annex A**)	
C. Climate Risk Screening	
1.	A CRVA was carried out for the Project. The vulnerabilities of the Project sites to disaster risk and climate change were observed during site visits and reviewed during consultations with local residents and Government agencies. Historical/observed climate data were obtained from the Department of Water Resources and Management (DOWRAM) for each of the Project provinces, the Second Integrated Urban Environmental Management in the Tonle Sap Basin Project of ADB, and the Climate Change Knowledge Portal of the World Bank Group website. Recent climate trends from relevant studies covering Cambodia and the Lower Mekong Basin, such as the UNDP Climate Change Country Profiles: Cambodia, were reviewed. **Annex D** provides a full list of references.
2.	A number of studies on the future trends of climate in Cambodia, in the Lower Mekong Basin and in the entire Mekong River Basin were reviewed. The rates of change from the following five selected sources were adopted: (i) McSweeney, C., New, M. & Lizcano, G. 2010. (ii) C.T. HOANH, Ki. JIRAYOOT, G. LACOMBE, V. SRINETR, 2010. (iii) Eastham, et al., 2008. (iv) ICEM, 2013, 2016. (v) The World Bank. Exploring Climate and Development Links. (Interactive map). **Annex D** provides the full list of references. The projected changes in mean annual temperature and precipitation from the above selected studies/sources were then applied to the obtained historical data to arrive at a range of probable mean annual temperature and precipitation in the future in the three Project towns.
3.	Projected rainfall intensities were obtained from the CRVA reports of two ADB projects, namely, the Rural Roads Improvement Project (RRIP) II, February 2018, and the Provincial Water Supply and Sanitation Project (PWSP), June 2017
4.	Future floods were sourced from the MRC Working Paper 2011-2015 on the Impact and Management of Floods and Droughts in the Lower Mekong Basin and the Implications of Possible Climate Change, March 2012. (See **Annex D** for the full list of references).
5.	Flood level and duration data, other than anecdotal, was not available during project preparation from the Municipality or Provincial Authorities when requested. (See Annex C for the full list of references).
6.	The findings of the climate risk assessment are:
6.1	Climate projections from the different models reviewed indicate increases in both temperature and precipitation.
6.2	The probable range of mean annual temperature between 2050 and 2060, would be for Kampong Cham, 29.1 to 31.4 ºC; for Kratie, 28.4 to 31.2 ºC; and for Stung Treng, 28.5 to 31.3 ºC (or a probable change range of 0.68 to 3.5ºC in the three towns). For mean annual rainfall, for Kampong Cham, from 1,560 to 1,751 mm; for Kratie, from 1,920 to 2,150 mm; and for Stung Treng, from 1,900 to 2,130 mm (or a probable change range of 68 to 313 mm in the three towns. These are the minimum and maximum across all results for the period 2050 and 2060 after adopting the projected changes from the five selected sources.

6.3	The projected increase in rainfall intensity during extreme event will not vary across the country. By 2030, during a 1 in 10-year event, the country will experience a 4% increase in 1-hour rainfall; by 2050, 7%. By 2030, during a 1-in 100-year event, the country will experience a 7% increase in 1-hour rainfall; by 2050, 12%. (PWSSP CRVA. 2017 June). The increases of a 1-day rainfall could be between 6-8% by 2030; 9-10% by 2050; and 28-34% by 2070. The increases of a 5-day rainfall could be between 9-14% by 2030; 16-20% by 2050; and 29-38% by 2090. (RRIP II CRVA 2018 February). Kampong Cham has been projected to experience extreme rainfall depth during a 1 in 10-year event of about 55 mm in1 hour; and during a 1 in 100-year event, about 74 mm in 1 hour, by 2050. (PWSSP, 2017 June)
6.4	Over the period 1985-2000 to 2042-2050, the mean annual high flow season discharge along the entire length of the Mekong River is projected to increase by 10-15%. This would impact on the mean annual "flood days" in the project towns. (Flood days are days with discharges greater that mean annual high flow season discharge.) In Kampong Cham, at mean high flow season discharge of 20,935 m^3/s, the mean annual number of flood days would rise to 95 days in 2042-2050 (from 91 days in 1985-2000). In Kratie, at mean high flow season discharge of 21,549 m^3/s, the mean annual number of flood days would rise to 93 days in 2042-2050 (from 88 days in 1985-2000). In Stung Treng, at mean high flow season discharge of 20,827 m^3/s, the mean annual number of flood days would rise to 93 days in 2042-2050 (from 88 days in 1985-2000). A comparison of the extent of flooding between that in the 2000 flood event and that of a large flood event in 2048 under a projected climate change state revealed an 8.8% increase in the extent of flooding (that is, flood depths above 0.0 m) in the 2048 event. This will increase with greater depths. For depths over 1.5 m, the projected increase will be 30-60%.
6.5	Project infrastructure components are considered at most risk from an increase in precipitation frequency and intensity, and associated flood risk. Temperature and extreme wind risks are considered lower risk and not likely to affect the performance of project outputs within the initial design life so are not considered further.
6.6	The CRVA has estimated the greenhouse gas (GHG) emissions from the operations of the controlled landfills and the wastewater treatment plants (WWTP) to emit a total of 39,879 tpy CO2-eq per year, contributed by each subproject as follows: (i) Kampong Cham 15,624 tpy CO2-eq; (ii) Kratie, 14,521 tpy CO2-eq; and (iii) Stung Treng, 9,734 tpy CO2-eq. **Table C.1** below provides a breakdown per component.[2] **Annex C** presents the procedure applied for the WWTP and the tool used for the controlled landfill.
6.7	Suggested measures to mitigate GHG emissions from controlled landfills include: (i) optimization of waste collection routes and service frequency; (ii) materials recovery at source to reduce the waste to be collected, hauled and deposited at the landfill; and (iii) composting at the landfill site. Using the IGES tool, a simulation was made to see how much emission would be saved if the aforementioned measures be implemented. The simulation revealed a reduction of greenhouse gas by 60%. (**Table C.1 and Annex C**)

[2] Used the following tools and procedures: (i) Emission Tool for Greenhouse Gas (GHG) Emissions from Municipal Solid Waste (MSW) Management in a Life Cycle Perspective. Nimala Menikpura. Janya Sang-Aru. Institute for Global Environmental Strategies (IGES). 2013; (ii) Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation. December 14, 2010. RTI International (Research Triangle Institute).

Table C.1 Estimated GHG Emissions for the Project (tonnes per year)

A. Kampong Cham Subproject	
Component	Estimated GHG emissions tpy CO2-eq *
WWTP	2,466.40
Controlled landfill	13,157.42
Total – Kampong Cham	15,623.82
B. Kratie Subproject	
Component	Estimated GHG emissions tpy CO2-eq *
WWTP	2,544.07
Controlled landfill	11,977.29
Total – Kratie	14,521.36
C. Stung Treng Subproject	
Component	Estimated GHG emissions tpy CO2-eq *
WWTP	1,683.65
Controlled landfill	8,048.90
Total – Stung Treng	9,733.55
D. Project	
Total	39,878.73

* Tools/procedures used:
- Research Training Institute International. 2010. Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source. Categories: Solid Waste Disposal. Wastewater Treatment, Ethanol Fermentation. Submitted to the US EPA.
- Institute for Global Environmental Strategies (IGES). GHG Calculator for Solid Waste Sector – IGES Tool.

6.8 Suggested measures to mitigate GHG emissions from lagoon-based wastewater treatment include: (i) ensuring energy efficiency in operations, e.g. through biogas recovery from the anaerobic ponds for use in operations and using of energy-efficient lights and other equipment; and (ii) establishing a perimeter buffer strip with densely planted with trees at the site. At this stage, it is not possible to calculate GHG savings.

Subproject	**Emission (tpy CO2eq)**		
	From operation	**With composting, etc. ***	**Savings**
Kampong Cham	13,157	5,357	7,800
Kratie	11,977	4,564	7,414
Stung Treng	8,050	3,112	4,938
Total	33,185	13,032	20,152

* Emission generated based on the following:
- Composting 300 tonnes per month for Kampong Cham and Kratie (which would be 18% and 19.8% of waste generated daily).
- Composting 200 tonnes per month for Stung Treng (or 19.7% of waste generated daily.
- Collection frequency of every other day (except for market waste).
- Used the IGES tool in estimating the GHG emissions. See **Annex C**.

III. Climate Risk Management Response within the Project

The preliminary engineering design incorporates the following climate resilience measures:

1. The current urban drains in Cambodian provincial towns have been laid over a period spanning 50 years or more, often without connectivity to other drainage assets or with a consistent grade. Preliminary engineering design has adopted a 1 in 2-year flood event as

	the basis of design. Higher factors of safety were considered but it was determined that this would make the pipes too large and expensive (as they would need to be imported and transported by land). In addition, when the pipes are bigger than needed for most of the time, the flow velocities are lower, so they get full of sediment and require more maintenance. The old drains will be replaced with new combined sewers that comprise 1000-1500m diameter pipes, box culverts and open channels. The open channels and box culverts have been specified to accommodate flows expected to be greater than those that can be conveyed with pipes.
2.	Combined sewer overflows (CSOs) will be included in the combined sewer system for the wastewater volume beyond maximum design flow.
3.	WWTP inlet controls will only allow the maximum design flow.
4.	For all three WWTPs, the plant will be raised an additional 1m above flood level.
5.	The bunds for the 80-m wide open channel in Kratie will be raised extra 2m.
6.	Access roads to the WWTPs in all three towns will be concrete instead of DBST, with larger drains to increase resilience to inundation.
7.	Operation manuals will be prepared for the combined sewer systems, WWTPs and landfills, that incorporate mechanisms to prepare for and respond to emergencies during extreme weather events.
8.	Detailed analysis of historical and future flood levels will be conducted to determine the appropriate factor of safety for bunds around WWTPs.
9.	Opportunities to introduce green infrastructure features into the Project will be explored during the detailed engineering design phase, such as availing of public parks and open spaces, temporary storage (detention areas) and allowing infiltration.
10.	At this conceptual design stage, the estimated incremental cost of disaster risk reduction and climate change adaptation measures is USD 3.02 million. For the infrastructure component, it means 3.7% of the total infrastructure costs. This includes the following: (i) for Kampong Cham, USD 494,500; (ii) for Kratie, USD 1,448,800; (iii) for Stung Treng, USD 276,280 and (iv) overall planning activities USD 800,000. These measures and costs will be further refined during the detailed design.

ABBREVIATIONS

ADB	Asian Development Bank
ARCC	Adaptation and Resilience to Climate Change
CRVA	Climate Risk and Vulnerability Assessment
DJF	December January February
DOWRAM	Department of Water Resources and Management
GHG	greenhouse gas
GMS	Greater Mekong Subregion
GMS-CTDP-4	Fourth Greater Mekong Subregion Corridor Towns Development Project
HDPE	high-density polyethylene
LID	low-impact development
MRC	Mekong River Commission
NR	National Road
PPTA	Project Preparatory Technical Assistance
PRECIS	Providing Regional Climates for Impacts Studies
RC	regional center
SON	September October November
UNDP	United Nations Development Programme
UNDP/GEF	United Nations Development Programme/Global Environmental Finance
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WWTP	wastewater treatment plant

WEIGHTS AND MEASURES

CO_2-eq	carbon dioxide equivalent
ha	hectare/s
km	kilometer/s
m	meter/s
m^3	cubic meter/s
mm	millimetre/s
tpy	tonne/s per year

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I. INTRODUCTION

1. This report is the Climate Risk and Vulnerability Assessment (CRVA) for the Fourth Greater Mekong Subregion Corridor Towns Development Project - Cambodia (or Project). The CRVA focuses on the infrastructure components of the Project. It aims to: (i) identify and assess the disaster and climate change risks to the Project and the vulnerabilities of the Project to climate change risks; (ii) identify disaster risk reduction and adaptation measures to manage the risks; (iii) identify the scale of, and measures to mitigate, climate emissions from the Project; and (iii) ensure that disaster risk reduction and adaptation measures are fully considered and incorporated in the designs of infrastructure components under each Subproject.

2. The CRVA focuses on the climate change effects that are rated “high” and “medium” in the climate risk screening using the AWARE for Project tool. These are flood, precipitation increase and water availability (associated with temperature increase). Temperature increase and increase of wind speed, rated “low” risks and not likely to affect the performance of project outputs within the initial design life are not considered further.

A. Approach Taken

3. The CRVA was carried out following the steps in the Climate Risk Management Framework, 2014, of the Asian Development Bank (ADB) and with reference to the Climate Change Strategic Plan 2014-2023 of the Government of Cambodia, which mainstreams climate change across sectors at different levels in the medium term through the development of climate change action plans by line ministries and into national and sub-national programs in the long term.

4. Initial climate risk screening was undertaken by the ADB using AWARE for Projects Tool.

5. The vulnerabilities of the Project sites to disaster risk and climate change were observed during site visits and were partly obtained from consultations with local residents and Government agencies.

6. Historical/observed climate data were obtained from the Department of Water Resources and Management (DOWRAM) for each of the Project provinces, the Second Integrated Urban Environmental Management in the Tonle Sap Basin Project of ADB, and the Climate Change Knowledge Portal of the World Bank Group website. Recent climate trends from other relevant studies, covering Cambodia and the Lower Mekong Basin, such as the United Nations Development Programme (UNDP) Climate Change Country Profiles: Cambodia, were reviewed. (Annex C provides a full list of references.).

7. A number of studies on the future trends of climate in Cambodia, in the Lower Mekong Basin and in the entire Mekong River Basin were reviewed. The rates of change from the following five selected sources were adopted:

(a) McSweeney, C., New, M. & Lizcano, G. 2010.
(b) C.T. Hoanh, K. Jirayoot, G. Lacombe, V. Srinetr, 2010.
(c) Eastham, et al., 2008.
(d) ICEM, 2013, 2016.
(e) The World Bank. Exploring Climate and Development Links. (Interactive map).

8. Projected rainfall intensities were obtained from two ADB projects, namely the Rural Roads Improvement Project II and the Provincial Water Supply and Sanitation Project. Future floods were sourced from the Mekong River Commission (MRC) Working Paper 2011-2015 on the Impact and Management of Floods and Droughts in the Lower Mekong Basin and the Implications of Possible Climate Change, dated March 2012, Mekong River Commission.

9. Flood level and duration data, other than anecdotal, was not available during project preparation from the Municipality or Provincial Authorities when requested.

10. The key disaster and climate risks, vulnerability of Project components, and disaster risk reduction and adaptation measures were identified in co-ordination with the project preparatory technical assistance (PPTA) engineering team.

11. The probable mean temperature and precipitation in the future were derived by applying the projected changes from selected studies covering the country, Lower Mekong Basin and Mekong River Basin to inform the CRVA.

II. CLIMATE CHANGE INITIATIVES OF CAMBODIA

12. Cambodia's Rectangular Strategy Phase III 2013 places priority on stepping up cooperation with stakeholders in development under the framework of green growth and climate change in the next five years. The Cambodia Climate Change Strategic Plan 2014-2023, the first comprehensive national policy document responding to climate change issues, mainstreams climate change across sectors at different levels in the medium term through the development of climate change action plans by line ministries and into national and sub-national programs in the long term. As of 2015, 14 sectoral climate change action plans had been developed.

13. The Ministry of Environment has its Climate Change Action Plan 2016-2018 with 17 priority actions supporting the eight strategic objectives of the National Strategic Development Plan. A new Environment and Natural Resources Code of Cambodia, which was on the revised 9th draft form by end of July 2017, will soon replace the current Law on Environmental Protection and Natural Resource Management of 1996. The new Code will require the conduct of environmental impact assessment to include climate risk and vulnerability assessment of proposed projects.

- Cambodia released its National Adaptation Programme of Action to Climate Change[3] (NAPA) in December 2006. The NAPA presents a realistic and achievable country-driven programme of action and priority activities that addresses the needs of Cambodia for adapting to the adverse effects of climate change. Among the priority actions identified include rehabilitation of coastal protection infrastructure and development of drainage systems, among others.
- Cambodia's Intended Nationally Determined Contribution (INDCs) communicated to the United Nations Framework Convention on Climate Change (UNFCCC) on 30 September 2015 aims to achieve the objective of the UNFCCC as set out in its Article 2, that is, "to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." (UNFCCC. 1992) The INDCs consisted of five sections, the second

[3] Ministry of Environment, Royal Government of Cambodia, "National Adaptation Programme of Action to Climate Change", October 2006

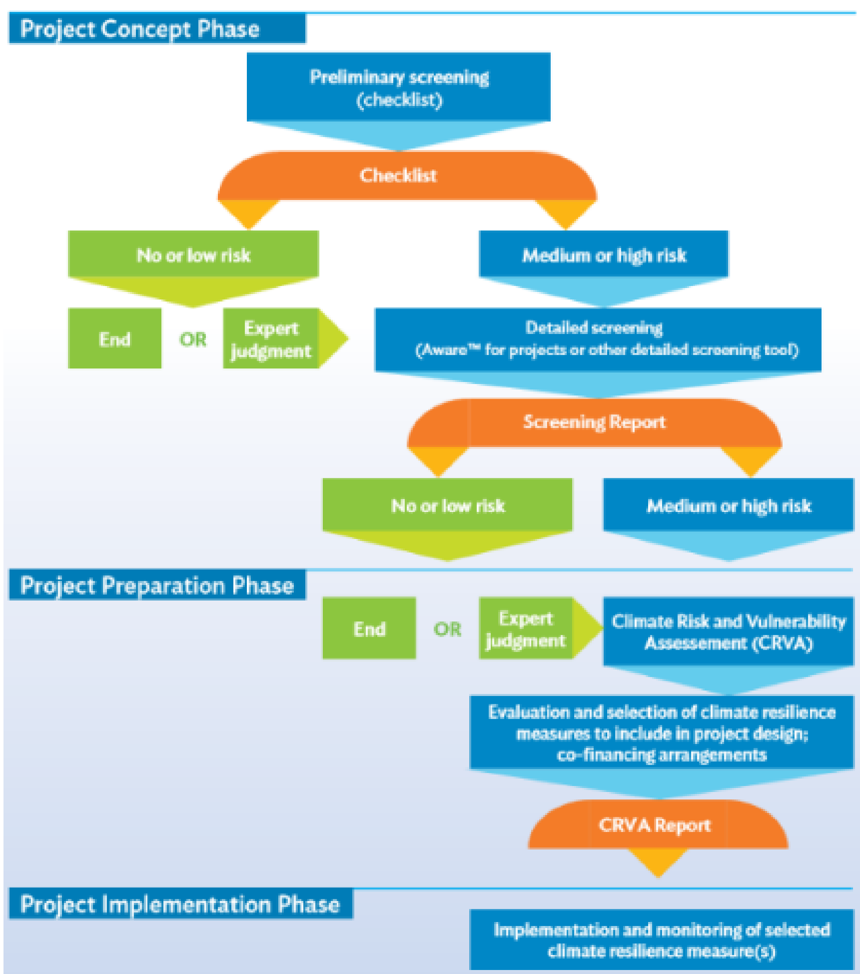
covers Adaptation covering the country's vulnerability to climate change and prioritized adaptation actions and the third of which was Mitigation, which included the country's intended contribution to reduce greenhouse gas emissions.

III. ADB ACTION ON CLIMATE CHANGE

14. ADB Action on Climate Change Midterm Review of Strategy 2020 of the Asian Development Bank (ADB) prioritizes the scaling up of ADB's support for climate adaptation and resilience in development planning and project design and implementation. ADB's Climate Risk Management Framework, 2014, aims to reduce climate risks to investment projects through the following steps **(Figure 1)**:

(i) Climate risk screening at the concept development stage to identify projects that may be at medium or high risk;
(ii) Climate change risk and vulnerability assessment during preparation of projects at risk;
(iii) Technical and economic evaluation of adaptation options;
(iv) Identification of adaptation options in project design; and
(v) Monitoring and reporting of the level of risk and climate-proofing measures.

Figure 1. Flow Chart for Climate Risk Management of Investment Project

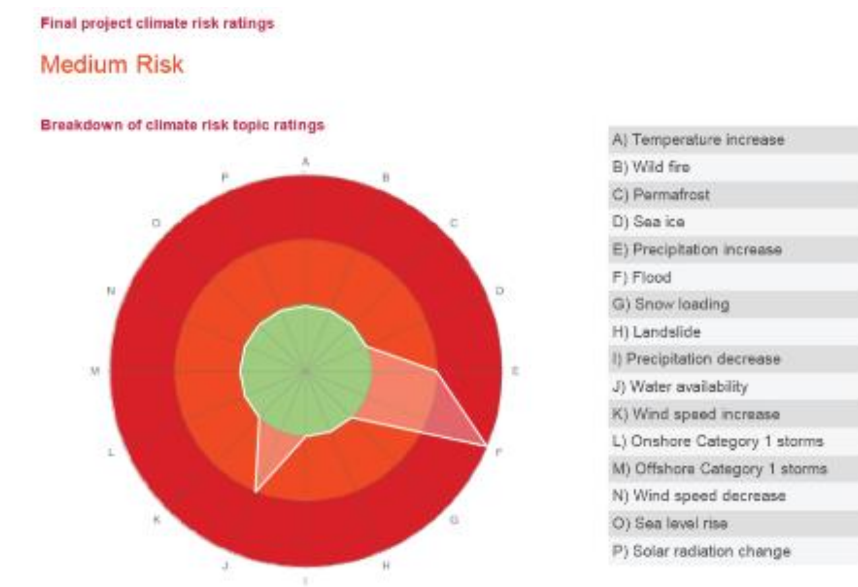


15. A climate risk screening was undertaken for the Fourth Greater Mekong Subregion Corridor Towns Development Project, using the AWARE for Project tool. Based on the screening, the project was assigned a "medium" risk rating. Flood was identified as high risk; precipitation increase and water availability as medium risk; and temperature increase, precipitation decrease and some other variables as low risk. All ADB projects rated medium or high require a more detailed CRVA. (**Figure 2**)

16. The identified adaptation measures in the CRVA will be subject to an evaluation on the basis of technical feasibility and economic viability. During project implementation, the most viable adaptation options or climate-proofing measures will be identified in consultation with the executing agency or project sponsors, and integrated in project design. The level of risk identified during project concept development, findings of the CRVA during project preparation, assessment and adaptation measures integrated in project design and associated incremental costs are documented for monitoring and reporting.

17. The ADB has published the Guidelines for Climate Proofing Investment in the Water Sector: Water Supply and Sanitation", intended to guide project preparation teams as they integrate climate risk management into the project cycle.

Figure 2. Climate Risk Rating of the Project – from AWARE for Project Tool



IV. THE PROJECT

18. The GMS-CTDP-4 (or Project) will support the Government of Cambodia in enhancing the competitiveness of three towns located along the Central Economic Corridor in the GMS, namely Kampong Cham, Kratie and Stung Treng. **(Figure 3)**.

19. The Project will deliver two outputs, the first is infrastructure output and is the main focus of this CRVA.

Output 1: Urban environmental infrastructure improved. The output will include: (i) a sewerage system comprising a new 5,050 cubic meter per day (m3/day) lagoon-based wastewater treatment plant (WWTP) with 137 km pipelines, 4,676 household connections and pump stations, 4.3 km drainage channel, and a controlled landfill with a volume capacity of 900,000 cubic meter (m3) and waste collection vehicles in Kampong Cham; (ii) a sewerage system comprising a new 4,900 m3/day lagoon-based WWTP with 143 km pipelines, 2,688 household connections and pump stations, 12 km drainage channel, a controlled landfill with a volume capacity of 433,500 m3 and waste collection vehicles, and pedestrian walk rehabilitation with energy-efficient street lights in Kratie; and (iii) a sewerage system comprising a new 3,800 m3/day lagoon-based WWTP with 147 km pipelines, 2,253 household connections and pump stations, a controlled landfill with a volume capacity of 291,000 m3 including collection vehicles, pedestrian walk pavement rehabilitation with street landscaping and energy-efficient street lights in Stung Treng.

Output 2: Institutional effectiveness, and policy and planning environment for regional economic connectivity enhanced. The output will strengthen governments' capacities by: (i) formulating provincial five-year strategic development plans; (ii) training on resilient town planning that incorporates climate change and disaster risks; (iii) improving staff capacity in critical areas (including urban service delivery, O&M of urban facilities, and managing public private partnerships); (iv) development of ICT-based public service and management systems including public asset management, and utility billing system for efficient and transparent government operations; and (v) raising public awareness on sanitation and environmental protection benefits

20. The towns of Kampong Cham, Kratie, and Stung Treng lie along National Road 7 and are located on the banks of the Mekong River.

21. The design and technology to be adapted for the lagoon-based wastewater treatment and controlled landfill components, and the facilities to be included for town center enhancement are broadly similar in the three project towns. A summary of the subproject designs relevant to all three town is provided below, followed by a more detailed discussion of the project outputs and components envisaged in each town.

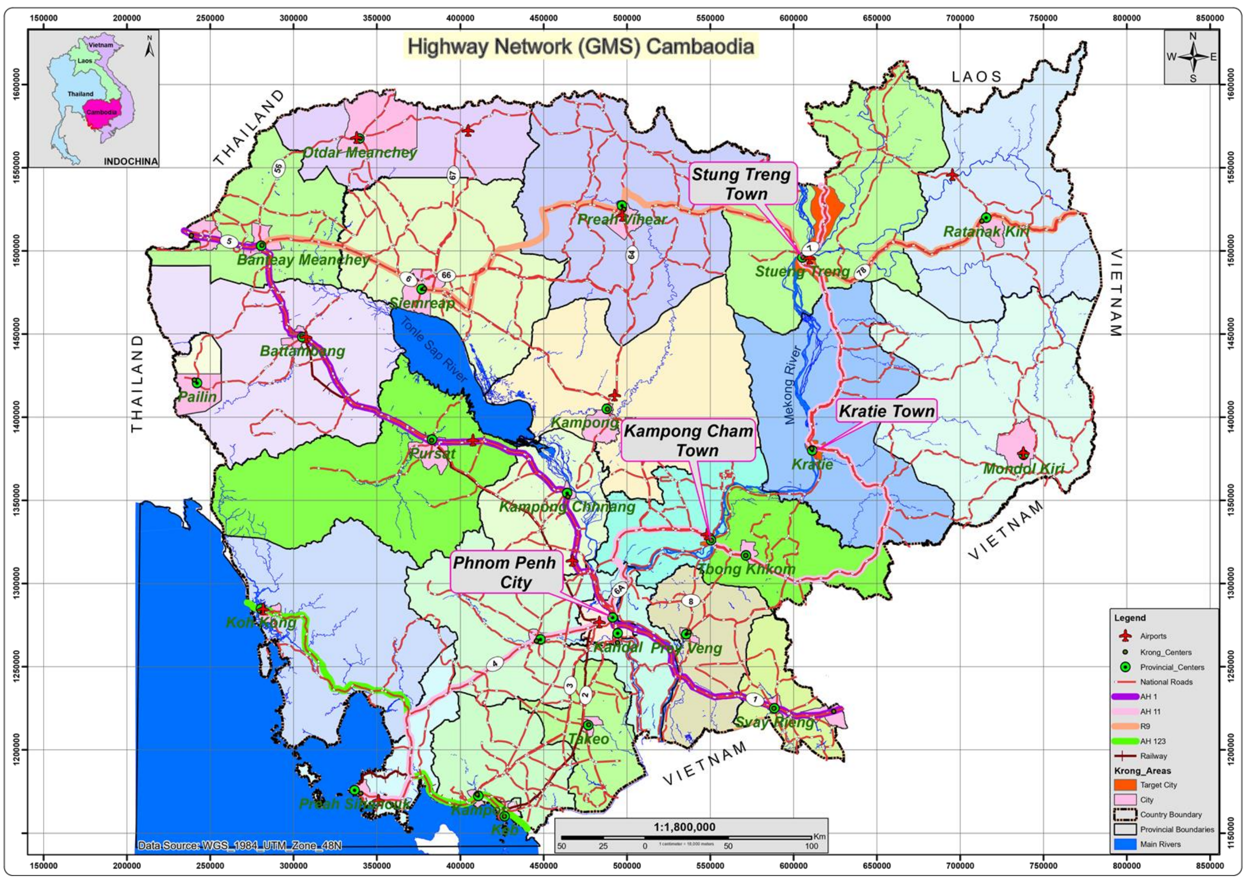
22. **Wastewater Treatment System Design and Technology.** A lagoon-based wastewater treatment system will be adopted which will comprise three sets of ponds connected in a series, starting with a deep anaerobic pond, moving through a facultative pond, and into a large and shallow maturation pond. The wastewater treatment facility will have the following features: (a) three (3) sets of lagoons in series comprising of four units of anaerobic lagoons, two (2) units of facultative lagoons, and two (2) units of maturation lagoons; (b) two (2) treated-sludge drying area; and (c) site office, equipment storage, parking area, site roads, and drainage. The combined sewer service area has been defined using main roads as boundaries to include the main urban area and any periphery residential areas of significance. The collection network will include main trunk sewers, collection pipelines along main roads, box culverts, open channels, and pumping stations.

23. **Controlled Landfill Design and Technology.** The controlled landfill will involve depositing wastes into lined cells, waste compaction and placement of soil cover in layers, leachate collection and recirculation. When full, waste cells are capped and planted. The proposed controlled landfill will be constructed with four lined cells. The capacity of the landfill can store waste up to 2040. The design will include provisions for leachate drains, leachate pump

for circulation, monitoring boreholes, sorting and recycling area, disposal and incineration area for hazardous wastes, access roads, water supply, site drains, site office with toilet, and perimeter fencing. The facility will also include equipment such as collection vehicles, bull dozer, and a crane.

24. **Town Center Enhancement.** Public amenities will be improved in Kratie and Stung Treng specifically near the riverside and market areas to enhance the recreational and tourism value of the town centers. Riverside improvements will include paving, kerbing, planting of trees, installation of streetlights, and provision of seating amenities, waste bins, and exercise equipment. The existing streets around the market connecting to the riverside will be cleared from encroachments and will be rehabilitated with new paving and kerbs, planting of trees, installation of street lights, and provision of waste bins.

Figure 3. Location of Project Towns in the GMS Central Corridor



A. The Kampong Cham Subproject

25. **Output 1.1:** The Kampong Cham Subproject has two components: (i) a lagoon-based wastewater treatment system, and (ii) a municipal solid waste controlled landfilled and equipment. Each component is described below.

26. **Kampong Cham lagoon-based wastewater treatment system.** This system includes both a combined sewer system (CSS) and a new wastewater treatment plant (WWTP). The proposed WWTP will be located within the 35-hectare Boeng Bassac area in Sambor Meas

Commune. The following will be delivered from the system under the project: (i) lagoon-based wastewater treatment facility with capacity of 5,050 m^3/d; (ii) 9.476 km trunk sewer/CSO with D1500 mm; (iii) 3.478 km trunk sewer/CSO pipes with D1200 mm; (iv) 2.156 km trunk sewer/CSO pipes with D1000 mm; (v) 0.756 km trunk sewer D 800mm; (vi) 0.687 km trunk sewer D 600mm; (vii) 120 km of wastewater collection pipes; (viii) 0.89 km box culverts 2-3m wide; (ix) 4.309 km open channels, 5-7m wide; and (x) four pump stations with a maximum capacity of 165 l/s.

27. The combined sewer system will be built in the main urban area, to serve the four (4) *sangkats*[4] of Kampong Cham and the target population within the coverage area as follows: (i) Krong Kampong Cham, 100%; (ii) Veal Vong, 100%; (iii) Sambor Meas, 50%; and (iv) Boeng Kok, 10% of the population. The proposed sewer system is designed as a single system to collect wastewater from domestic and commercial connections in the town center area, and storm water from the catchment areas, which will be pumped into the new WWTP by four pumping station units. The system will also allow septage to be co-treated in the WWTP. The final treated effluents from the WWTP will be discharged into the Boeng Bassac Lagoon, which has a stream connected to the Mekong River**. Figure 4** presents the proposed location for Kampong Cham's treatment plant.

28. The lagoon-base WWTP, to be developed on a 10-hectare public land parcel, is designed to treat wastewater and storm water flows up to 2040. **Figure 5** shows the conceptual layout of the WWTP facility.

29. **Kampong Cham municipal solid waste-controlled landfill and equipment.** This component will consist of a controlled landfill with volume capacity of 900,000 m^3 sized to receive generated waste from Kampong Cham until 2040. The new controlled landfill will be developed in an 11-hectare government-owned site located in Phkay Proek Village, Mien Commune, Prey Chor District, which is about 17 kilometers from Kampong Cham town center. **Figure 6** presents the proposed location of the landfill. **Figure 7** shows the conceptual layout of the facility.

30. The controlled landfill will include the following features: (i) four waste cells sized at 150m x 150m and 10 m deep, lined with compacted clay/earth and geomembrane high-density polyethylene (HDPE) recirculation system, (iii) sorting and recycling area, (iv) separate disposal and incineration area for hazardous wastes, (v) site office with toilet, (vi) water supply and monitoring bore holes, (vii) power supply, (viii) concrete access road (1.5 km and 4m wide) and all-weather site roads, (ix) site drains, (x) perimeter fencing, (xi) six waste collection and compaction vehicles and one crane. Existing dumpsites in Kampong Cham are privately owned. Hence, their closure has not been considered for inclusion in the Project.

[4] A sangkat is the Cambodian equivalent of a commune. Cambodia's sub-national administration consists of three tiers, namely: (i) capital city/province, (ii) district/municipality/khan, and (iii) sangkat/commune.

Figure 4. Proposed Combined Sewer Service Area and Location of Wastewater Treatment Plant in Kampong Cham

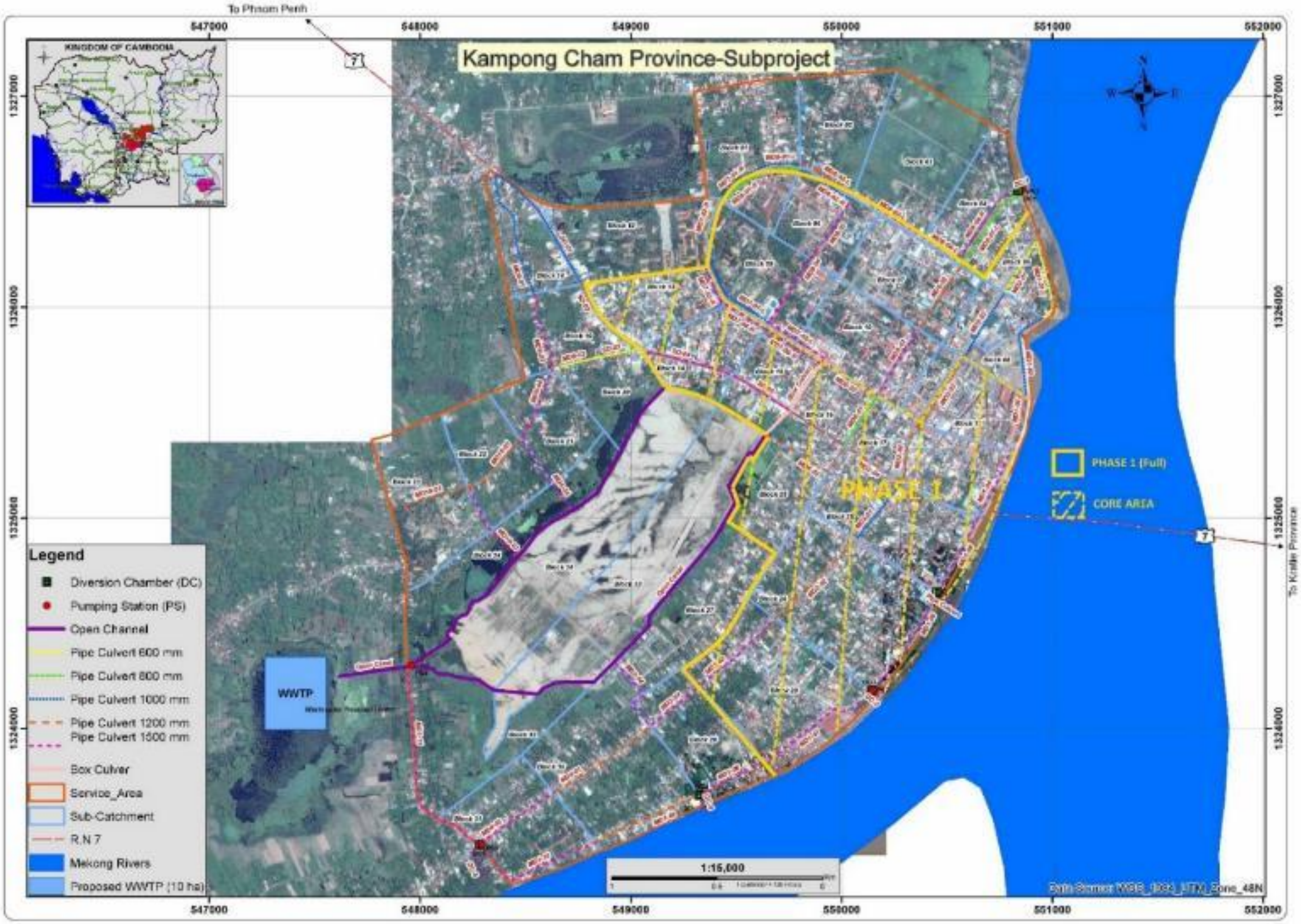


Figure 5. Conceptual Layout of the Kampong Cham Lagoon-Based Wastewater Treatment Plant

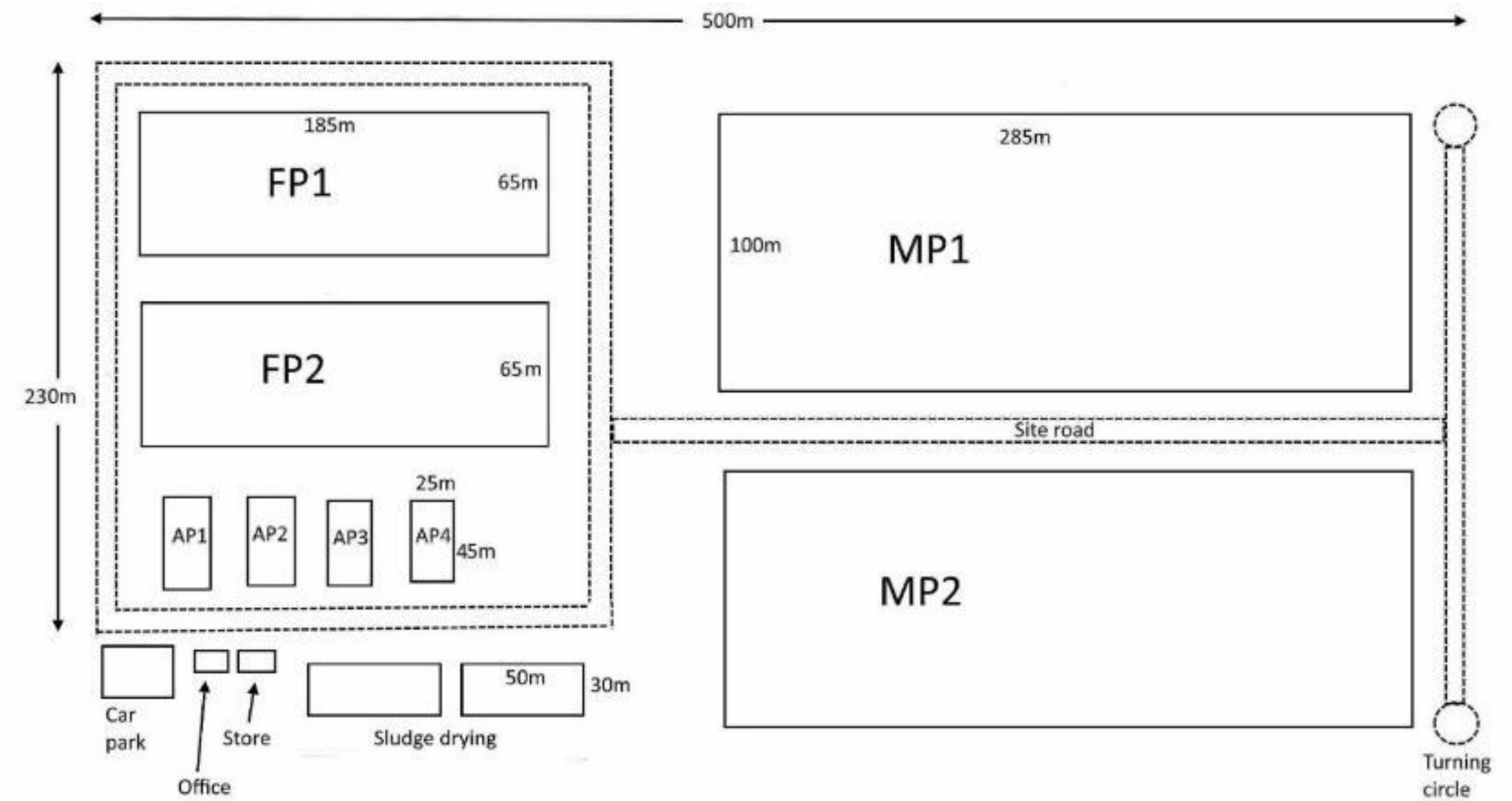


Figure 6. Location of the Proposed Kampong Cham Controlled Landfill

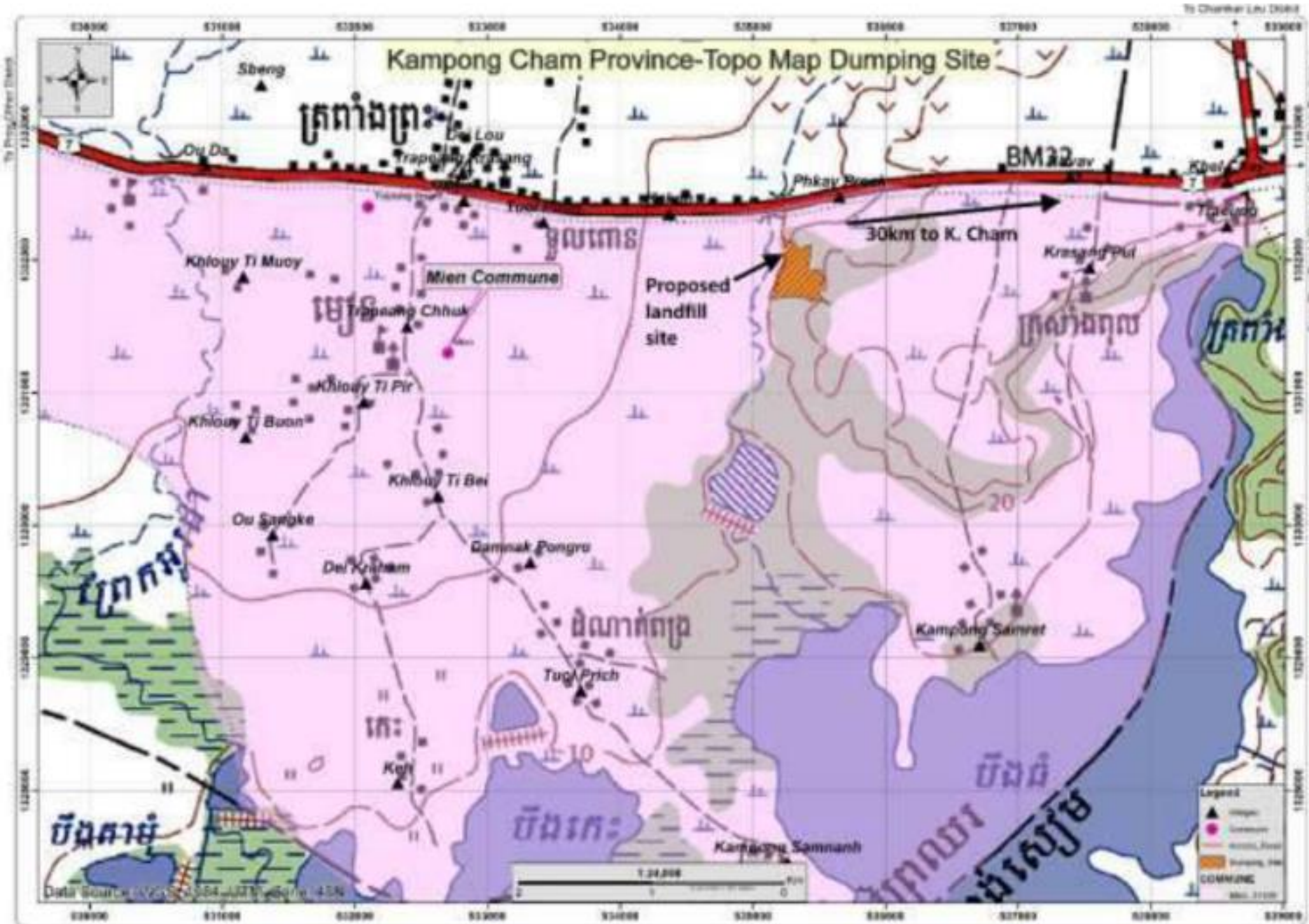
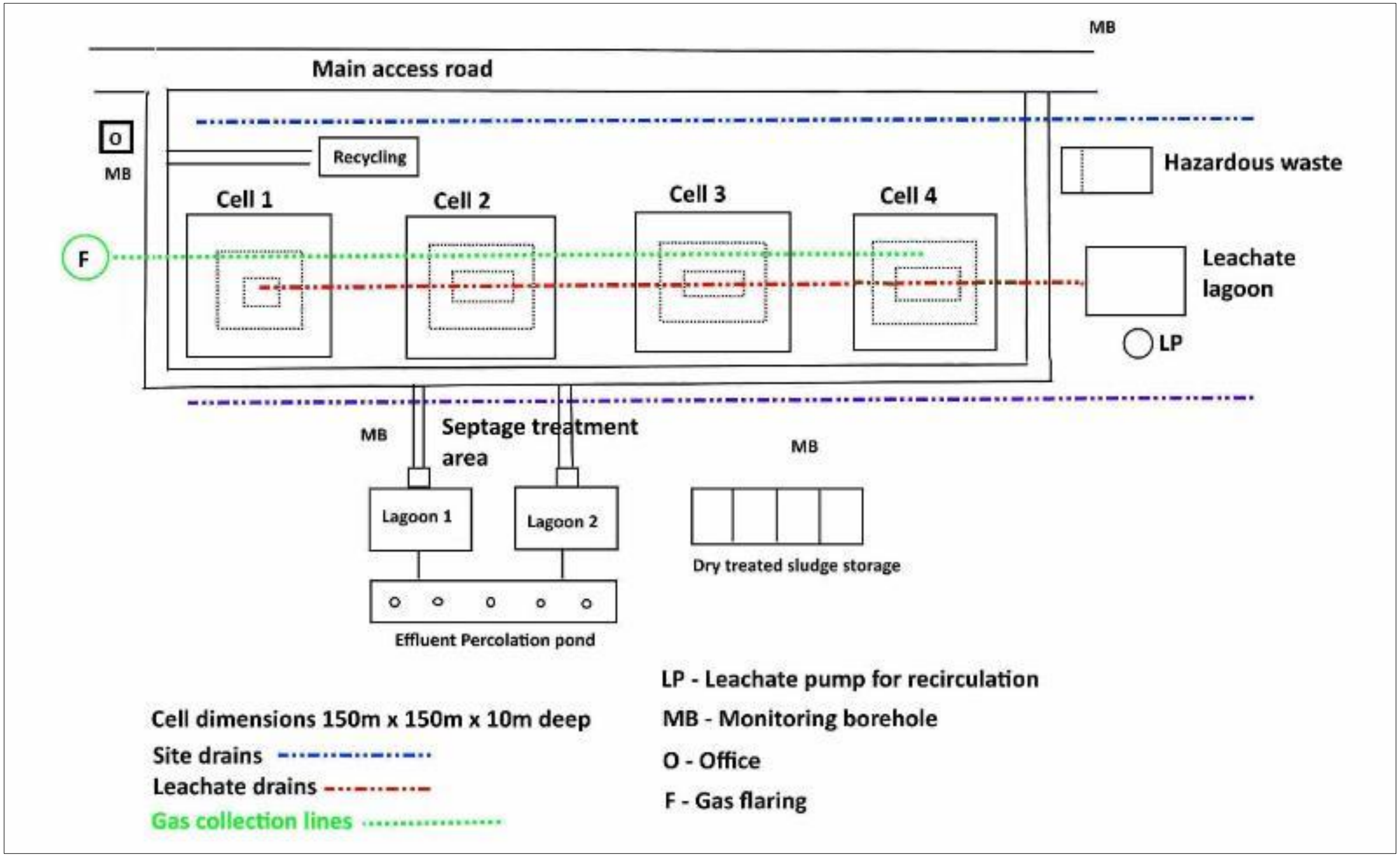


Figure 7. Layout for the Kampong Cham Municipal Solid Waste Controlled Landfill



B. The Kratie Subproject

31. **Output 1.2**: The proposed Subproject consists of three components: (i) a lagoon-base wastewater treatment system, (ii) a municipal solid waste controlled landfilled and equipment, and (iii) town center enhancement. Each of these is described below.

32. **Kratie lagoon-base wastewater treatment system**. This system will comprise a CSS and a WWTP and that will address the drainage requirements and the collection and treatment of wastewater from domestic and commercial sources in Katie's urban center. The following will be delivered from the system under the project: (i) lagoon-base wastewater treatment facility with capacity of 4,900 m^3/d; (ii) 4.722 km trunk sewer/CSO with D1500 mm; (iii) 0.603 km trunk sewer/CSO pipes with D1200 mm; (iv) 0.399 km trunk sewer/CSO pipes with D1000 mm; (v) 138 km wastewater collection pipes; (vi) two pumps stations with capacity of 245l/s; (vii) 1.1 km access road (10 m wide); and (viii) 1 bunded drainage canal (80m x 7m x 12000m, W-H-L).

33. The proposed combined sewer will include the main urban center along the Mekong River, and the new urban area eastwards along Road 377. The service area will cover parts of sangkats Krong Kracheh, Krakor, Ou Russei, and Roka Kandal, to serve 100%, 25%, 50% and 10% of their population, respectively. The location of the WWTP and the CSS service area are shown on **Figure 8**.

34. The WWTP will be constructed on a 10.5-hectare public land site, located to the southeast of the main urban area as shown on **Figure 8**. Initially designed to collect and treat storm water and wastewater until 2040, the WWTP may be extended either by acquiring further land for a parallel set of lagoons, or by retrofitting to increase the capacity such as the installation of aerators or trickling filters. The final treated effluents from the WWTP will be discharged into the nearby lagoon**. Figure 9** shows the features of the proposed WWTP.

Figure 8. Location of the Proposed Kratie WWTP, Combined Sewer System Coverage, and Existing Dumpsite

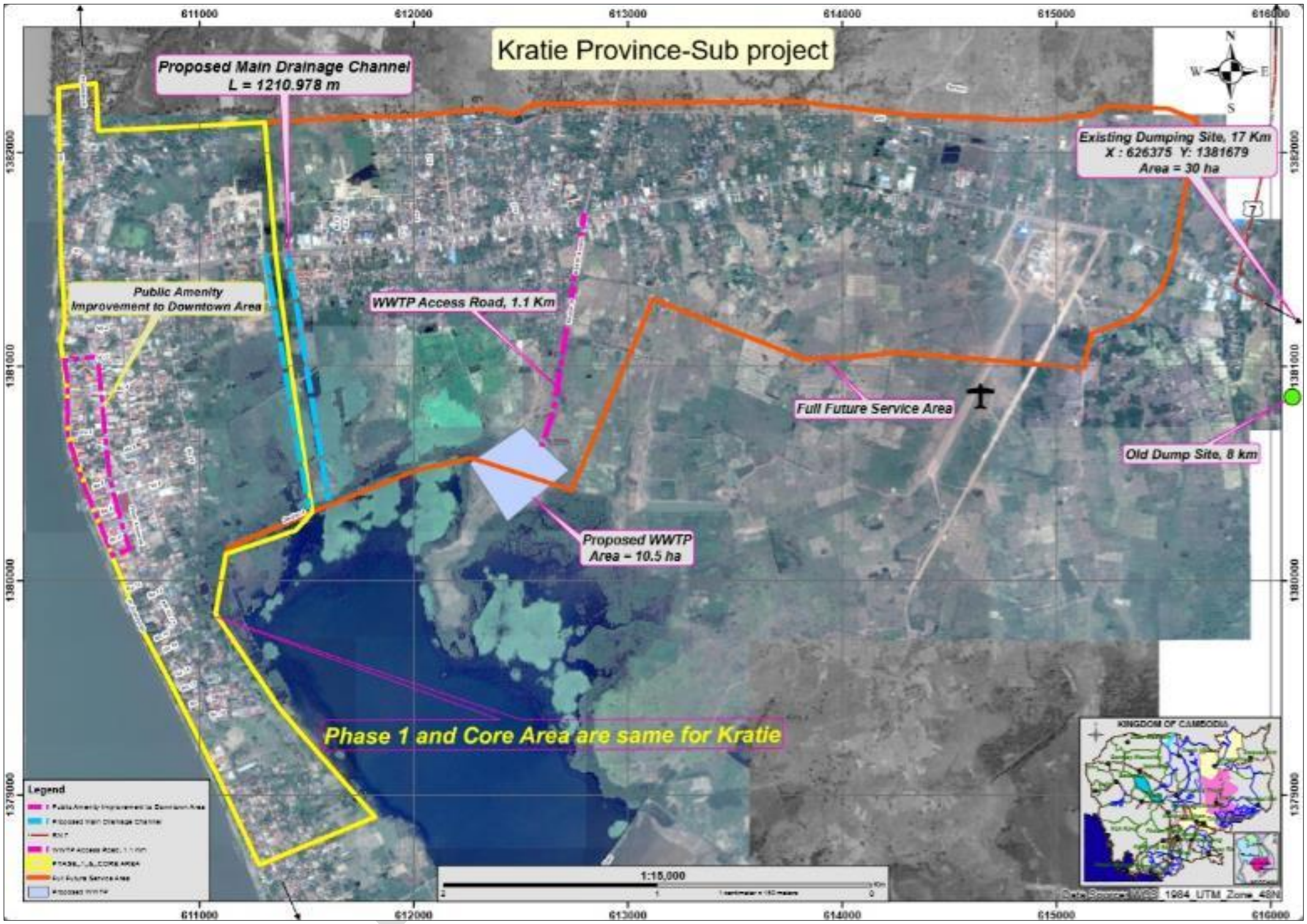
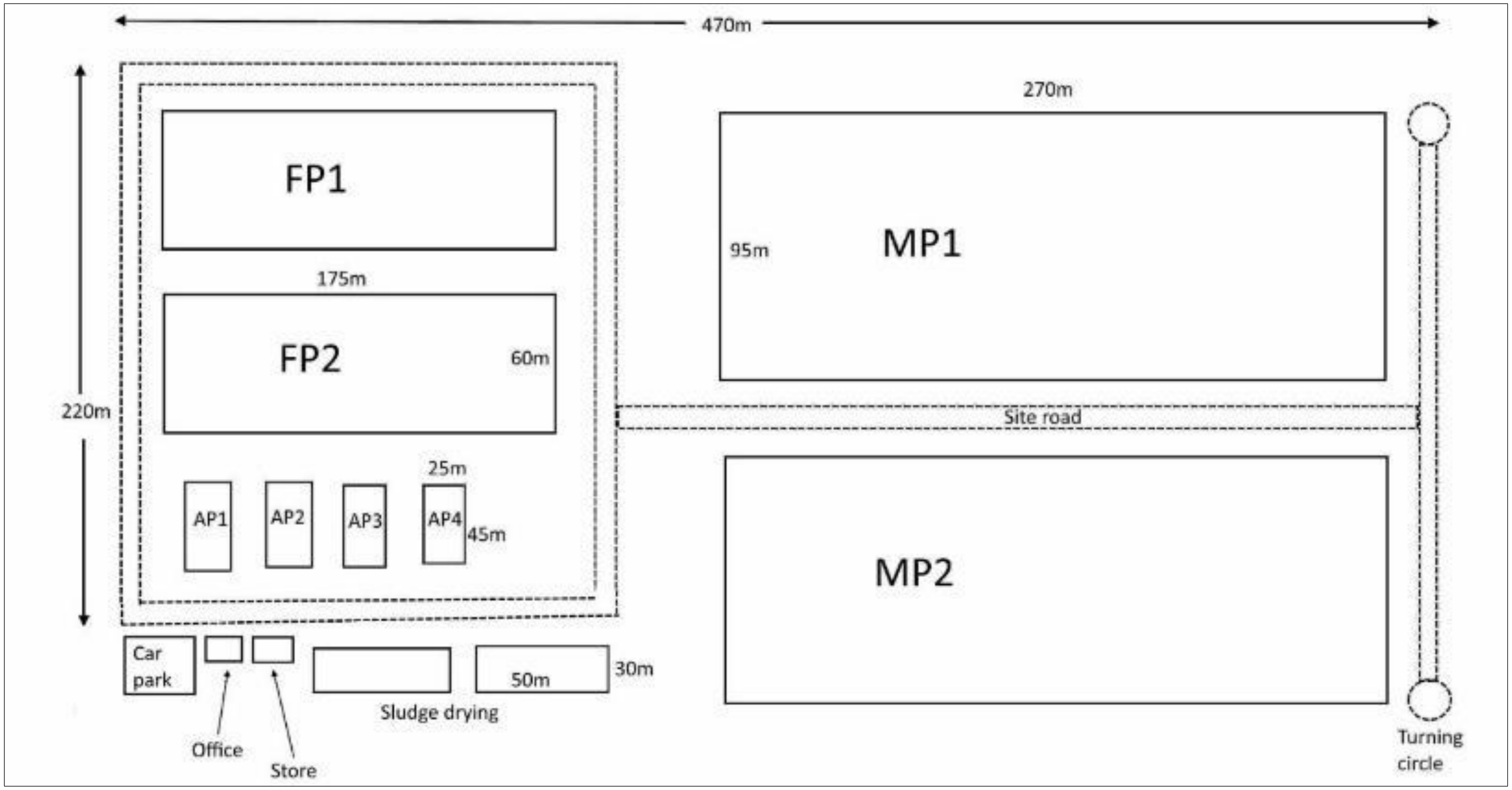


Figure 9. Conceptual Layout of the Proposed Kratie Wastewater Treatment Plant



35. **Kratie municipal solid waste-controlled landfill and equipment.** The proposed controlled landfill will be developed at the 30-hectare site where the existing dumpsite is located. The site is about 17 kilometers east of the town center and can be accessed from National Road No. 7 through a 1.6-kilometer N-S road that connects to a SW-NE road that forms the southern boundary of the landfill property, as shown in **Figure 8**.

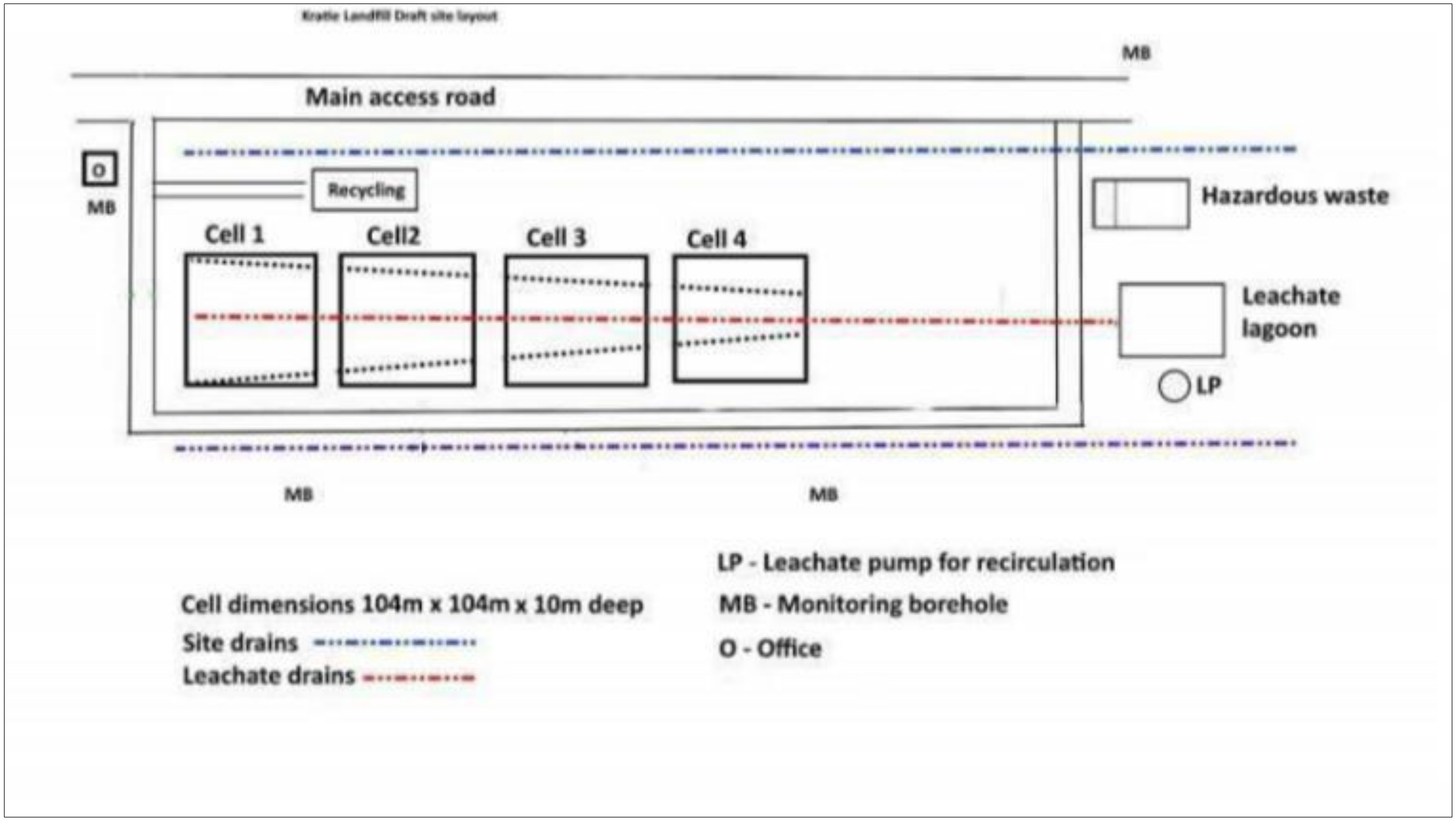
36. This controlled landfill with lined cells will have a capacity of 433,500 m^3, sized to receive the town's solid wastes until 2040. The specific features of the landfill include (i) four (4) waste cells (104 m x 104m x 10m) lined with compacted clay/earth and geomembrane (HDPE); (ii) recirculation system, (iii) sorting and recycling area, (iv) separate disposal and incineration area for hazardous wastes, (v) site office with toilet, (vi) water supply and monitoring bore holes, (vii) power supply, (viii) concrete access road (1.5 km and 4m wide) and all-weather site roads, (ix) site drains, (x) perimeter fencing, (xi) six waste collection and compaction vehicles and one crane for handling recyclables. The conceptual layout of the proposed controlled landfill is in **Figure 10.**

37. This component will also include the closure of the old dumpsite, the location of which is also shown in **Figure 8**. It is proposed to retire and close this dumpsite in one lined cell with a capacity of 146,000 m3, of dimensions 120m x 120m x 10m (length, width, depth), with leachate drains and lined pond. The dumping operations at this site started in 2006, but officially closed in 2015 in response to requests from communities to have the dumping operations moved to another place. However, the dumpsite continues to receive wastes, with approximately 40 tonnes per day disposed at the site. An environmental compliance audit of the dumpsite will be completed early in the detailed design stage by the Environmental Specialist of the PMCS. The findings of the ECA will inform the closure proposals.

38. **Kratie town center enhancement.** The proposed town center improvements intend to enhance the public or recreational amenities along the riverside and market square areas. The specific improvements will cover the (a) area along the riverfront walkway along Preah Soramarith Quay, for approximately 1,500 meters between the water supply department (Road No. 12) to the south, and the roundabout where Road No. 377 enters town to the north, and (b) the block of streets around the central market.

39. Proposed improvements will include (i) installation of 92 energy-efficiency streetlights, (ii) pavement rehabilitation covering an area of 10,600 m^2, (iii) 2,300 meters of kerbing, and (iv) provision of auxiliary equipment (i.e., 92 benches, 50 rubbish bins, 92 trees planted, and 10 items of exercise equipment).

Figure 10. Layout for the Kratie Municipal Solid Waste Controlled Landfill



C. The Stung Treng Subproject

40. **Output 1.3:** The Stung Treng Subproject includes three components: (i) a lagoon-base wastewater treatment system, (ii) a municipal solid waste controlled landfilled and equipment, and (iii) town center enhancement. Each of these is described below.

41. **Stung Treng lagoon-base wastewater treatment system.** Similar to the wastewater components in the other two towns, this component includes a combined sewer system and a WWTP. The proposed combined sewer system will be designed to address drainage requirements and the collection and treatment of wastewater from domestic and commercial sources in the urban center. The deliverables of this component include: (i) lagoon-base wastewater treatment facility with capacity of 3,800 m^3/d; (ii) 8.9 km of trunk sewer/CSO with D1500 mm; (iii) 3.973 km of trunk sewer/CSO pipes with D1200 mm; (iv) 2.48 km of trunk sewer/CSO pipes with D1000 mm; (v) 1.204 km of trunk sewers D800 mm; (vi) 0.222 km of trunk sewers D600 mm; (vii) 130 km wastewater collection pipes; (viii) 0.09 km of box culvert 2m wide; (ix) six wastewater pumps stations with capacity of maximum 270 l/s; and (x) four pump stations for flood control on riverbank.

42. The combined sewer will serve the three (3) sangkats and the target population within the coverage area are as follows: (i) Krong Stung Treng, 75%; (ii) Srah Ruessei, 10%; and (iii) Preah Bat, 90% of the population.

43. The WWTP will be constructed on a 10-hectare public land parcel and is designed to collect and treat wastewater until 2040. Treated effluents from the WWTP will be discharged into an existing stream within the site which flows into the Mekong River. No water users were observed but this should be further investigated during detailed engineering design. The general location of the wastewater system is shown in **Figure 11**, and the conceptual layout of the WWTP is shown in **Figure12**.

44. **Stung Treng municipal solid waste-controlled landfill and equipment**. A new controlled landfill covering an area of 12 hectares will be developed in a 100-hectare public land across the town, about 13 kilometers from the town, as shown in **Figure 13**. The facility will have a capacity of 291,000 m3, sized to receive the town's generated wastes until 2040. It will also have 5 waste collection and compaction vehicles; and one crane for handling recyclables.

45. The landfill will include (i) four (4) waste cells (85 m x 85m x 10m) lined with compacted clay/earth and geomembrane (HDPE); (ii) recirculation system, (iii) sorting and recycling area, (iv) separate disposal and incineration area for hazardous wastes, (v) site office with toilet, (vi) water supply and monitoring bore holes, (vii) power supply, (viii) concrete access road (1.5 km and 4m wide) and all-weather site roads, (ix) site drains, and (x) perimeter fencing. The conceptual layout of the proposed controlled landfill is shown as **Figure 14**.

46. This component will also include the closure of the existing dumpsite, the location of which is also shown in **Figure 13**. The existing dumpsite, which comprises at least five (5) non-contiguous dumping grounds, is located along National Road (NR) 7, approximately 10 kilometers from the foot of the Sekong Bridge across the town center. An environmental compliance audit will be undertaken early in the detailed design stage by the Environmental Specialist of the PMCS. The findings will inform the closure design.

47. **Stung Treng town center enhancements**. Town center enhancements are proposed to improve the recreational value of selected streets of the Stung Treng town. The target areas for

improvement will be (a) along the riverfront walkway, for a distance of approximately 1,100 m between the Four Rivers Hotel (near Road 69) to the west, and Road 55 to the east; (b) at the 30 meter-wide strip between the main double carriageway boulevard (Roads 63 and 64) that run through the center of Stung Treng in a south-north direction down to the riverfront; and (c) around the market square specifically Roads Nos. 51,12, and 14 (see **Figure 11**).

48. Proposed improvements will include: (a) installation of 72 energy-efficiency streetlights, (b) pavement rehabilitation covering an area of 5,800 m2, (c) 1,800 meters of kerbing, and (d) provision of auxiliary equipment (i.e., 87 benches, 50 rubbish bins, 21,000 m2 of landscaped garden with water feature, and one playground).

Figure 11. Location of the Stung Treng Lagoon-Base Wastewater Treatment System and Coverage of the Combined Sewerage Sytem

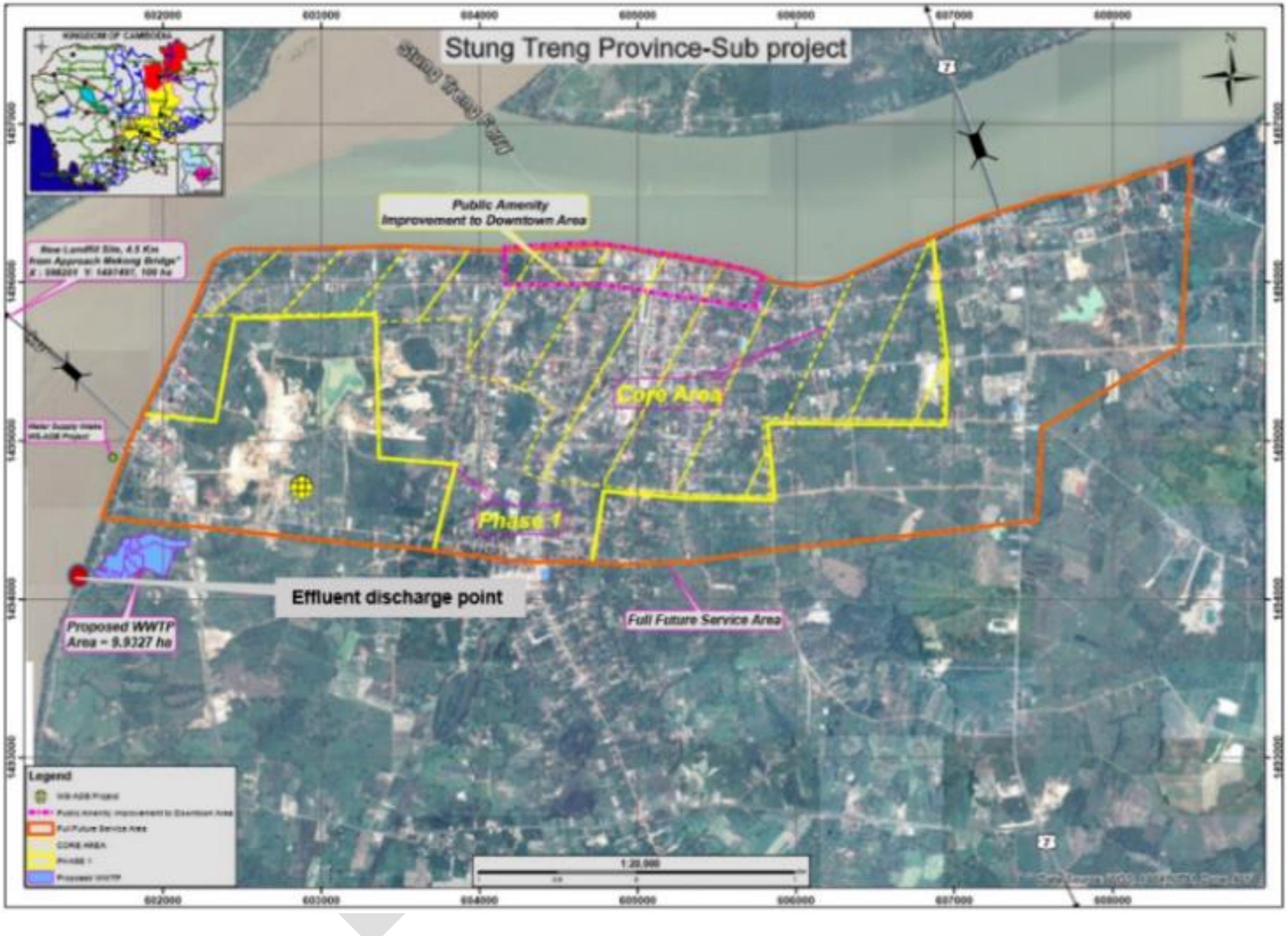


Figure 12. Conceptual Layout for the Stung Treng Wastewater Treatment Plant

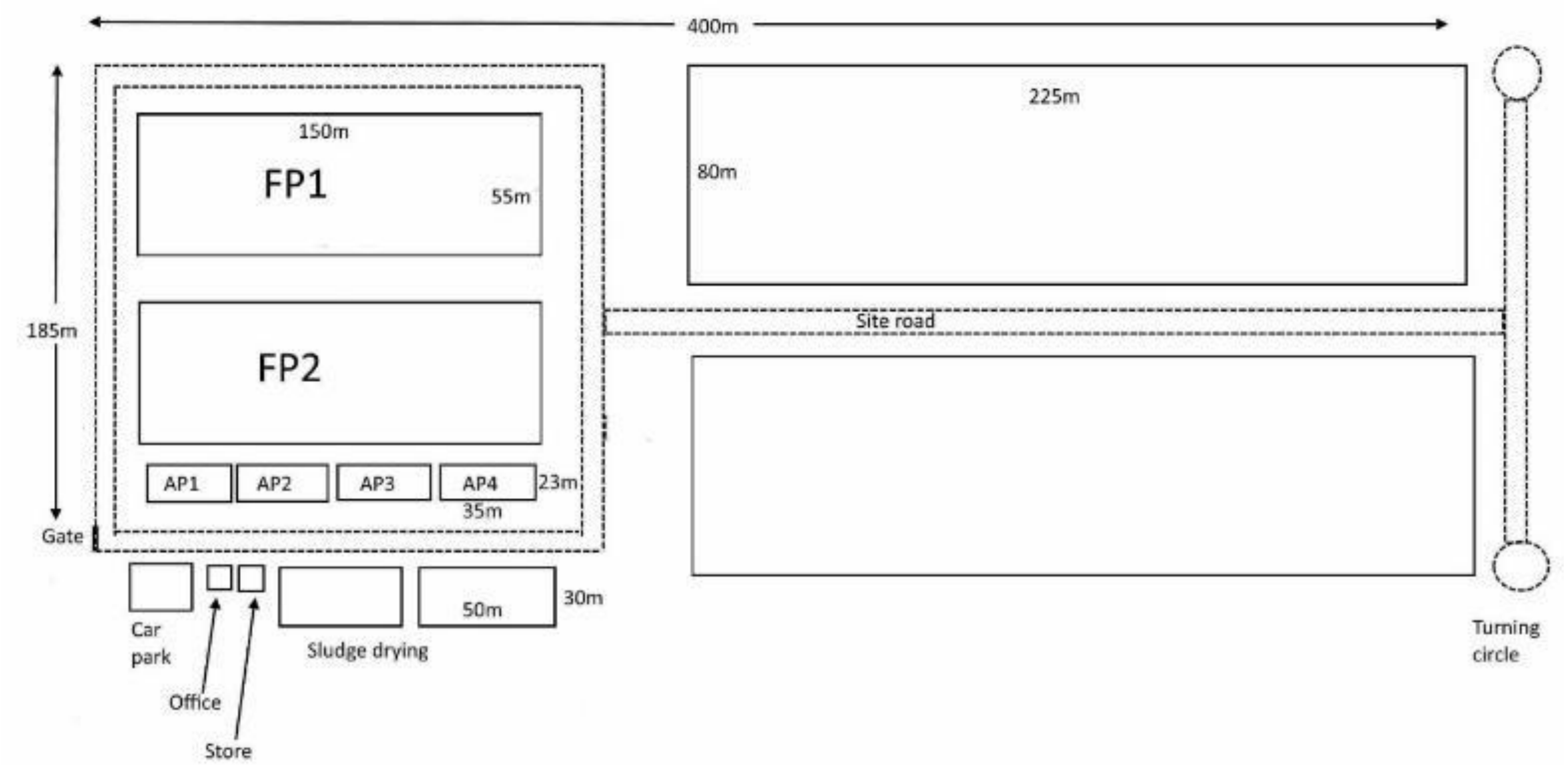
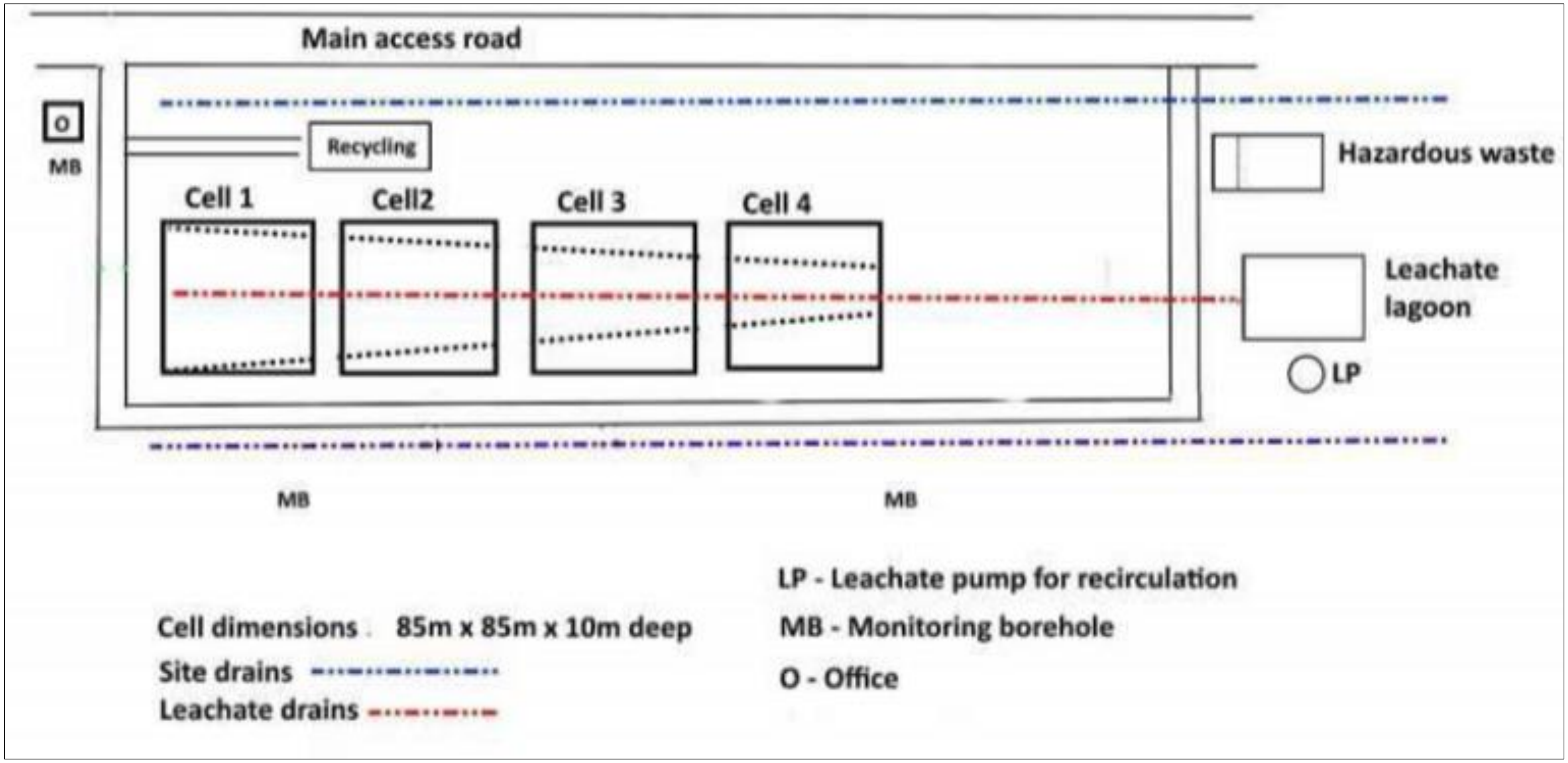


Figure 13. Location of the Proposed Stung Treng Controlled Landfill and Existing Dumpsite

Figure 14. Layout for the Stung Treng Municipal Solid Waste Controlled Landfill



V. VULNERABILITY OF PROJECT SITES

49. The Project towns are situated in the Cambodian lowlands. Kampong Cham and Kratie is within the Mekong floodplains[5]. All towns are along the Mekong River. Stung Treng is also situated at the confluence of Sekong and Mekong Rivers and of Sekong and Sesan Rivers. Due to their geographic locations, the three towns are exposed to: (i) riverine floods, as a result of overtopping the banks; and (ii) flash floods that result from both Mekong runoff and heavy rains in Cambodia.

A. Kampong Cham

50. The Kampong Cham urban area is largely at elevation 18-22m with flat terrain.[6] There used to be two large ponds or wetland areas to the immediate west of town, Boeng Snay and Boeng Bassac. Boeng Snay has been filled in for development.

51. **Lagoon-Based Wastewater Treatment System**. The service area of the combined sewer system under the Subproject will cover a large portion of the main urban area, which is predominantly residential and commercial, with at least 11 educations institutions, 5 religious institutions and a hospital. There are no protected areas or sites for biodiversity conservation identified within or close to the proposed CSS.

52. In the service area, there are three main low points, all of which suffer from flooding reported up to 800-mm deep for up to 4 hours following heavy rainfall events. Two of these are in areas where the town has encroached on what was previously wetland in the east of Boeng Snay. The third low point is in the northeast corner of town in a block bounded by Kampuchea Krom Road and Pra Monivong Road. This area is close to the Mekong (approximately 250 m) but is in a low point with drains that were installed to follow the road level instead of at an appropriate grade for purpose. **Figure 15** are photos of WWTP site.

53. Open channels trunk sewers are proposed alongside Boeng Snay. Boeng Snay was filled in without any alternative provision for drainage or wastewater retention. This has caused stormwater to flow and be stored around the edges, particularly the northern edge, of Boeng Snay. The unfilled areas around (east, west and south of) Boeng Snay are waterlogged during the rainy season. Urban development has reached the northern edge, and is fast closing in on the eastern edge, of Boeng Snay.

54. Boeng Bassac, the remaining wetland, is the site for the proposed wastewater treatment plant. It is up to 35 ha in size (of which about 10 ha will be used for the WWTP) and is at elevation 11-13m. Boeng Bassac and its vicinities are waterlogged during the rainy season.

55. The area block within which Boeng Bassac is situated is bordered on all sides by road. To the east is the road on embankment that separates Boeng Bassac from Boeng Snay. The pump house that will be upgraded under this component is situated here, shown in **Figure 16.** To the north and west, the road is lined with residential development. There are a few residences within 140 to 150 meters from the northwestern edge of Boeng Bassac. **Figure 17** shows the nearest housing community from the lagoon. To the south the road has least residential development.

56. Land cover within the area block of Boeng Bassac is largely agricultural, shrub/grassland,

[5] The Mekong floodplains encompasses the region from Kratie Township in Central Cambodia to the Vietnamese East Sea.
[6] General elevation at the town center strip close to the Mekong River. Obtained from Google Earth Pro.

with some areas planted with trees. Two streams flow from Boeng Bassac. On the southeast edge, stream flows about 900m to Mekong River. On the west, a stream flows at least 1.5km to reach Boeng Smuos. Almost the entire area block is waterlogged in the rainy season, about 4-5 months. There are no protected area or sites for biodiversity conservation in the proposed project location.

57. **Controlled landfill**. The site for the proposed landfill is in Pkay Preuk Village, Mien Commune, Prey Chhor District, Kampong Cham Province, about 17km west of the Kampong Cham Town. The site, 11.14 ha in size, is on elevated land (a plateau). Hence, site is not flood prone. Site can be accessed through an earth road. On the west of the site a small stream, Stung O Proyorl, meanders from the commune across NR 7 to the lagoon south of the site. Site photos are shown in **Figure 18.**

58. To the north of the site is NR 7, which is lined with residences. NR 7 is about 600m from the center of the site, and about 250m from the northernmost edge of the site. The nearest residences to the north are within 600m from the center of the site. To the east is the Regional National Police School, about 402m from the east edge of the site. To the south is the Boeng Thum, a large lagoon, about 2.3 km from the center of the site. Surrounding the site are agricultural lands. The site is presently grass/shrub land with some trees. There are no cultural/heritage sites and areas for biodiversity conservation within or close to the village location of the site.

59. In all Project sites in Kampong Cham, there are no critical slopes and unstable soils within their respective areas of influence.

Figure 15: Photos of WWTP Site from the Road on its West and of the Pump House

View of WWTP site from the road where the pump station is located

Left Photo: Western end of the culvert that is leading water from the vicinity of the new development area in the east to the lagoon (WWTP site) in the west.
Right Photo: The road under which he aforementioned culvert runs, and the pump house which will be upgraded under the subproject.

Figure 16: Photo of the Filled Boeng Snay Taken from the Pump House

View of the filled Boeng Snay new development area from the pump house with surrounding water-logged areas

Figure 17: Nearest Housing Community from the NW edge of the Lagoon

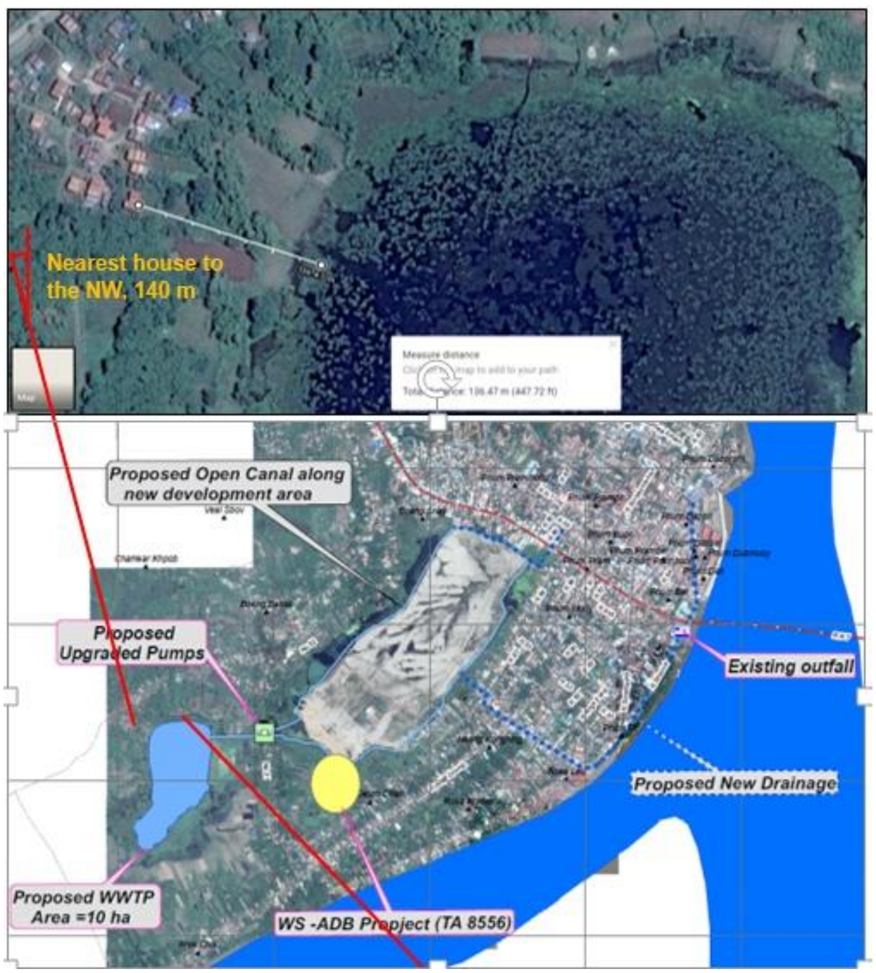


Figure 18: Photos of the Proposed Controlled Landfill Site in Kampong Cham

The existing vegetation/forest resources in proposed landfill site

Small stream is near the proposed landfill site

The transmission line and electric pole in the proposed landfill site (the north part at entrance)

B. Kratie

60. Kratie town center is largely at elevation 20-29m with flat to gently sloping terrain.[7] Prek Te River forms the southern boundary of the town; but it is almost four kilometers from the town center. There are two wetlands within the town boundaries. The small one, Koko Nimol Lake, is northeast of the town center; the large one (name unknown) is southeast of the town center. Koko Nimol Lake is at elevation 17m and releases water to the Mekong River through a small stream. Surrounded by areas prone to flooding, the small stream is overwhelmed with surface runoff during the rainy season. When water level of the Mekong River is high during heavy rainfall, stream flow to the Mekong River for discharge would not be possible.

61. The large wetland southeast of the town center is at elevation 13m. It receives the large movement of floodwater during the wet season that runs behind the main town, north to south, through an 80-m wide man-made channel. It also receives the floodwaters from the town center since the riverbanks are higher than the interior wetlands.

62. **Lagoon-Based Wastewater Treatment System**. The service area of the combined sewer system under the Subproject is predominantly residential and commercial with at least 4 schools, a hospital, at least 4 religious institutions and a public library. As the main urban area of Kratie is almost entirely within the Mekong River IBA from Kratie Town to the Lao Border, the service area of the combined sewer system is within this IBA.

63. The existing 80-m wide channel is partly defined with embankments and is halfway from the large wetland southeast of the town center. About three-fourths of length of the channel that will be improved under the Subproject is in an area that is largely undeveloped but waterlogged in the rainy season. The remaining one fourth is bordered: (i) on the west by Road 377, the Public Library, the Queen Kosamak High School and the Kratie Water Supply Authority; and (ii) on the east by a residential community. The Town Plan has identified the area around the channel for future development.

64. The proposed WWTP will be situated at the northeast of the large wetland southeast of the town center. The site has been observed to be waterlogged for 4 to 5 months during the rainy season. Areas north, east, southeast and south of the wetland are mixed farm plots and shrub- and grasslands. The nearest residential area is about 1.5 kilometers west of the WWTP site, and the approach of the Kratie Airport runway is about 2 kilometers southeast of the project location. The proposed access road to the WWTP will be along a commercial establishment, a school, some agricultural lands, and nearby residences. The WWTP site is estimated to be at least 500m east of the eastern boundary of the Mekong River IBA. Photos of the open channel and proposed WWTP site are shown in **Figure 19**.

65. **Municipal Solid Waste Controlled Landfill**. The proposed controlled landfill site at elevation 43-48m; generally flat, and is not flood prone (according to the Local Government). The site is in a rural setting, predominantly shrub- and grass land with some forested areas. On the west are some cultivated agricultural lands, the nearest of which is about 500m away. A small stream runs within the site, close to the eastern boundary of the site and leads to a medium-sized pond to the south. **Figure 20** shows photos of the controlled landfill site.

66. The site is far from human settlements. The nearest community is at the junction of its access road with NR7, about 1.75 km away. Two families are part-time waste pickers at the

[7] General elevation at the town center strip close to the Mekong River. Obtained from Google Earth Pro.

existing dumpsite. They live in the surrounding village.

67. The proposed location for the controlled landfill has no affected protected area or areas for biodiversity conservation identified within its proximity.

68. The old dumpsite in Kratie is located at a 10-ha provincial land in Kapo Village, Ou Russei Commune, about 9km east of the town (from the Kratie town hall, including the 1km access road). It is accessed from NR 7. It has been left open, without fence, and waste picking operations continue. The dumpsite is about 4.5 km away from the runway of Kratie Airport which is still operational. Housing structures can be found along the access road. The closest water body is a pond, at least 1.3km to the southeast. Surrounding the site are agricultural lands with shrub/grasslands and forested areas in between. A big Buddha statue is located about 800 m away.[8] There is no protected area or area for biodiversity conservation in the old dumpsite's proximity. **Figure 21** is a photo of the old dumpsite and photos of waste picking operations are shown in **Figure 22.**

69. **Town Center Enhancement.** The proposed areas of focus are along the walkway fronting the Mekong River, downtown area, and around the central market. The riverfront walkway at Preah Soramarith Quay is at elevation 19-22m; whereas Mekong River (its east bank) is at elevation 11-14m near the town center. The walkway is estimated to be within 20m from the Mekong River. Around central market, many restaurants and guesthouses are located.

70. In all project sites in Kratie, there are no critical slopes and unstable soils within their respective areas of influence.

Figure 19: Photos of the Open Channel and Proposed WWTP Site

Site for main drainage channel

[8] According to local authority and social specialist of Buddha Statues, per inquiry by PPTA National Environmental Specialist.

View of the WWTP, pumping station and ring road (section A) sites from the main drainage channel site

Figure 20: Photos of the Controlled Landfill Site

Figure 21: Photo of the Old Dumpsite

Figure 22: Photo of Continuing Waste Picking Operations in the Old Dumpsite

C. Stung Treng

71. Stung Treng Town Center is above the normal elevation of Mekong and Sekong Rivers. The elevation of the riverside areas along Mekong and Sekong Rivers is 47-55m.[9] The terrain is flat at the riverside. Further inland, terrain is sloping gently.

72. **Lagoon-Based Wastewater Treatment System**. The proposed combined sewer system with the floodgate and pumping stations will mainly cover the main urban area, to serve the residential and commercial establishments, including schools, temples, mosques, pagodas, a provincial government office, hospital, and health center. Within the proposed combined sewer service area, there are three streams leading to Sekong River and two streams leading to Mekong River. The largest 3 of these streams have flood control gates installed, which are closed in the wet season to prevent river water flowing up the creeks into the town. However, these gates are currently manually operated with a gear mechanism and key, which is reportedly problematic for the Department of Public Works and Transport.

73. Stung Treng does not suffer from flooding from the Sekong or Mekong. Periodic flooding is caused by overland flow from the south of town running towards the rivers. The flow cannot enter the rivers as the outfall gates are closed, and so the creeks back up and flood surrounding streets. Prior to the gates being installed, the creeks backed up against the higher wet season recipient river levels. There is one significant and recurring flood area approximately 300m back from the river over Prek Pou creek, around the intersection of streets 18 and 57. Drainage works to relieve ponding in this area were completed in December 2017, but will yet be tested with a wet season this year.

74. The proposed WWTP will be developed over a lowland, near to the Mekong River. The area is largely open shrub/grass land. The site is about ten hectares. A stream, serving as the natural drainage course for this area and areas to the east, traverses the WWTP site.

75. The WWTP site is within an area block that is bordered on all side by roads as shown in Figure 3.18. Residential structures exist to the south of the WWTP site, and a low-density residential development exists to the west. About four to five houses are at the southeast area of the block, close to the eastern road. The surrounding vicinity of the WWTP site is mainly agricultural, grassland, and forested land, with some crops currently cultivated by farmers on agricultural lands.

76. The site is waterlogged during the rainy season especially when the water level at the Mekong River is high.

77. A large western portion of Stung Treng Town is within the Mekong River IBA; while the northern portion from Sekong River up to Street 22 is within the Sekong IBA. Hence, a large portion of the CSS works is within both IBAs; while the WWTP site is within the Mekong River IBA. Photos of floodgate sites are shown on **Figures 23 – 27**.

78. **Controlled landfill**. A new 100-ha site in Thala Borevath District has been identified for the proposed controlled landfill. It is about 5km from the foot of the Mekong Bridge across the town center. Site is in the upland area that can be accessed through a 1-km laterite rural road from NR 7. Site is scrub land with scattered trees with at least two perennial streams flowing southward. The access road is used by farmers to access their farms.

[9] General elevation at the town center strip close to the Mekong River. Obtained from Google Earth Pro.

79. The estimated center of the property is about 860 meters from the main road, and about 1 kilometer away from the nearest house. The southern boundary of the site is at least 3 kilometers from the western bank of the Mekong River, while the center of the site is about 5.8 kilometers from the confluence of Mekong and Sekong Rivers (edge of Sekong River IBA), and about 13.5 kilometers from the confluence of Sekong and Sesan Rivers (edge of the Sesan River IBA). There are two historical sites near the proposed landfill location, namely, Preah Ko Temple (5.5 km) and Phnom Preah Theat Temple (6.5km).

80. The existing dumpsite is part of a 147ha public property along NR7. The eastern boundary of the property is about 300 meters from the west bank of the Sekong River; and the center of the property is about 4 kilometers from the north bank of Sesan River, and 4 kilometers from the east bank of the Mekong River. Photos of the existing old dumpsite are shown in **Figure 28**. Based on the information on protected areas by UN Environment World Conservation Monitoring Centre (UNEP-WCMC), the property is partly within the RAMSAR site boundary. There is only one house inside the property which belongs to the caretaker assigned by Government, and with three (3) waste pickers operating (but not residing) in the site.

81. **Town Center Enhancement.** The proposed area of focus is along the riverfront walkway and the market area, which are within the Sekong River IBA. Being at the town center, development is predominantly residential and commercial, with at least 2 temples and one school.

82. In all project sites in Stung Treng, there are no critical slopes and unstable soils within their respective areas of influence.

Figure 23: Roads East and West of the Stung Treng Wastewater Treatment Plant

Left: East road of the block where access road is proposed to start.
Right: West road of the area block. The bridge shown here is over the stream that comes from the WWTP site.

Left: The road south of the proposed wastewater treatment plant site.
Right: One of the 5 houses along the south road of the area block. The rest are small houses.

Figure 24: Proposed Automation of Floodgate and Installation of Pump Station at Road 2

Figure 25: Proposed Automation of Floodgate and Installation of Pump Station at Dam Nak Bridge

Figure 26: Proposed Automation of Floodgate and Installation of Pump Station at O Thmor Leat Bridge

Figure 27: Proposed Automation of Floodgate and Installation of Pump Station at Prek Pou Bridge

Figure 28: Photos of the Stung Treng Existing Dumpsite

Lower left: The only house in the property, occupied by the caretaker assigned by the government. This house is located along the access road.
Lower right: Access road from NR7, showing here the house of the site caretaker.

D. Summary of Concerns

83. The following salient concerns on Project sites must be taken into account in designs:

84. The Project sites, except those for the controlled landfills, experience flooding each year, either fully or partly. The AWARE for Projects tool has rated flood as "high" risk. Flood level and duration data, other than anecdotal, was not available from the Municipality or Provincial Authorities, when requested. A detailed analysis of flood risk is important to determine the appropriate factors of safety in designs.

85. The proposed combined sewer service areas are experiencing flooding at various locations. The conduct of thorough investigation of flooded areas and their causes prior to or during detailed engineering design would provide good basis for design of an effective drainage system, including recommending non-structural measures that should be brought to the attention of the Local Governments. Opportunities for low-impact development (LID) or green infrastructure features under the Project, where or as applicable, should be availed of to tackle flood risk. These include, for example, pervious roadside surfaces/areas, availing of public parks and open spaces (could be just outside the service area), for temporary storage (detention areas) and allowing for infiltration.

86. All WWTP sites are waterlogged in the rainy season. In sites where communities exist

within at least 200-m radius from the WWTP, particularly the WWTP site in Kampong Cham, sufficient buffer area between the facility and the community for the safety of the people from risks associated with WWTP operations should be considered.

87. In Stung Treng, the WWTP has a stream within it. Design should consider the “rerouting” of the stream. The rerouting should ensure more effective surface drainage of the areas this stream is serving.

88. The old drainage systems in all towns is considered as no longer adequate for the pressures of climate change. Interfacing a new system (in areas currently without drainage) with these old systems would not be effective in achieving sustainable drainage/sewer services.

89. Design must take into account the tendency of: (i) infilling of drainage channels to give way to urban development or expansion; and (ii) depositing solid waste onto open channels/drains. There is opportunity to include measures that could prevent these tendencies to happen. One opportunity would be including linear parks, adopting LID features, at the borders of the open channel in Kratie. The design should be developed in collaboration/coordination with not only the Local Government but also the existing communities currently alongside the existing channel, encouraging their vigilance over the existence and cleanliness of the open channel for sustained effective services.

VI. CLIMATE

90. Cambodia’s tropical monsoon climate is characterized by a rainy season and a dry season. The rainy season, which lasts from May to early October, accounts for 90% of annual precipitation. The dry season, from November to April, brings drier and cooler air from November to March, and then hotter air in April and early May.[10]

91. The maximum mean temperature is about 28^{O}C and the minimum mean temperature about 22^{O}C. Maximum temperatures are common before the start of the rainy season and may rise to more than 38^{O}C. The average annual rainfall from 1994 to 2004 varied between 1,400 mm and 1,970 mm. The geographical incidence of extreme weather events, such as droughts and floods, varies, and while floods affect lowlands areas, the geographical distribution of droughts is widespread. Storms occur more frequently between August and November, with the highest frequency in October. The country is rarely exposed to the full force of tropical cyclones and typhoons as it is surrounded by mountain chains, which dissipate a typhoon’s force.[11]

A. Historical Data

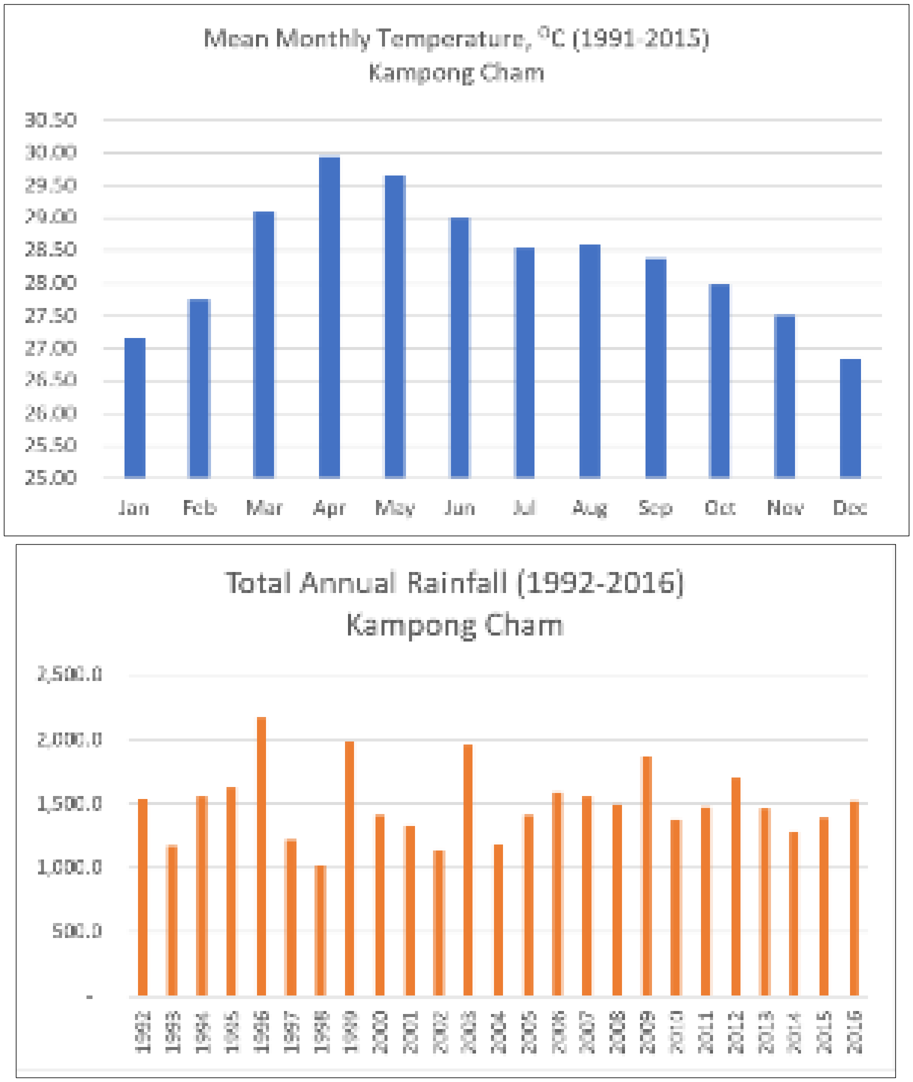
92. Based on the historical data gathered by the PPTA Team for each of the Project towns: **(See Annex A for the data.)**

93. **Kampong Cham**. During the 25-year period 1991-2015, Kampong Cham had a: (i) mean monthly temperature ranging from 26.86 ^{O}C in December to 29.94 ^{O}C in April; and (ii) a mean

[10] Lifted from: 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.
[11] Lifted from: 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.

annual temperature of 28.37 °C. During the 25-year period 1992-2016, the town had: (i) a mean monthly rainfall ranging from 12.4 mm in January to 281.6 mm in September; (ii) a mean annual rainfall of almost 1,500 mm; (ii) highest annual rainfall of 2,164 mm in 1996; and (iv) lowest annual rainfall of 1,024 mm in 1998 **(Figure 29)**.

Figure 29: Mean Monthly Temperature (1991-2015)[a] and Total Annual Rainfall (1992-2016)[b] - Kampong Cham



[a/] Data source: World Bank Climate Change Knowledge Portal. http://sdwebx.worldbank.org
[b/] Data source: Second Integrated Urban Environmental Management in the Tonle Sap Basin Project, ADB

94. **Kratie.** During the 25-year period 1991-2015, Kratie had a: (i) mean monthly temperature ranged from 26.03 °C in December to 29.94 °C in April; and (ii) mean annual temperature of 27.70 °C. During the 19-year period 1998-2016, the town had a: (i) mean monthly rainfall ranging from 7.2 mm in January to 504.1 mm in September; (ii) mean annual rainfall of 1,837 mm; (iii) highest annual rainfall of 2,550 mm in 1999; and (iv) lowest annual rainfall of 1,209 mm in 2015. **(Figures 30 and 31)**

Figure 30: Mean Monthly Temperature (1991-2015)[12] – Kratie

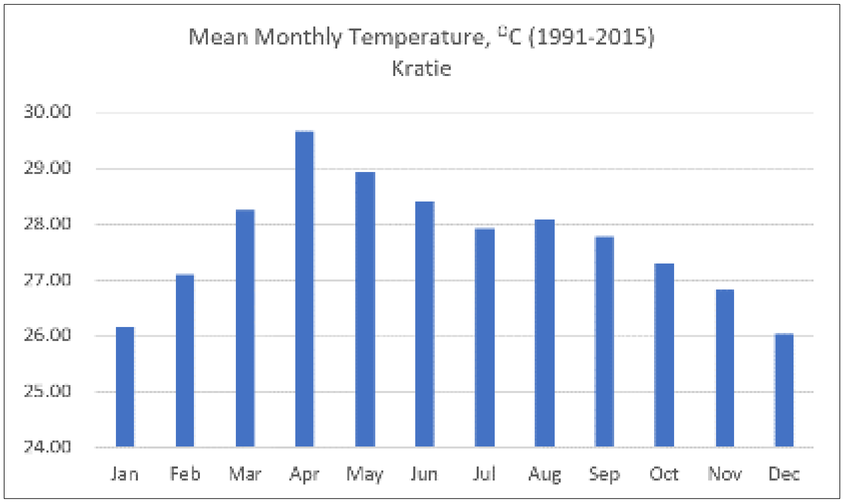
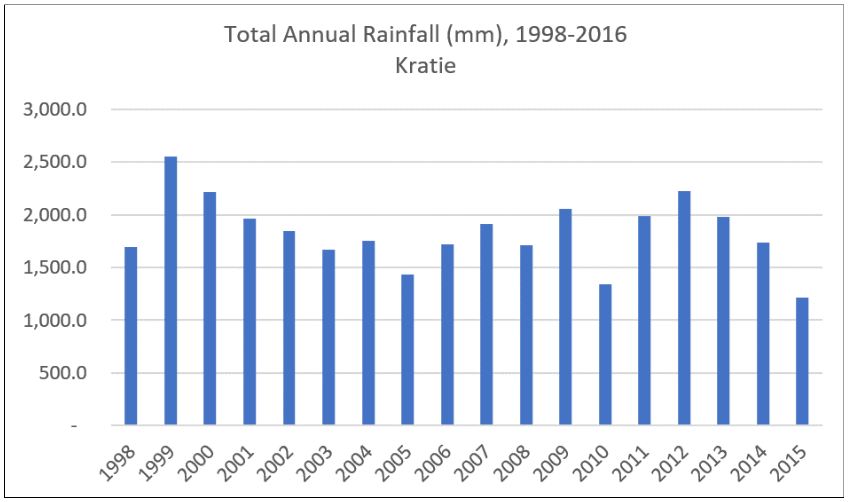


Figure 31: Total Annual Rainfall (1998-2016)[13] – Kratie



95. **Figures 32 and 33** provide a graphical summary of the temperature and rainfall patterns in Stung Treng During the 25-year period 1991-2015, Stung Treng had a: (i) mean monthly temperature ranging from 25.5 ^{O}C in December and 30.5 ^{O}C in April; (ii) mean annual temperature of 27.82 ^{O}C; (iii) mean monthly rainfall ranging from almost 0.0 mm in January to 347.27 mm in September; and (iv) mean annual rainfall of 1,822 mm.

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[12] Data source: World Bank Climate Change Knowledge Portal. http://sdwebx.worldbank.org
[13] Data source: DOWRAM, Kratie Province

Figure 32: Mean Monthly Temperature (1991-2015)[16] - Stung Treng

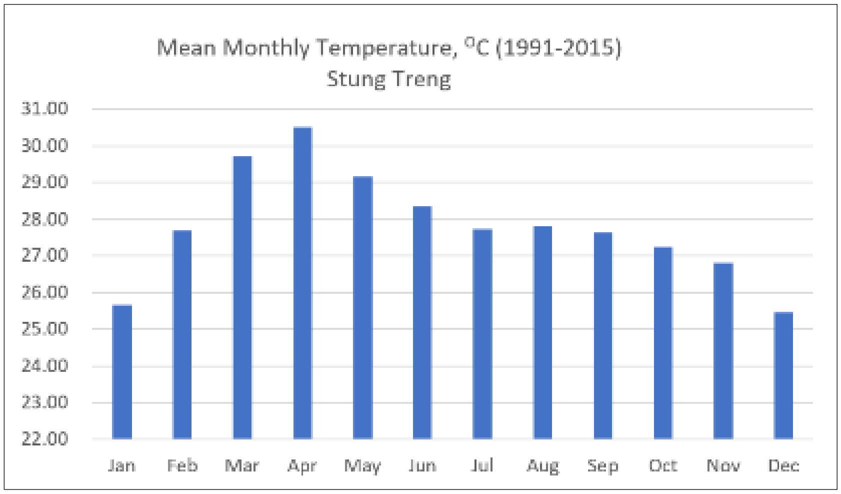
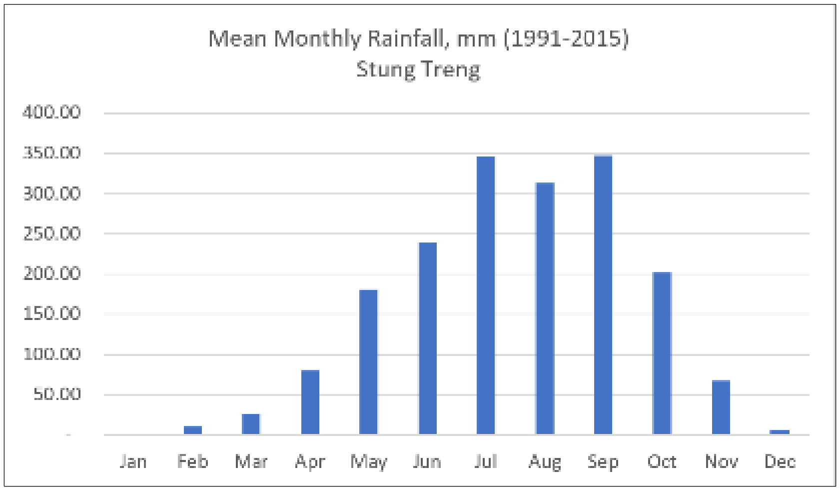


Figure 33: Mean Monthly Rainfall (1991-2015)[14] - Stung Treng



B. Recent Climate Trends

96. Cambodia is one of the 52 countries covered by the UNDP project on improving the accessibility of observed and projected climate information for studies of climate change in developing countries. The project produced the Climate Change Country Profiles for the 52 countries. According to the profile for Cambodia,[15] the recent climate trends are as follows:

- Mean annual temperature has increased by 0.8^{O}C since 1960, at a rate of around 0.18^{O}C per decade. The rate of increase is most rapid in the drier seasons (December to May) at a rate of 0.20-0.23^{O}C per decade and slower in the wet seasons (June to November) at a rate 0.13-0.16^{O}C per decade.
- The frequency of hot days[16] and hot nights has increased significantly since 1960 in almost every season.

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[14] Data source: World Bank Climate Change Knowledge Portal. http://sdwebx.worldbank.org

[15] C. McSweeney, M. New, and G. Lizcano. UNDP Climate Change Profiles: CAMBODIA.

[16] 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

- o The average number of 'hot' days per year in Cambodia has increased by 46 (an additional 12.6% of days[17]) between 1960 and 2003. The rate of increase is seen most strongly in September to November (SON) when the average number of hot SON days has increased by 8 days per month (an additional 25.7% of SON days) over this period.
- o The average number of 'hot' nights per year increased by 63 (an additional 17.2% of nights) between 1960 and 2003. The rate of increase is seen most strongly in December to February (DJF) when the average number of hot DJF nights has increased by 7.4 days per month (an additional 23.8% of DJF nights) over this period.

- The frequency of 'cold' days[18] had decreased significantly in DJF and SON, and cold nights in all seasons, since 1960.
  - o The average number of 'cold 'days per year has decreased by 19 (5.2% of days) between 1960 and 2003. This rate of decrease is most rapid in DJF when the average number of cold DJF days has decreased by 2.8 days per month (9.0% of DJF days) over this period.
  - o The average number of 'cold' nights per year has decreased by 46 (12.6% of days). This rate of decrease is most rapid in DJF when the average number of cold DJF nights has decreased by 4.7 nights per month (15.0% of DJF nights) over this period.

- Mean rainfall over Cambodia does not show any consistent increase or decrease since 1960.
- The proportion of rainfall that occurs in heavy[19] events has not altered significantly since 1960.
- The only significant change in the magnitude of maximum 1- and 5-day events observed is a decrease in 1-day maxima in DJF of -1.38mm per decade.

C. Future Climate Trends

97. **Mean Annual Temperature and Rainfall**: A number of studies (or sources of information) on the future trends of climate in Cambodia, in the Lower Mekong Basin and in the entire Mekong River Basin was reviewed (**Annex C.)** The projected changes in mean annual temperature and precipitation from a few selected studies/sources were then applied to the obtained historical data to arrive at a range of probable mean annual temperature and precipitation in the future in the three Project towns. The selected studies/sources and their projected changes are briefly discussed in the subsequent paragraphs.

a. <u>C. McSweeny, M. New, and G. Lizcano. UNDP Climate Change Country Profiles: CAMBODIA</u>. The profiles were developed for 52 countries, including Cambodia, using existing climate data to generate country-level data plots from the most up-to-date climate observations and the multi-model projections from the World Climate Research Program

[17] The increase in frequency over the 43-year period between 1960 and 2003 is estimated based on the decadal trend quoted in the summary table.

[18] 3 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

[19] A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold that is exceeded on 5% of rainy days in current the climate of that region and season.

Coupled Model Intercomparison Project 3 archive.[20] Combined ranges of A2, A1B and B1 results for change in mean annual: (i) temperature are 0.40 to 1.30 ^{O}C for 2030s, 0.70 to 2.70 ^{O}C by 2060s, and 1.40 to 4.30 ^{O}C by 2090s; and (ii) precipitation are -6 to +7% for 2030, -7 to +17% for 2050, and -12 to +17% for 2100.

b. Chu Thai HOANH, Kittipong JIRAYOOT, Guillaume LACOMBE, Vithet SRINETR, 2010. Impacts of climate change and development on Mekong flow regime. First assessment – 2009. MRC Technical Paper No. 29. Mekong River Commission, Vientiane, Lao PDR. Future climate projection daily data for the two Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (A2 and B2) provided by the SEA START Regional Center were based on the ECHAM4 general circulation model from the Max Planck Institute for Meteorology, Germany and downscaled to the Mekong region using the PRECIS system. The PRECIS data for the Baseline 1985 - 2000 were adjusted by comparing them with the available observed data in the Decision Support Framework (MRC's suite of computer-based numerical modelling and knowledge-based tools). For Lower Mekong Basin, the projected changes of mean annual: (i) temperature is 0.70 ^{O}C for 2010-2050; and (ii) precipitation is 4.5% for 2010-2050.

c. Eastham, J., F. Mpelasoka, M. Mainuddin, C.Ticehurst, P. Dyce, G. Hodgson, R. Ali and M. Kirby, 2008. Mekong River Basin Water Resources Assessment: Impacts of Climate Change. CSIRO: Water for a Healthy Country National Research Flagship. Eleven (11) general circulation models were selected to construct scenarios of future (2030) temperature and precipitation for the Intergovernmental Panel on Climate Change A1B scenario. The projected changes, obtained from viewing the spatial distribution for projected change for the three towns of Kampong Cham, Kratie & Stung Treng in: (i) mean temperature by 2030 is 0.70 to 0.80 ^{O}C; and (ii) precipitation by 2030 is 101-200 mm.

d. United States Agency for International Development (USAID) Mekong Adaptation and Resilience to Climate Change (USAID Mekong ARCC) Final Report. September 2016 and USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin. Main Report. November 2013. By 2050, average annual temperature, particularly in the eastern plains of Cambodia: could increase as much as 3 to 5 ^{O}C. From viewing the map Figure 7 (of first reference) on temperature increase for 2050, the three towns are projected to have the following increases: (i) Kampong Cham, 2.51 to 3.0 ^{O}C; (ii) Kratie, 3.01 to 3.5 ^{O}C; (iii) Stung Treng, 3.01 to 3.5 ^{O}C. Annual precipitation is forecasted to rise throughout the LMB by anywhere from 35 mm to 365 mm, from viewing the map Figure 8 on precipitation change for 2050, the three towns are projected to have the following increases: (i) Kampong Cham, 101 to 150 mm; (ii) Kratie,101 to 150 mm; and (iii) Stung Treng, 151 to 175 mm.

e. Exploring Climate and Development Links. The World Bank.[21] By 2100, mean temperature, particularly in the eastern plains of Cambodia, could increase as much as 3 to 5 ^{O}C. From viewing the maps on "Temperature Change by 2100", all the three towns are projected to have temperature changes as follows: (i) under Scenario A2, +3 to +4 ^{O}C; and (ii) under Scenario B1, +1 to +2 ^{O}C. From viewing the maps on "Precipitation Change by 2100", all the three towns are projected to have precipitation changes as follows: (i) under Scenario A2, +30 to +60 mm; and (ii) under Scenario B1, +60 to 100 mm.

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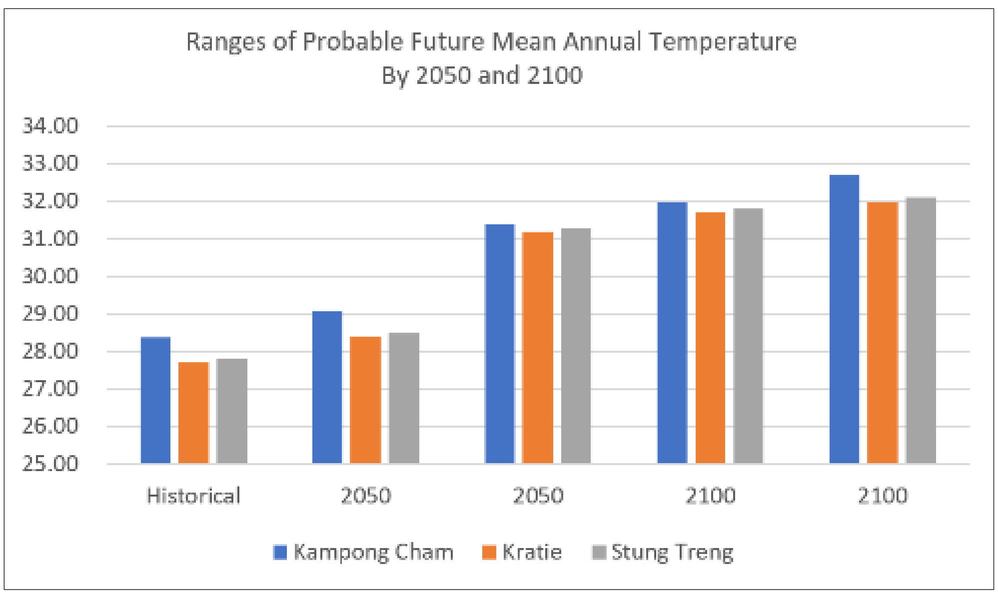
[20] (Meehl et al., 2007). Lifted from Draft UNDP Climate Change Profiles Documentation. C. McSweeney et al. http;//country-profiles. http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/

[21] Can be accessed at http://climate4development.worldbank.org/

98. The probable range of temperature and precipitation in the 2050 and 2100s are summarized below.

- Climate projections from the different models reviewed (including those not among the selected sources) are indicating increase in both temperature and precipitation.
- Between 2050 and 2060, the towns could have mean annual temperature, as follows:
  - Kampong Cham, between 29.1 and 31.4 ^{O}C;
  - Kratie, between 28.4 and 31.2 ^{O}C; and
  - Stung Treng, between 28.5 and 31.3 ^{O}C.
- Between 2090 and 2100, the towns could have mean annual temperature, as follows:
  - Kampong Cham, between 32.4 and 32.7^{O}C;
  - Kratie, between 31.7 and 32.0 ^{O}C; and
  - Stung Treng, between 31.8 and 32.1 ^{O}C.
- Between 2050 and 2060, the towns could have mean annual rainfall, as follows:
  - Kampong Cham, between 1,560 mm and 1,750 mm
  - Kratie, between 1,920 and 2,150 mm; and
  - Stung Treng, between 1,900 and 2,130 mm.
- Between 2090 and 2100, the towns could have mean annual rainfall, as follows:
  - Kampong Cham, between 1,600 mm and 1,750 mm
  - Kratie, between 1,937 and 2,150 mm; and
  - Stung Treng, between 1,920 and 2,130 mm. (**Figures 34 and 35 and Table 1**)

Figure 34: Ranges of Probable Future Mean Annual Temperature[22]



[22] Ranges from the collated studies of the PPTA Team.

Figure 35: Ranges of Probable Future Mean Annual Rainfall[23]

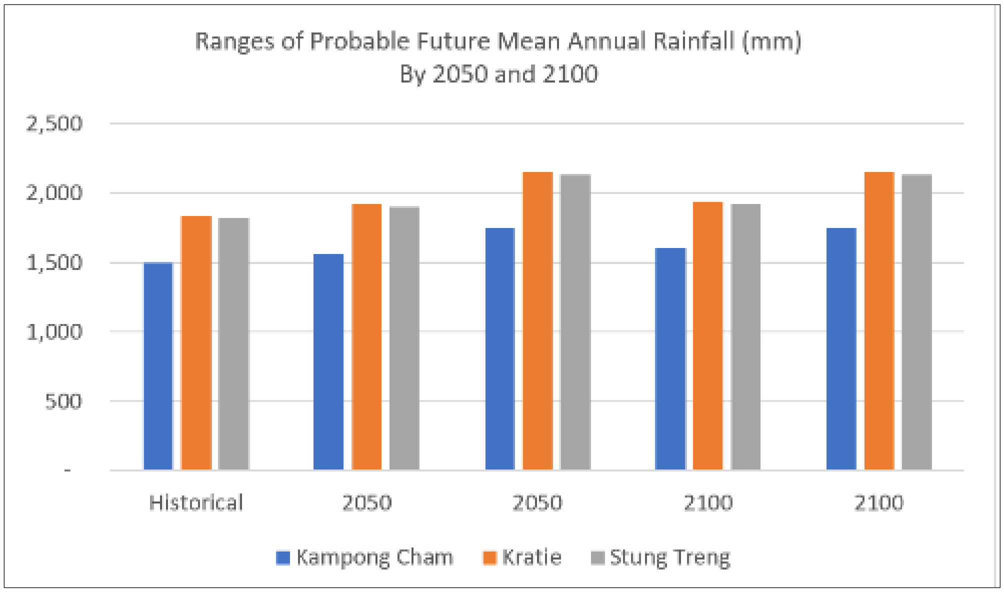


Table 1: Probable Future Mean Annual Temperature and Rainfall

A. TEMPERATURE

	Town	Mean Annual Temperature (°C)[a]	2025	2030s	2050	2060s	2090s	2100
1	Kampong Cham	28.37		29.7		31.1	32.7	
	Kratie	27.70		29.0		30.4	32.0	
	Stung Treng	27.82		29.1		30.5	32.1	
2	Kampong Cham	28.37			29.1			
	Kratie	27.70			28.4			
	Stung Treng	27.82			28.5			
3	Kampong Cham	28.37		29,2				
	Kratie	27.70		28.5				
	Stung Treng	27.82		28.6				
4	Kampong Cham	28.37			31.4			
	Kratie	27.70			31.2			
	Stung Treng	27.82			31.3			
5	Kampong Cham	28.37						32.4
	Kratie	27.70						31.7
	Stung Treng	27.82						31.8

B. RAINFALL

	Town	Mean Annual Rainfall (mm)[b]	2025	2030s	2050	2059	2090s	2100
1	Kampong Cham	1.496		1.601		1.751	1.751	
	Kratie	1.837		1.966		2.150	2.150	
	Stung Treng	1.822		1.950		2.132	2.132	

[23] Ibid.

2	Kampong Cham	1.496			1.564			
	Kratie	1.837			1.920			
	Stung Treng	1.822			1.904			
3	Kampong Cham	1.496		1.696				
	Kratie	1.837		2.037				
	Stung Treng	1.822		2.022				
4	Kampong Cham	1.496			1.646			
	Kratie	1.837			1.987			
	Stung Treng	1.822			1.997			
5	Kampong Cham	1.496						1.596
	Kratie	1.837						1.937
	Stung Treng	1.822						1.922

[a] Derived the mean annual temperature using the mean temperature data for 1991 to 2015 obtained from the Climate Change Knowledge Portal of the World Bank.

[b] Data time periods and sources: (i) Kampong Cham. 1992-2016. ADB Second Integrated Urban Environmental Management in the Tonle Sap Basin Project; (ii) Kratie. 1998-2016. DOWRAM Kratie Province; and (iii) Stung Treng. 1991-2015. Climate Change Knowledge Portal of the World Bank.

<u>Applied the projected changes from the following sources:</u>

1 C. McSweeny. M. New, and G. Liscano. UNDP Climate Change Country Profiles: CAMBODIA

2 Chu Tahi HOANH, Kittipong JIRAYOOT, Guillaume LACOMBE, Vithet SRINETR, 2010. Impacts of Climate Change and Development on Mekong Flow Regime. First assessment – 2009. MRC Technical Paper no. 29, Mekong River Commission, Vientiane, Lao People's Democratic Republic.

3 Eastham, J., F. Mpelasoka, M. mainuddin, C. Ticehurst, P. Dyce, G. Hodgson, R. Ali and M. Kirby, 2008. Mekong River Basin Resources Assessment: Impacts of Climate Change. CSIRO: Water for a Healthy Country National Research Flagship.

4 USAID Mekong Adaptation and Resilience to Climate Change (USAID Mekong ARCC) Final Report. September 2016. USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin: Main Report. Prepared for the United States Agency for International Development by ICEM – International Centre for Environmental Management. Bangkok: USAID Mekong ARCC Project, November 2013

5 Exploring Climate and Development Links. The World Bank. (climate4development.worldbank.org)

D. Rainfall Intensity

99. Projections for rainfall intensity during extreme events were obtained from the CRVA Reports of two ADB projects in Cambodia: (i) Rural Road Improvement Project (RRIP) II, 2018, February: and (ii) Provincial Water Supply and Sanitation Project (PWSSP), 2017, June.

100. Both projects used the Flood Risk Management Interface (FRMI) software to simulate flood risk projections; historical climate data obtained from MOWRAM and Ministry of Public Works and Transport; and the extreme scenario RCP8.5. RRIP II used the CCSIRO's CCAM model to project extreme rainfall. PWSSP used the CLIM system model to project rainfall and temperature under various RCP scenarios for target years.

101. According to the PWSSP simulation:

- The projected increase in rainfall intensity during extreme event will not of vary across the country
- By 2030, during a 1-in-10-year event, the country will experience a 4% increase in 1-hour rainfall; by 2050, 7%.
- By 2030, during a 1-in-100-year event, the country will experience a 7% increase in 1-hour rainfall; by 2050, 12%.
- For Kampong Cham, one of the four towns covered by PWSSP, extreme rainfall depth duration has been projected to experience changes in 2050 as follows:

- ✓ During a 1 in 10-year event, about 55 mm in1 hour; and
- ✓ During a 1 in 100-year event, about 74 mm in 1 hour.

102. According to the RRIP II simulation:

- The increases of a 1-day rainfall could be between 6-8% by 2030; 9-10% by 2050; and 28-34% by 2070.
- The increases of a 5-day rainfall could be between 9-14% by 2030; 16-20% by 2050; and 29-38% by 2090.

103. Both CRVA reports are saying that the 1-hour rainfall figure represents 20-40% of the **daily** rainfall in extreme events.

VII. FLOODS

A. Background[24]

104. Floods caused by storm rainfalls occur in the rainy season, particularly from July to October. There are 2 types of flooding – flash (caused by heavy rainfall) and Mekong/Tonle Sap. During the monsoon season, Cambodia experiences flash floods usually after heavy rainfall. The provinces of Battambang, Kampong Chnang, Kampong Speu, Kampong Thom, Kampot, Kandal, Pursat and Rattanakiri are regularly hit by flash flooding. The second type of flood, the much slower but prolonged flooding, is caused by the overflow of Tonle Sap river and Mekong tributaries, inundating the provinces of Kampong Cham, Kratie, Kandal, Prey Veng, Stung Treng, Svay Rieng and Takeo.[25] Floods account for 65% of the total number of natural disasters that occurred in 1980-2011. The recent notable floods, which occurred in August/September 2000, on August 18, 2002, on August 10, 2011 and in September 2013were all caused by storm rainfall.

- Mekong River flooding in August 2000 was caused by heavy rain that started in the last eleven days of July. The flood of September 2000 was caused by storm rainfall in the upper basin of Lao PDR. Overflowing of the Mekong River caused the flood and a state of emergency was declared in Phnom Penh and the three regions of Stung Treng, Kratie, and Kampong Cham. This flood caused the most extensive damage in recent years.
- The flood on August 18, 2002 occurred in the northeast and the southeast parts of the country along the left bank of the Mekong River.
- The flood on August 10, 2011, was caused by a series of tropical storms and heavy monsoon rains combined, making 2011 the worst flood season on the lower Mekong River since 2000. Floods swept across Cambodia, impacting 17 of the country's 24 provinces.
- Heavy rains that started in the third week of September 2013 resulted in floods in 20 provinces throughout the north-west and along the Mekong River in central and southern Cambodia.

105. The extent of the flood in 2000 and 2011 have remained the largest to date. The 2000 flood peak had a longer duration, resulting in a broader flood extent around Tonle Sap (MRC, 2011). The 2011 flood had higher water depths near Phnom Penh and in the direction of the border with Vietnam, probably the result of a more intense flood peak with a shorter duration and improved flood protection around Tonle Sap.

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24 Lifted from: Country Report Cambodia. AHA Center. Japan International Cooperation Agency. March 2015.
25 http://www.adrc.asia/countryreport/KHM/2013/KHM_CR2013B.pdf

106. Flood levels and duration data for the Project towns, other than anecdotal, were not available during project preparation from the Municipality or Provincial Authorities, when requested.

107. A presentation entitled ADB Experiences of Integrated Disaster Risk Management in Cities was presented during the Joint Cambodia-Lao PDR Workshop for the Project held in Phnom Penh in November 2017. The presentation highlighted the common disaster risk issues faced by the towns, including:

- Urban planning is not risk-sensitive and increases exposure to hazards
    a. Unwittingly steering growth in hazard-prone areas
    b. Conversion of wetlands for development purposes increases flood risk
    c. Lack of zoning regulation that factor natural hazards as considerations
- Building characteristics and informal settlements increase vulnerability
    a. Haphazard subdivision of plots
    b. Shoddy construction (cost-savings, corruption)
    c. Change in building use over time, thereby affecting its structural performance
- Lack of hazard considerations in urban infrastructure planning and maintenance
    a. Project-based approach does not always consider systemic linkages between infrastructure
    b. Heavy dependence on grey infrastructure and lack of awareness on green infrastructure
    c. Lack of maintenance due to inadequate budget and limited enforcement
    d. Designed for specific standards that may not be appropriate with changing hazard patterns.

B. Future Floods

108. Climate change is expected to significantly affect the Mekong River Basin. The predicted changes in rainfall and temperature could cause greater variability in the hydrological regime resulting in increased flood risks. With a meter of sea level rise, the low-lying areas downstream of Kratie and in the Mekong Delta would be inundated.

109. According to the MRC Working Paper 2011-2015 on the Impact and Management of Floods and Droughts in the Lower Mekong Basin and the Implications of Possible Climate Change, dated March 2012, of the Mekong River Commission, over the period 1985-2000 to 2042-2050, the mean annual high flow season discharge along the entire length of the Mekong River is projected to increase by 10-15%. This would impact on the mean annual "flood days[26]" in the project towns as follows:

- In Kampong Cham, at mean high flow season discharge of 20,935 m^3/s, the mean annual number of flood days would rise to 95 days in 2042-2050 (from 91 days in 1985-2000).
- In Kratie, at mean high flow season discharge of 21,549 m^3/s, the mean annual number of flood days would rise to 93 days in 2042-2050 (from 88 days in 1985-2000).
- In Stung Treng, at mean high flow season discharge of 20,827 m^3/s, the mean annual number of flood days would rise to 93 days in 2042-2050 (from 88 days in 1985-2000).

110. A comparison of the extent of flooding between that in the 2000 flood event and that of a

[26] Flood days are days with discharges greater than mean annual high-flow design discharge;

large flood event in 2048 under a projected climate change state revealed an 8.8% increase in the extent of flooding (that is, flood depths above 0.0 m) in the 2048 event. This will increase with greater depths. For depths over 1.5 m, the projected increase would be 30-60%. The comparison applied the peak daily discharge at Kratie of 54,900 m^3/s in the 2000 flood event and a projected discharge at Kratie in 2048 of 95,300 m^3/s, a whopping 74% increase.

VIII. CLIMATE CHANGE EFFECTS, IMPACTS AND DISASTER RISK REDUCTION AND ADAPTATION MEASURES

111. Increase in intensity and frequency of precipitation and associated flooding, temperature increase are the climate change effects deemed to have impacts that should be considered in the design of Project components.

A. Precipitation Increase

112. Climate change is expected to bring in more intensive and more frequent extreme rainfall events. Increase in rainfall would result in higher volume of runoff and worsened flooding (increase in the extent, depth and duration) throughout the country. The Cambodia floodplains is projected to experience increases of extreme floods with depths of up to 2.0m.[27] Precipitation increase and associated flooding are rated as “high” risks in this assessment. It could cause significant impacts on proposed infrastructure if not carefully accounted for in the designs. The potential impacts of precipitation increase on the proposed Project components are provided in the following paragraphs.

B. Climate Change Impacts on Urban Infrastructure

113. The primary manifestations of climate change; viz., increases in temperatures and alterations in the form, frequency, intensity and total quantity of precipitation; are in turn projected to give rise to a range of changes in natural systems. Many of these changes carry important implications for wastewater management, stormwater management and solid waste management that are the major focus of infrastructure improvement in the three cities. The implications and impacts of each of the major climate variables are presented in detail in the following paragraphs:

1. Implications and Impacts of Increasing Temperature on Wastewater Infrastructure

114. The main effect of climate change is increased temperature. The projections for Cambodia is a mean annual increase of 0.7 to 0.8°C by the 2030s as compared to the present. Increased temperatures and, especially the risk of increased dry spells and heat waves, will pose challenges in management of odours as the biological processes start early in the conveyance system. Also, the increased temperature results in corrosion in wastewater conveyance systems. Additionally, the resulting impacts of rising temperatures has on the rainfall patterns would require the utilities to take up water conservation efforts during drought periods, as well. And, with higher temperatures and lower flows due to water conservation efforts, the potential for both hydrogen sulphide odour problems and internal pipe corrosion will both be increased.

115. These projected increases in air and water temperatures shall impact the operation of wastewater treatment facilities both positively and negatively. As mentioned earlier, wastewater

[27] ADB TA-8179 CAM Mainstreaming Climate Resilience into Development Planning – Package 1. Final Inception Report. Annex 10: Climate Change Projections for Cambodia. ICEM.

treatment involves a number of chemical and biological processes that are temperature-dependent. And, COD, N and P removal are to some degree temperature-sensitive, with efficiency improving with temperature over a range from roughly 5°C – 30°C. Thus, increases in ambient temperatures can potentially improve the performance of water treatment plants.

116. However, the potential gains in efficiency must be weighed against the likely negative impacts of increased water temperatures on the concentration of contaminants and pathogens in wastewater that is subjected to treatment. Significant impact on the technical and economic performance of wastewater treatment facilities are to be expected.

2. Implications and Impacts Due to More Intense Rainfall Events on Wastewater Infrastructure

117. In Cambodia, climate change is not expected to impact on the overall annual rainfall. However, it is projected that there shall be a 10-15% increase in the frequency of high-intensity rainfalls that occur presently.

118. Wastewater treatment plants are designed to operate within a range of intake flows and loadings. Designs are developed on the basis of historical meteorological and hydrological records, and on the specification of the wastewater collection system. It is highly undesirable to have system inflows that fall outside the design parameters; either in terms of BOD loads or in terms of low or high flows. If climate change results in reductions in assimilative capacity of the receiving waters, water quality based effluent limits for the pollutant would need to be more stringent, and treatment costs would increase correspondingly. Additionally, intense rainfall events that increase the loadings of nutrients, pathogens and toxins into receiving waters shall magnify the other adverse effects of warmer waters that shall hold less dissolved oxygen and foster more algal growth.

119. When storm water inflow a combined sewer system as is the case in Cambodia causes the combined flow volume to exceed capacity, a mixture of untreated wastewater and storm water is often discharged from outfalls directly to surface or coastal waters, generating threats to human and environmental health.

3. Implications and Impacts of warmer and drier summer conditions on Wastewater Infrastructure

120. Global warming is expected to result in warmer and shorter winters in Cambodia. The elevated temperatures resulting from climate changes are likely to result in increased evaporation from soil and surface water bodies, potentially resulting in drier summer conditions even where rainfall changes are not significant such as in Cambodia.

121. Changes in regional climate and hydrology will also result in changes in freshwater discharge patterns, sediment loads, and the export of nutrients and other contaminants mobilized from upland sources as a consequence of increased rainfall intensity.

4. Climate Change Impacts on Lagoon-based Wastewater Treatment Plant

122. For the three project cities of Kampong-Cham, Kratie and Stung-Treng, lagoon-based wastewater treatment systems are being designed and implemented under the project. The treatment process in aerated lagoons is similar to the natural process in flowing water bodies and biological degradation of pollutants is based on attached growth. The biofilm built on the lagoon

bottom and slope needs a continuous supply of oxygen and organic pollutants to achieve treatment standards. The circulation of wastewater and dissolved oxygen ensures optimal conditions for aerobic growth at the lagoon bottom. Thus, organic pollution is reduced. As noted above, oxygen is a key component of the chemical processes that break down pathogens in wastewater and rising temperatures can result in less oxygen being available for necessary treatment processes.

123. Also, due to the long retention time and the low-volume load, aerated lagoons have a high capacity for peak-load buffering. Since the project cities have CSO that lead to the aerated-lagoons, simultaneous rainwater treatment is easily possible. Hence, the choice of lagoon-based wastewater treatment for the three project cities is an appropriate choice to achieve effective wastewater treatment. However, for managing high-intensity rainfall events, an improved solution that includes creation of additional storage capacity in the first lagoon. In this case, storm water is retained until, at maximum water level, an overflow or bypass structure goes into operation.

5. Climate Change Impacts on Solid Waste Management

124. Climate change could result in changes in temperatures, cloud cover, rainfall patterns, wind speeds, and storms: all factors that could impact future waste management facilities' development and operation. The time scales for climate change and waste management are similar. For instance, landfill sites can be operational for decades and remain active for decades following their closure. There is, therefore, a need to consider potential changes in waste management over significant timescales and respond appropriately. The impact of climate change on solid waste management is briefly summarized in **Table 2.**

Table 2: Impact of Climate Change on Solid Waste Management

Climate Variable	Potential Climate Change	Impacts on SWM
Temperature	• Annual warming upto 0.8°C in Cambodia; • More hot days increases especially in dry seasons; • Number of cold days decreases especially in rainy seasons;	• Increased water demand for both workers and site operations; • Decline in air quality and subsequent negative impacts of heat on vulnerable groups; • Impact on biological processes e.g., composting, anaerobic digestion etc.; • Increased risk of changes in distribution of vermin and pests;
Rainfall	• More wetter days • Precipitation intensity increases in rainy season	• Increased risk of flooding from groundwater, surface water, tidal and sea surfaces; • Disruption to infrastructure e.g., road, rail resulting in disrupting wastewater collection and transport; • Increased rainfall intensity could affect slope stability at landfill sites; • Impact on biological processes e.g., composting, anaerobic digestion etc.;
Cloud cover	• Reduction in cloud cover	• Risk to workers because of increased exposure to sunshine during outdoor operations;
Humidity	• Specific humidity increases especially during rainy season;	• Impacts on outdoor biological processes

Climate Variable	Potential Climate Change	Impacts on SWM
Sea level	• Increase in Mean Sea Level	• Inundation of waste management facilities; • Increased erosion of coastal areas.

125. In the project cities, the climate change impacts on the lagoon-based wastewater treatment system and the controlled landfill are provided in the following paragraphs:

126. **Lagoon-based wastewater treatment system**

- Increased risk of direct flood damage to treatment plant, pumping, conveyance and outfall
- Collection network overload. Potential damages to the network.
- More frequent and larger combined sewer overflow, discharging untreated wastewater.
- Hastened deterioration of pipelines due to ground saturation and increased ground movement.
- WWTP overload, resorting to bypass or spill. Too much influent will cause lower performance of the WWTP.
- Inundation of the WWTPs and pumping stations causing damage of mechanical and electrical equipment and stand-by power generator. Flooding and heavy rains could make it difficult and dangerous for maintenance and repair crew to respond to the problem.
- Construction in areas that are now waterlogged for months in the rainy season would probably be adversely affected in the aspects of construction schedule, construction quality, risks to workers health and safety and costs.

127. **Controlled landfill**

- Increased stormwater to manage at the landfill site.
- Erosion/instability of waste cells.
- Erosion of side slopes of active waste cells.

128. **Town Center Enhancement**

- Higher volume of runoff causing saturation of pavement and its foundation, causing premature failure of pavement or deterioration of pavement integrity.

IX. DISASTER RISK REDUCTION AND CLIMATE ADAPTATION MEASURES

129. Suggested disaster risk reduction and adaptation measures for each component under the Project are presented in **Tables 3, 4 and 5**. The measures shown in the tables are those that have been assessed as technically feasible by the PPTA Engineering Team. The estimated total incremental disaster risk reduction and climate change adaptation cost, as of preliminary engineering design stage, is USD 2.22 million, or 3.7% of the estimated total infrastructure base cost, USD 60.41 million for Output 1 and USD 0.8 million for Output 2. The overall incremental disaster risk reduction and climate adaptation cost is USD 3.02 million (**Table 6**).

Table 3: Potential Impacts and Disaster Risk Reduction and Adaptation Measures (Kampong Cham Subproject)

A. Lagoon-Based Wastewater Treatment System

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	**Recommended for Consideration/Incorporation in Detailed Design**
PRECIPITATION INCREASE • Higher volume of runoff and worsened flooding. Collection network overload. Potential damages to the old networks.	• Preliminary design has incorporated structural adaptation measures for precipitation increase and associated flood risk: o Old system will be replaced with new combined collection system covering entire service area. o Pipes are sized for potential increase in runoff: - pipes up to 1500mm diameter; - open channels for flows expected to be greater than can be conveyed with 1500mm diameter; and - pipes (sizes, grades, routes) designed as part of an integrated system for full city.	• Undertake detailed analysis of historical and future flood levels will be conducted to determine the appropriate factor of safety for bunds.
• More frequent and larger combined sewer overflow, discharging untreated wastewater	• Combined sewer overflow (CSO) for wastewater volume beyond maximum design flow.	• Design the overflow chamber pipe levels to only overflow when the wastewater volume reaches maximum design flow. • Incorporate LID/green infrastructure into the system, where or as applicable, such as availing of public parks and open spaces, for temporary storage (detention areas) and allowing infiltration. This will mitigate overwhelming the pipe network with runoff. Designed well, these detention areas could enhance parks and open spaces. • Prepare an Operations Manual for the combined sewer system (CSS) linked with a WWTP Operations Manual --- that prescribes: - the monitoring of the water quality of the overflow-receiving water bodies, following an overflow activity; and - the removal of obstructions to flow in the CSS prior to the onset of rainy season and periodically during the rainy season to maximize use of the collection system and for maximized flow to the WWTP.
• Hastened deterioration of pipelines due to ground saturation and increased ground movement	• Alumina-lined concrete pipe specified, resistant to hydrogen sulphide attack.	• Consider the recommendation for alumina-lined concrete pipes.

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
• WWTP overload, resorting to bypass or spill. Too much influent will cause lower performance of the WWTP	• Control of WWTP inlet will limit wet season inflows to only the design flow. All excess water would go to overflow. Control of inlet will consist of a Parshall flume on inlet for flow measurement, a valve on inlet and a bypass with valve. WWTP will not spill unless abandoned. During extreme wet events, there should be checking of inflow and adjusting of the valve.	• Ensure inlet controls are engineered to only allow the design maximum flow that the WWTP is to treat. • Include a disaster preparedness/management section in the WWTP Operations Manual, specifying the set up and maintenance of a crew of adequate number of trained staff for WWTP operations and disaster preparedness and response during extreme weather.
• Inundation of the WWTPs and pumping stations causing damage of mechanical and electrical equipment and stand-by power generator. Flooding and heavy rains could make it difficult and dangerous for maintenance and repair crew to respond to the problem.	• Bunds around lagoons with site roads above flood levels. Bunds raised 1-2m above flood levels. • Use of submersible pumps. • Power & controls at roadside above flood level. • No permanent generator, portable one to be stored at the WWTP.	• Prepare a WWTP Operations Manual that includes an Emergency Response Plan.
• Construction in areas that are now waterlogged for months in the rainy season would probably be adversely affected in the aspects of construction schedule, construction quality, risks to workers health and safety and costs	• WWTP Earthworks (bunds, infill, excavation) to be programmed for dry season.	• Specify in bid documents for construction schedule to incorporate 4-5 months each year of waterlogged conditions in the WWTP site and some spots in the service area. Schedule must also take into account the concern on pipelaying in the wet season to cause poor settlement and affect final grade.
• Power outages are possible during a long hot and dry season, disrupting WWTP operations.		

B. Controlled landfill

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
PRECIPITATION INCREASE • Increased stormwater to manage at the landfill site.	• Stormwater management system to be designed for appropriate longer return period over and above usual 2 year-period.	
• Increased leachate production.	• Recommended the combination of the following to manage leachate: • Recirculation of leachate; and	

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
	• lagoon treatment.	
	• Composite cell liner, geomembrane (HDPE) liner with clay/earth cover.	• Conduct geotechnical investigations. Based on the findings, confirm or adjust the proposed cell liner to ensure protection from leakage. • Prepare a Landfill Operations Manual to include specifications for the cover material and procedures for periodic and final cover.
• Erosion of side slopes of active and completed waste cells.		• Based on the findings from the geotechnical investigation on soil characteristics, specify the appropriate cell slopes. • For completed cells, allow vegetation (using erosion control/storm- and drought-tolerant plants) and reinforce side slopes' stability with geotextile layers.

Table 4: Potential Impacts and Disaster Risk Reduction and Adaptation Measures (Kratie Subproject)

A. Lagoon-Based Wastewater Treatment System

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
PRECIPITATION INCREASE • Higher volume of runoff and worsened flooding. Collection network overload. Potential damages to the old networks.	• Preliminary design has incorporated structural adaptation measures for precipitation increase and associated flood risk: o Old system will be replaced with new combined collection system covering entire service area. o Pipes are sized for potential increase in runoff: - pipes up to 1500mm diameter; - open channels for flows expected to be greater than can be conveyed with 1500mm diameter; and - pipes (sizes, grades, routes) designed as part of an integrated system for full city.	• Undertake detailed analysis of historical and future flood levels to determine the factors of safety for application in designs.
• More frequent and larger combined sewer overflow, discharging untreated wastewater	• Combined sewer overflow (CSO) for wastewater volume beyond maximum design flow.	• Design the overflow chamber pipe levels to only overflow when the wastewater volume reaches maximum design flow. • Incorporate LID/green infrastructure into the system, where or as applicable, such as

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures: Preliminary Engineering Design Response	Adaptation Measures: Recommended for Consideration/Incorporation in Detailed Design
		availing of public parks and open spaces, for temporary storage (detention areas) and allowing infiltration. This will mitigate overwhelming the pipe network with runoff. Designed well, these detention areas could enhance parks and open spaces. • Prepare an Operations Manual for the combined sewer system (CSS) linked with a WWTP Operations Manual --- that prescribes: - the monitoring of the water quality of the overflow-receiving water bodies, following an overflow activity; and - the removal of obstructions to flow in the CSS prior to the onset of rainy season and periodically during the rainy season to maximize use of the collection system and for maximized flow to the WWTP.
• Hastened deterioration of pipelines due to ground saturation and increased ground movement	• Alumina-lined concrete pipe specified, resistant to hydrogen sulphide attack.	• Consider the recommendation for alumina-lined concrete pipes. •
• WWTP overload, resorting to bypass or spill. Too much influent will cause lower performance of the WWTP	• Control of WWTP inlet will limit wet season inflows to only the design flow. All excess water would go to overflow. Control of inlet will consist of a Parshall flume on inlet for flow measurement, a valve on inlet and a bypass with valve. WWTP will not spill unless abandoned. During extreme wet events, there should be checking of inflow and adjusting of the valve.	• Ensure inlet controls are engineered to only allow the design maximum flow that the WWTP is to treat. • Include a disaster preparedness/management section in the WWTP Operations Manual, specifying the set up and maintenance of a crew of adequate number of trained staff for WWTP operations and disaster preparedness and response during extreme weather.
• Inundation of the WWTPs and pumping stations causing damage of mechanical and electrical equipment and stand-by power generator. Flooding and heavy rains could make it difficult and dangerous for maintenance and repair crew to respond to the problem.	• Bunds around lagoons with site roads above flood levels. Bunds raised 1-2m above flood levels.	• Prepare a WWTP Operations Manual that includes an Emergency Response Plan.
	• Use of submersible pumps. • Power & controls at roadside above flood level. • No permanent generator, portable one to be stored at the WWTP.	
• Construction in areas that are now waterlogged for months in the rainy season would probably be adversely affected in	• WWTP Earthworks (bunds, infill, excavation) to be programmed for dry season. -	• Specify in bid documents for construction schedule to incorporate 4-5 months each year of waterlogged conditions in the WWTP site and some spots in the service area. Schedule must also take into account the concern on pipelaying in the wet

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
the aspects of construction schedule, construction quality, risks to workers health and safety and costs		season to cause poor settlement and affect final grade.

B. Controlled landfill

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
PRECIPITATION INCREASE • Increased stormwater to manage at the landfill site.	• Stormwater management system to be designed for appropriate longer return period over and above usual 2 year-period.	
• Increased leachate production.	• Recommended the combination of the following to manage leachate: • Recirculation of leachate; and • Lagoon treatment.	
	• Composite cell liner, geo-membrane (HDPE) liner with clay/earth cover.	• Conduct geotechnical investigations. Based on the findings, confirm/adjust the cell liner to ensure leakage protection. • Prepare a Landfill Operations Manual to include specifications for the cover material and procedures for periodic and final cover.
• Erosion of side slopes of active and completed waste cells.		• Based on the findings from the geotechnical investigation on soil characteristics, specify the appropriate cell slopes. • For completed cells, allow vegetation (using erosion control/storm- and drought-tolerant plants) and reinforce side slopes' stability with geotextile layers.

C. Town Center Enhancement

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	Recommended for Consideration/Incorporation in Detailed Design
PRECIPITATION INCREASE • Higher volume of runoff and worsened flooding, causing saturation of pavement and its foundation, causing premature failure of pavement or deterioration of pavement integrity.		• Specify adequate pavement grade to lead runoff away from the pavement to: (i) the combined sewers; (ii) pervious spaces close by; and/or (iii) riverbank slopes. •

Table 5: Potential Impacts and Disaster Risk Reduction and Adaptation Measures (Stung Treng Subproject)

A. Lagoon-Based Wastewater Treatment System

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	**Recommended for Consideration/Incorporation in Detailed Design**
PRECIPITATION INCREASE • Higher volume of runoff and worsened flooding. Collection network overload. Potential damages to the old networks.	• Preliminary design has incorporated structural adaptation measures for precipitation increase and associated flood risk: o Old system will be replaced with new combined collection system covering entire service area. o Pipes are sized for potential increase in runoff: - pipes up to 1500mm diameter; - open channels for flows expected to be greater than can be conveyed with 1500mm diameter; and - pipes (sizes, grades, routes) designed as part of an integrated system for full city.	• Undertake detailed analysis of historical and future flood levels to determine the factors of safety for application in designs. •
• More frequent and larger combined sewer overflow, discharging untreated wastewater	• Combined sewer overflow (CSO) for wastewater volume beyond maximum design flow.	• Design the overflow chamber pipe levels to only overflow when the wastewater volume reaches maximum design flow. • Incorporate LID/green infrastructure into the system, where or as applicable, such as availing of public parks and open spaces, for temporary storage (detention areas) and allowing infiltration. This will mitigate overwhelming the pipe network with runoff. Designed well, these detention areas could enhance parks and open spaces. • Prepare an Operations Manual for the combined sewer system (CSS) linked with a WWTP Operations Manual --- that prescribes: - the monitoring of the water quality of the overflow-receiving water bodies, following an overflow activity; and - the removal of obstructions to flow in the CSS prior to the onset of rainy season and periodically during the rainy season to maximize use of the collection system and for maximized flow to the WWTP.
• Hastened deterioration of pipelines due to ground saturation and increased ground movement	• Alumina-lined concrete pipe specified, resistant to hydrogen sulphide attack.	• Consider the recommendation for alumina-lined concrete pipes.

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	**Recommended for Consideration/Incorporation in Detailed Design**
• WWTP overload, resorting to bypass or spill. Too much influent will cause lower performance of the WWTP	• Control of WWTP inlet will limit wet season inflows to only the design flow. All excess water would go to overflow. Control of inlet will consist of a parshall flume on inlet for flow measurement, a valve on inlet and a bypass with valve. WWTP will not spill unless abandoned. During extreme wet events, there should be checking of inflow and adjusting of the valve.	• Ensure inlet controls are engineered to only allow the design maximum flow that the WWTP is to treat. • Include a disaster preparedness/management section in the WWTP Operations Manual, specifying the set up and maintenance of a crew of adequate number of trained staff for WWTP operations and disaster preparedness and response during extreme weather.
• Inundation of the WWTPs and pumping stations causing damage of mechanical and electrical equipment and stand-by power generator. Flooding and heavy rains could make it difficult and dangerous for maintenance and repair crew to respond to the problem.	• Bunds around lagoons with site roads above flood levels. Bunds raised 1-2m above flood levels.	• Prepare a WWTP Operations Manual that includes an Emergency Response Plan.
	• Use of submersible pumps. • Power & controls at roadside above flood level. • No permanent generator, portable one to be stored at the WWTP.	
• Construction in areas that are now waterlogged for months in the rainy season would probably be adversely affected in the aspects of construction schedule, construction quality, risks to workers health and safety and costs	• WWTP Earthworks (bunds, infill, and excavation) to be programmed for dry season.	• Specify in bid documents for construction schedule to incorporate 4-5 months each year of waterlogged conditions in the WWTP site and some spots in the service area. Schedule must also take into account the concern on pipe laying in the wet season to cause poor settlement and affect final grade.

B. Controlled landfill

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	**Recommended for Consideration/Incorporation in Detailed Design**
PRECIPITATION INCREASE • Increased stormwater to manage at the landfill site.	• Stormwater management system to be designed for appropriate longer return period over and above usual 2 year-period.	
• Increased leachate production.	• Recommended the combination of the following to manage leachate: • Recirculation of leachate; and • Lagoon treatment.	
	• Composite cell liner, geomembrane (HDPE) liner with clay/earth cover.	• Conduct geotechnical investigations. Based on the findings, confirm or adjust the proposed cell liner to ensure protection from leakage. • Prepare a Landfill Operations Manual to include specifications for the cover material and procedures for periodic and final cover.
• Erosion of side slopes of active and completed waste cells.		• Based on the findings from the geotechnical investigation on soil characteristics, specify the appropriate cell slopes. • For completed cells, allow vegetation (using erosion control/storm- and drought-tolerant plants) and reinforce side slopes' stability with geotextile layers.

C. Town Center Enhancement

Disaster Risk and Climate Change Effects and Potential Impacts	Adaptation Measures	
	Preliminary Engineering Design Response	**Recommended for Consideration/Incorporation in Detailed Design**
PRECIPITATION INCREASE • Higher volume of runoff and worsened flooding, causing saturation of pavement and its foundation, causing premature failure of pavement or deterioration of pavement integrity.	• Drainage on both sides of Roads 14 and 22.	• Specify adequate pavement grade to lead runoff away from the pavement to: (i) the combined sewers; (ii) pervious spaces close by; and/or (iii) riverbank slopes.

Table 6: Disaster Risk Reduction and Climate Change Adaptation Actions and Estimated Incremental Costs

Action	Physical/ Non-Physical	Incremental Change or New Activity Based on Risk Assessment	Risk Addressed	Cost (USD)		
				Base (Preliminary Design Phase without Adaptation)	**Estimated Incremental** (Preliminary Design Phase with Adaptation)	**Total Component**
Output 1. Urban Environmental Infrastructure Improved						
KAMPONG CHAM						
Lagoon-Based Wastewater Treatment System						
Pipe network	Physical	Pipes sized to 2-year return period	Increase in precipitation	10,994,396	-	10,994,396
WWTP	Physical	Raising of plant extra 1m	Flood risk	2,979,025	294,500	3,273,525
MSW Controlled Landfill	Physical	Concrete road instead of DBST, plus larger drains	Increase in precipitation	5,895,600	200,000	6,095,600
			Sub-total	**19,869,021**	**494,500**	**20,363,521**
KRATIE						
Lagoon-Based Wastewater Treatment System						
Pipe network	Physical	Pipes sized to 2-year return period	Increase in precipitation	8,626,678	-	8,626,678
80-m stormwater channel	Physical	Raising bunds extra 2m	Flood risk	2,293,200	982,800	3,276,000
WWTP	Physical	Raising of plant extra 1m	Flood risk	2,799,640	266,000	3,065,640
MSW Controlled Landfill	Physical	Concrete road instead of DBST, plus larger drains	Increase in precipitation	5,895,600	200,000	6,095,600
Town Center Enhancement	-	-	-	685,700	-	685,700
			Sub-total	**20,300,818**	**1,448,800**	**21,749,618**
STUNG TRENG						
Lagoon-Based Wastewater Treatment System						
Pipe network	Physical	Pipes sized to 2-year return period	Increase in precipitation	9,131,909	-	9,131,909
WWTP	Physical	Raising of plant extra 1m	Flood risk	2,669,260	26,280	2,695,540
MSW Controlled Landfill	Physical	Concrete road instead of DBST, plus larger drains	Increase in precipitation	5,534,000	250,000	5,784,000
Town Center Enhancement	-	-	-	685,700	-	685,700
			Sub-total	**18,020,869**	**276,280**	**18,297,149**
			Output 1 Sub-total	**58,190,708**	**2,219,580**	**60,410,288**
Output 2: Institutional effectiveness, and policy and planning environment for regional economic connectivity enhanced						
ICT for Public Management (Public Asset Database, Flood Early Warning)	Non-Physical		Flood, Disaster Risk Management and Urban Planning	0	500,000	500,000
Project Management Consulting Service	Non-Physical			0	300,000	300,000
			Output 2 Sub-total	**0**	**800,000**	**800,000**
			TOTAL	**58,190,708**	**3,019,580**	**61,210,288**

X. CLIMATE MITIGATION

130. Landfill generates greenhouse gases, largely methane or CH4 (about 50 to 55%) and carbon dioxide or CO_2 (about 40 to 45%). Wastewater treatment generates CH_4, CO_2 and nitrous oxide (N_2O).

131. Greenhouse gas (GHG) emissions from the operations of the wastewater treatment facilities and controlled landfills were estimated using the following tool and procedure: (i) IGES tool for GHG calculation for Solid Waste Sector.[28] (ii) Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation. December 14, 2010. RTI International (Research Triangle Institute). The Project was estimated to emit a total of 39,879 tpy carbon dioxide equivalent (CO_2-eq) per year, contributed by each subproject as follows: (i) Kampong Cham 15,624 tpy CO_2-eq; (ii) Kratie, 14, 521 tpy CO_2-eq; and (iii) Stung Treng, 9.734 tpy CO_2-eq. **Table 7** below provides a breakdown per component.

132. The global warming potential (GWP) applied in the estimation is for a 100-year time horizon. The unit "tpy CO_2eq" stands for tonnes per year CO_2 equivalent". This unit was devised to facilitate comparison of global warming impact of the gases or the ability of each GHG to trap heat in the atmosphere relative to carbon dioxide. For a 100-year time horizon, CH_4 has a GWP of 21; N_2O has 310.

133. **Annex B** presents the procedure applied for the WWTP and the tool used for the controlled landfill.

Table 7: Estimated GHG Emissions from the Project

A. Kampong Cham Subproject	
Component	Estimated GHG emissions tpy CO_2-eq *
WWTP	2,466.40
Controlled landfill	13,157.42
Total – Kampong Cham	15,623.82
B. Kratie Subproject	
Component	Estimated GHG emissions tpy CO_2-eq *
WWTP	2,544.07
Controlled landfill	11,977.29
Total – Kratie	14,521.36
C. Stung Treng Subproject	
Component	Estimated GHG emissions tpy CO_2-eq *
WWTP	1,683.65
Controlled landfill	8,048.90
Total – Stung Treng	9,733.55
D. Project	
Total	39,878.73
* Tools/procedures used: - Research Training Institute International. 2010. Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from	

[28] Emission Tool for Greenhouse Gas (GHG) Emissions from Municipal Solid Waste (MSW) Management in a Life Cycle Perspective. Nimala Menikpura. Janya Sang-Aru. Institute for Global Environmental Strategies (IGES). 2013.

Selected Source. Categories: Solid Waste Disposal. Wastewater Treatment, Ethanol Fermentation. Submitted to the US EPA. - Institute for Global Environmental Strategies (IGES). GHG Calculator for Solid Waste Sector – IGES Tool.

134. There are measures that can be implemented to mitigate landfill emissions without having to apply high technologies, such as:

- Optimized waste collection routes and service frequency
- Prompt maintenance of waste collection trucks.
- Materials recovery at source, to reduce the waste to be collected, hauled and deposited at the landfill.
- Composting at the landfill site.
- Intensive awareness campaign for waste minimization, segregation, at reuse.
- Household waste segregation to be linked with itinerant waste buyers
- Using energy efficient lighting at the landfill.
- A perimeter buffer strip densely planted with trees at the landfill.

135. Using the IGES tool, a simulation was made to see how much emission would be saved if the following measures would be implemented:

- Waste to be collected is reduced by 15% due to active recycling at source.
- Waste collection frequency is every other day except for market waste.
- Composting of about 20% of the waste collected (about 200- 300 tonnes per month at the landfill site.

136. The simulation revealed a reduction of greenhouse gas by 60%. (**Table 8** and **Annex C**)

137. Measures that can be suggested for mitigating GHG emissions from lagoon-based wastewater treatment would be: (i) ensuring energy efficiency in operations, using of energy-efficient lights and other equipment; (ii) establishing a perimeter buffer strip densely planted with trees at the site.

Table 8. Emission Reduction with Mitigation

Subproject	**Emission (tonnes CO_{2eq}/yearly managed waste)**		
	From operation	**Wit composting, etc. ***	**Savings**
Kampong Cham	13,157	5,357	7,800
Kratie	11,977	4,564	7,414
Stung Treng	8,050	3,112	4,938
Total	33,185	13,032	20,152

* Emission generated if to apply the following:
- Composting 300 tonnes per month for Kampong Cham and Kratie (which would be 18% and 19.8% of waste generated daily).
- Composting 200 tonnes per month for Stung Treng (or 19.7% of waste generated daily.
- Collection frequency of every other day (except for market waste). Used the IGES tool in estimating the GHG emissions. See **Annex C**.

XI. FINDINGS AND CONCLUSIONS

138. The nature of the proposed components, except the town center enhancement

component, will be vulnerable to climate change. Hence, it is critical that project components are designed to increase resilience to climate change.

139. Project sites, except those for the controlled landfills, experience flooding each year, either fully or partly. The sites for the WWTPs in all three towns and trunk sewers in Kampong Cham are most vulnerable to climate change, being waterlogged during the rainy season. The AWARE for Project tool has rated flood as “high” risk. A detailed analysis of flood risk is important to determine/confirm the appropriate factors of safety for bunds around the WWTPs.

140. Climate projections from the different models reviewed are indicating increase in both temperature and precipitation. The probable range of mean annual temperature between 2050 and 2060, encompassing the three towns, would be from 28.4 to 31.4 ^{o}C; for mean annual rainfall, from 1,560 to 2,150 mm.

141. Rainfall increases, and more intensive rainfall events will lead to increases in the extent, depth and duration of flooding. From viewing available maps of flood projections, it appears Kampong Cham could have a maximum flood depth between 1.6 and 3 m for about 4 to 14 days; and Kratie could have normal maximum flood depth for about 3 days. These are mainly interpretations of the maps.

142. In this assessment, precipitation increase and associated worsened flooding are rated as “high” risks. Temperature increase and associated lowering of the groundwater table and land subsidence, as “moderate” risks; Taking these risks into account and incorporating adaptation measures in the designs would make the Project technically resilient to the challenges of climate change.

143. The proposed adaptation measures, consisting of hard and soft measures, have been deemed as technically feasible by the PPTA Engineering Team. The estimated incremental climate change adaptation cost is USD 2.22 million or about 3.7% of the estimated total infrastructure base cost, as of preliminary design stage, USD 60.41 million for Output 1 and USD 0.8 million for Output 2. The overall incremental climate adaptation cost is USD 3.02 million.

CAM AWARE Climate Risk

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Section 1 of 15

Report generated by: Genevieve O'Farrell, Asian Development Bank | Date created: 12.06.2017 03:37

01

Introduction

This report summarises results from a climate and geological risk screening exercise. The project information and location(s) are detailed immediately below.

The screening is based on the Aware™ geographic data set, compiled from the latest scientific information on current geological, climate and related hazards together with projected changes for the future where available. These data are combined with the project's sensitivities to hazard variables, returning information on the current and potential future risks that could influence its design and planning.

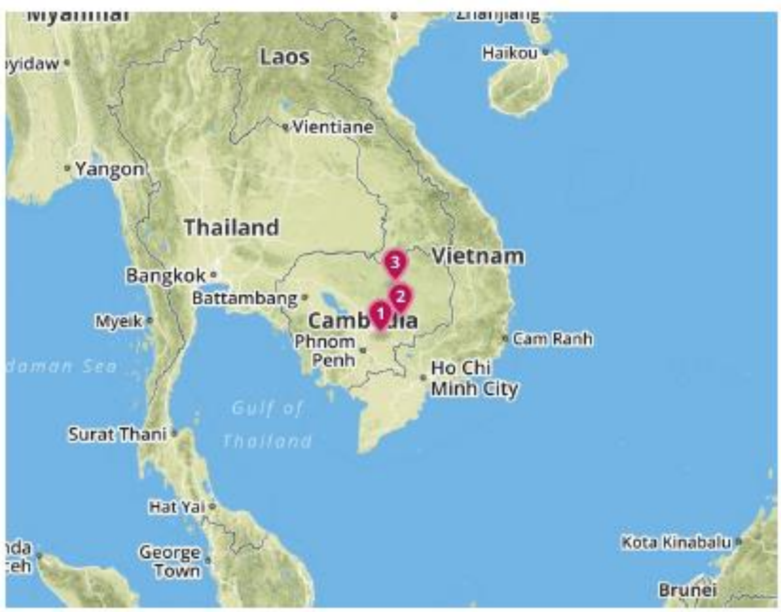
Project Information

PROJECT NAME:	GMS 4th Corridor Towns Development Project
SUB PROJECT:	Cambodia
PROJECT NUMBER / REFERENCE:	TA9192
SECTOR:	Water and Other Urban Infrastructure Services
SUB SECTOR:	Urban sewerage - wastewater treatment
DESCRIPTION:	Kampong Cham - improved drainage, wastewater treatment plant/network, solid waste management Kratie - ring road, drainage, wastewater treatment plant Stung Treng - drainage

02

Chosen Locations

1) Kampong Cham
2) Kratie
3) Stung Treng



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03

Project Climate Risk Ratings

Below you will find the overall climate risk level for the project together with a radar chart presenting the level of risk associated with each individual climate risk topic analysed in Aware™. Projects with a final "High risk" rating are always recommended for further more detailed climate risk analyses.

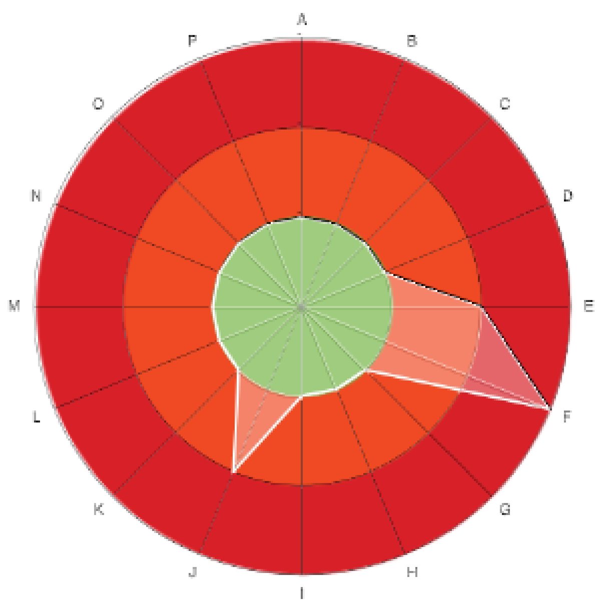
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing and possible future climate conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage current and future climate change risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project climate risk ratings

Medium Risk

Breakdown of climate risk topic ratings



- A) Temperature increase
- B) Wild fire
- C) Permafrost
- D) Sea ice
- E) Precipitation increase
- F) Flood
- G) Snow loading
- H) Landslide
- I) Precipitation decrease
- J) Water availability
- K) Wind speed increase
- L) Onshore Category 1 storms
- M) Offshore Category 1 storms
- N) Wind speed decrease
- O) Sea level rise
- P) Solar radiation change

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04
HIGH
RISK

FLOOD

ACCLIMATISE COMMENTARY

• Our data suggest that the project is located in a region which has experienced recurring major flood events in the recent past. A high exposure in Aware means that between 1985 and 2016 there have been at least one significant, large-scale flood event in the region. This is based on post-processed data from the Dartmouth Flood Observatory at the University of Colorado.

• The risk and type of flooding is dependent on local geographical factors including:
- Proximity to the coast and inland water courses
- Local topography
- Land use characteristics, including land use in upstream catchment area
- Design and maintenance level of drainage infrastructure
- Vulnerability of exposed assets
• Up to date information on flood risk worldwide is available online, for example UNEP / UNISDR's Global Risk Data Platform and Dartmouth Flood Observatory's Global Active Archive of Large Flood Events.

1. What does this mean for the design and construction of my project?

• If floods are identified as a potential problem for the project, it is recommended that:
- More localized information is collected on past floods and their consequences in the exact project location, especially since flood hazard can change significantly over short distances; depending on the findings, a site-specific flood risk assessment (including flood modelling) might be required that provides a good understanding of the current and future flood risk level
- Information is collected on land use and building regulations, such as flood zonation ordinances
- The project siting, design and construction features ensure that site-specific flood risk management measures are undertaken. Such measures could include a combination of grey infrastructure (such as flood defence infrastructure) and green infrastructure (such as restoration of wetlands) to reduce flood risk, as well as measures to manage the residual flood risk (such as through flood early warning, flood preparedness planning, flood insurance etc.)

2. What does the science say could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence the frequency and intensity of flood events.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from flooding. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

3. As a starting point you may wish to consider the following questions:

Q1 Would the expected performance and maintenance of the project be impaired by flooding?
Q2 Is there a plan to integrate climate change into a flood risk assessment for the project?
Q3 Does the project siting consider flood risk to ensure the proposed project will not be impacted by flooding and will not increase risk of flooding?
Q4 Does the project design and construction features incorporate measures to manage flood risk, both in the immediate term and as risk of flooding changes as a consequence of climate change?
Q5 Will the project include emergency management plans which make provision for continued successful operation in the event of floods?

4. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
• Click here or here for the latest news and information relating to floods and climate change.

☐ I have acknowledged the risks highlighted in this section.

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05
MEDIUM RISK

PRECIPITATION INCREASE

Would an increase in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

Yes - a little.

The design of the project may have to be slightly modified to cope with the impact of increased precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of heavy precipitation events as well as potential future changes.

2. How could current heavy precipitation affect the project even without future climate change?

• Seasonal runoff may lead to erosion and siltation of water courses, lakes and reservoirs.
• Flooding and precipitation induced landslide events.
• In colder regions, seasonal snow falls could lead to overloading structures and avalanche risk.
• If our data suggests that there are existing hazards associated with heavy precipitation in the region, they will be highlighted elsewhere in the report. This may include existing flood and landslide risks.

3. What does the science say could happen by the 2050s?

• Climate model projections agree that annual average precipitation will increase in the project location. This indicates a relatively low degree of uncertainty that precipitation will increase in the region.
• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to water and climate change.

☐ I have acknowledged the risks highlighted in this section.

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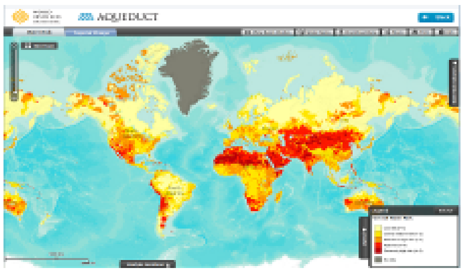
06
MEDIUM RISK

WATER AVAILABILITY

ACCLIMATISE COMMENTARY



• Our data suggest that the project is located in a region where there may be future water stress (2020s - 2050s). A high exposure in Aware means that either water stress is 'extreme' or high seasonal temperatures coincide with relatively low rainfall. Extreme water stress is defined as 'less than 0.5 million litres available per person per year' based on climate information as well as the effects of income, electricity production, water-use efficiency and other driving forces. This is post-processed data from Alcamo et al., 2007. Away from populated regions, high exposure also occurs where high seasonal temperatures (above 28 degrees Celsius average over 6 months) coincide with low rainfall (less than 100mm per month average over 6 months). This is based on post-processed data from the Global Precipitation Climatology Centre (GPCC), Climatic Research Unit (CRU) and a range of GCM projections.
• The situation may be exacerbated if there is increased competition for water with other users in the area and changes in local demographics.
• An associated reduction in water quality could also have a negative impact on the project.

1. What the science says could happen in the future and what does this mean for the design of my project?

• Climate change is projected to influence water availability. Regions that are already dry may suffer further if future precipitation is projected to decrease. Increased evaporation due to rising temperature will further impact on water availability. Seasonal availability of water may also change whereby there may be a shift in the timing of its availability.
• Existing engineering designs may not take into consideration the impact of climate change on the risks from water availability and design standards may not be met. See "Critical thresholds" in the "Help & glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.
• If water availability is identified as a potential problem for the project, it is recommended that a more localised and in-depth assessment is carried out. This information can then be used to inform the project design process if necessary.
• If you want to know more about projected changes in water availability in the project location, please refer to: the World Resources Institute's Aqueduct.

2. As a starting point you may wish to consider the following questions:

Q1 How would a lack of water impact the expected performance of the project?
Q2 Would a reduction in water supply have consequences for the expected maintenance of the project?
Q3 Will there be a water shortage continuity strategy in place for the project?
Q4 Will it be necessary to carry out water availability risk assessments in any of the project locations? If so, these assessments should take into account climate change?
Q5 Will there be an investment in water efficient technology or practices to help minimise the quantities of water required for its operational processes?

3. What next?

• See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
• Click here or here for the latest news and information relating to water and climate change.

☐ I have acknowledged the risks highlighted in this section.

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07
LOW
RISK

TEMPERATURE INCREASE

Would an increase in temperature require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer
No - modifications are not required.
The design of the project would be unaffected by increases in temperature.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

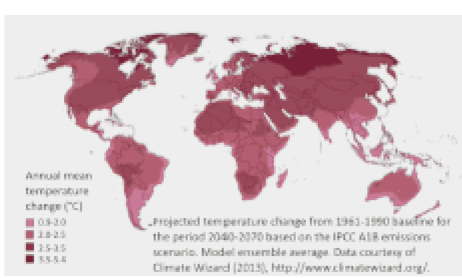
• Even though you have suggested that project designs would not be sensitive to rising temperatures, it is worth considering existing temperature related hazards in the region where the project is planned.
• There is a potential for an increase in incidences where current design standards will not be sufficient. See "Critical thresholds" in the "Help and glossary" section for further details on how a changing climate can impact on critical thresholds and design standards.

• The design, operational and maintenance standards should be reviewed - take into consideration current impacts of high temperatures as well as potential future changes.

2. How could current high temperatures affect the project even without future climate change?

• Heatwaves put stress on buildings and other infrastructure, including roads and other transport links. In cities, the 'urban heat island' can increase the risk of heat related deaths.
• Warm weather can raise surface water temperatures of reservoirs used for industrial cooling. In addition, this could impact local eco-systems, improving the growing conditions for algae and potentially harmful micro-organisms in water courses.
• Heatwaves can have an impact on agricultural productivity and growing seasons.
• High temperatures can have implications for energy security. Peak energy demand due to demand for cooling can exceed incremental increases on base load in addition to the risk of line outages and blackouts.
• Human health can be affected by warmer periods. For example, urban air quality and disease transmission (e.g. malaria and dengue fever) can be impacted by higher air temperatures.
• Wildfire risk is elevated during prolonged warm periods that dry fuels, promoting easier ignition and faster spread.
• Permafrost and glacial melt regimes as impacted by warm periods.
• If our data suggests that there are existing hazards associated with high temperatures in the region, they will be highlighted elsewhere in the report. This may include existing wildfire risks as well as areas potentially impacted by permafrost and glacial melt.

3. What does the science say could happen by the 2050s?



Projected temperature change from 1961-1990 baseline for the period 2040-2070 based on the IPCC A1B emissions scenario. Model ensemble average. Data courtesy of Climate Wizard (2015), http://www.climatewizard.org/.

• Climate model projections do not agree that annual average temperature increase will reach 2°C in the project location.
• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to temperature and climate change.

I have acknowledged the risks highlighted in this section.

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08
LOW RISK

PRECIPITATION DECREASE

Would a decrease in precipitation require modifications to the design of the project in order to successfully provide the expected services over its lifetime?

Chosen Answer

No - modifications are not required.

The design of the project would be unaffected by decreases in precipitation.

ACCLIMATISE COMMENTARY

1. What does this mean for the design of my project?

• Even though you have suggested that designs would not be affected by a decrease in precipitation, it is worth considering existing precipitation related hazards in the region where the project is planned.

2. How could reduced precipitation affect the project even without future climate change?

• Decreased seasonal runoff may exacerbate pressures on water availability, accessibility and quality.
• Variability of river runoff may be affected such that extremely low runoff events (i.e. drought) may occur much more frequently.
• Pollutants from industry that would be adequately diluted could now could become more concentrated.
• Increased risk of drought conditions could lead to accelerated land degradation, expanding desertification and more dust storms.
• If our data suggests that there are existing hazards associated with decreased precipitation in the region, they will be highlighted elsewhere in the report. This may include water availability and wildfire.

3. What does the science say could happen by the 2050s?

• Climate model projections do not agree that annual average precipitation will decrease in the project location which could indicate a relatively high degree of uncertainty (see the section "Model agreement and uncertainty" in "Help and glossary" at the end of this report). On the other hand, this could also mean precipitation patterns are not expected to change or may even increase (see elsewhere in the report for more details of projections related to precipitation increase).
• If you want to know more about projected changes in the project location across a range of GCMs and RCPs please refer to USGS's CMIP5 Global Climate Change Viewer for detailed maps.

4. What next?

1. See the section "Further reading" in "Help and glossary" at the end of this report which lists a selection of resources that provide further information on a changing climate.
2. Click here or here for the latest news and information relating to water and climate change.

I have acknowledged the risks highlighted in this section.

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09

The sections above will provide details on all high and medium climate hazard risks from Aware™ where these are suggested by the climate sensitivities of the project and / or the underlying data. Selected Low risks may also be detailed. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project designers.

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10 Project Geological Hazard Risk Ratings

Below you will find the overall geological hazard risk level for the project together with a radar chart presenting the level of risk associated with each individual geological risk topic analysed in Aware™. Projects with a final "High risk" rating are always recommended for further more detailed geological risk analyses.

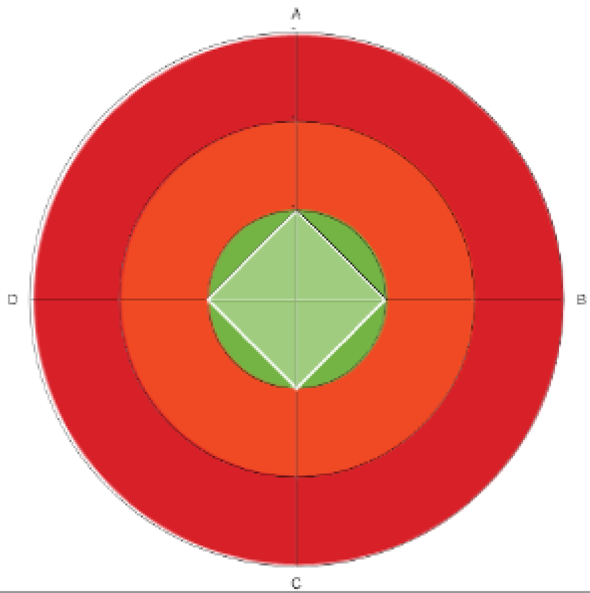
The radar chart provides an overview of which individual risks are most significant. This should be used in conjunction with the final rating to determine whether the project as a whole, or its individual components, should be assessed in further detail. The red band (outer circle) suggests a higher level of risk in relation to a risk topic. The green band (inner circle) suggests a lower level of risk in relation to a risk topic.

In the remaining sections of this report more detailed commentary is provided. Information is given on existing geological conditions and associated hazards. A number of questions are provided to help stimulate a conversation with project designers in order to determine how they would manage geological risks at the design stage. Links are provided to recent case studies, relevant data portals and other technical resources for further research.

Final project geological hazard risk ratings

Low Risk

Breakdown of geological hazard risk topic ratings



A) Earthquake
B) Seismic landslide
C) Tsunami
D) Volcano

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11

The sections above will provide details on all high geological hazard risks from Aware^{TM} where these are suggested by the underlying data. Local conditions, however, can be highly variable, so if you have any concerns related to risks not detailed in this report, it is recommended that you investigate these further using more site-specific information or through discussions with the project.

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HELP AND GLOSSARY:

Model agreement and uncertainty:

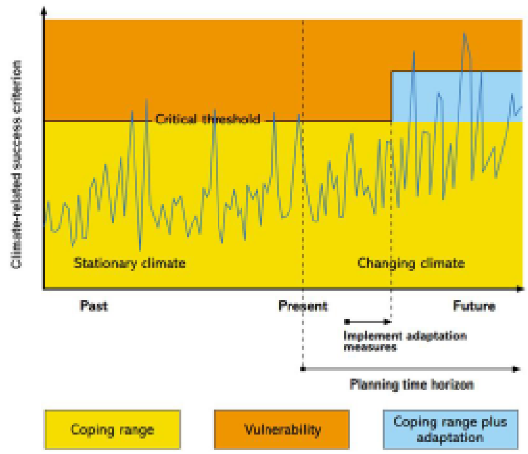
Although climate models are constantly being improved, they are not good enough to predict future climate conditions with a degree of confidence which would allow precise adaptation decisions to be made. Outputs from different climate models often differ, presenting a range of possible climate futures to consider, and ultimately a wide range of possible actions to take. In Aware, climate projections make use of GCM ensemble percentiles to determine: for temperature increase, whether 75% of CMIP5 GCM ensemble agree on a magnitude of change; for precipitation increase and decrease, whether 75% of CMIP5 GCM ensemble agree on the direction of change.

Even with improvements in climate modelling, uncertainties will remain. It is likely that not all the climate statistics of relevance to the design, planning and operations of a project's assets and infrastructure will be available from climate model outputs. The outputs are typically provided as long-term averages, e.g. changes in average monthly mean temperature or precipitation. However, decisions on asset integrity and safety may be based on short-term statistics or extreme values, such as the maximum expected 10 minute wind speed, or the 1-in-10 year rainfall event. In such cases, project designers or engineers should be working to identify climate-related thresholds for the project (see "Critical thresholds" section below) and evaluate whether existing climate trends are threatening to exceed them on an unacceptably frequent basis. Climate models can then be used to make sensible assumptions on potential changes to climate variables of relevance to the project or to obtain estimates of upper and lower bounds for the future which can be used to test the robustness of adaptation options.

The key objective in the face of uncertainty is therefore to define and implement design changes (adaptation options) which both provide a benefit in the current climate as well as resilience to the range of potential changes in future climate.

Critical thresholds:

A key issue to consider when assessing and prioritising climate change risks is the critical thresholds or sensitivities for the operational, environmental and social performance of a project. Critical thresholds are the boundaries between 'tolerable' and 'intolerable' levels of risk. In the diagram below, it can be seen how acceptable breaches in a critical threshold in today's climate may become more frequent and unacceptable in a future climate.

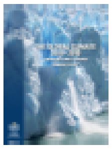
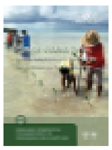
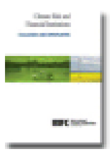


The relationship between a critical threshold and a climate change related success criterion for a project. [Source: Willows, R.I. and Connell, R.K. (Eds.) (2003). *Climate adaptation: Risk, uncertainty and decision-making*. UKCIP Technical Report, UKCIP, Oxford].

Climate change scenarios can be used to see if these thresholds are more likely to be exceeded in the future. The simplest example is the height of a flood defence. When water heights are above this threshold, the site will flood. The flood defence height is the horizontal line labelled 'critical threshold'. Looking at the climate trend (in this case it would be sea level or the height of a river) – shown by the blue jagged line – it can be seen that the blue line has a gradual upward trend because of climate change. This means that the critical threshold is crossed more often in the future – because sea levels are rising and winter river flows may be getting larger. So, to cope with

this change, adaptation is needed – in this case, one adaptation measure is to increase the height of the flood defence.

Further reading and resources:

	Report detailing changes in global climate: The Global Climate 2001 - 2010
	IPCC report on climate-related disasters and opportunities for managing risks: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)
	IPCC report on impacts, adaptation and vulnerability: Climate Change 2014: Impacts, Adaptation, and Vulnerability
	IFC report on climate-related risks material to financial institutions: Climate Risk and Financial Institutions. Challenges and Opportunities.
	Nationally Determined Contributions (NDCs) submitted under the COP21 Paris Agreement: NDC Registry.
	ADB report on investment in disaster resilience: Investing in Resilience: Ensuring a Disaster-Resistant Future.
	UNISDR's report on disaster risk success stories: Disaster risk reduction: 20 examples of good practices from Central Asia.
	UNISDR's review and analysis of data and information on disaster risk patterns and trends: Global Assessment Report on Disaster Risk Reduction.
	CRED's International Disasters Database: EM-DAT.
	Pacific Risk Information System of national-level hazard and risk information for 15 countries: PCRAFI.

	DesInventar Project's historical disaster impact catalogues: DesInventar.
	National progress reports to UNISDR on DRM commitments: HFA National Progress Reports.
	National documents DRM policy and strategy documents and studies: Disaster risk reduction in the world.
	National-level factsheets based on the Global Assessment Report: Country Profiles.
	GEM NEXUS Building and population inventory : GED4GEM database.
	GAR analysis tool of exposure including population, capital stock and economic indicators: Risk Data Platform CAPRAViewer.

Aware data resolution:

The proprietary Aware data set operates at a resolution of 0.5 x 0.5 decimal degrees (approximately 50 km x 50 km at the equator). These proprietary data represent millions of global data points, compiled from environmental data and the latest scientific information on current climate / weather related hazards together with potential changes in the future. Future risk outcomes are based on projections data from the near- to mid-term time horizons (2020s or 2050s, depending on the hazard and its data availability).

Global climate model output, from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (Meehl et al., 2007) and 5 (CMIP5) multi-model dataset (Taylor et al., 2012), were resampled to a 0.5 degree grid.

[Taylor, K.E., R.J. Stouffer, G.A. Meehl (2012) "An Overview of CMIP5 and the experiment design." Bulletin of the American Meteorological Society, 93, 485-498.

[Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor: The WCRP CMIP3 multi-model dataset: A new era in climate change research, Bulletin of the American Meteorological Society, 88, 1383-1394, 2007]

Aware data application:

In some instances Risk Topic ratings are only based on Aware data, including:
- Flood
- Permafrost
- Landslides – precipitation induced
- Earthquake
- Landslides – seismic induced
- Volcano
- Tsunami

Country level risk ratings:

These are generated from the data points within a country's borders. For single locations, site-specific data are used, and for multiple locations or countries, composite data across the portfolio of locations are used.

Glossary of terms used in report

"Climate model projections agree": for temperature, defined as 75% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as 75% of CMIP5 GCM ensemble members agreeing on the direction of annual average precipitation change.

"Climate model projections do not agree": for temperature, defined as only 25% of CMIP5 GCM ensemble members agreeing that annual average temperature increase will reach 2°C; for precipitation increase or decrease, defined as only 25% of CMIP5 GCM ensemble members

agreeing on the direction of annual average precipitation change.

The overall climate risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high climate risk if greater than or equal to 3 individual risk topics score high. A project scores overall medium climate risk if between 1 and 2 individual risk topics score high. A project scores overall low climate risk if none of the individual risk topics score high.

The overall geological risk score for the project (high, medium or low) is based on a count of high risk topic scores. A project scores overall high geological risk if greater than or equal to 2 individual risk topics score high. A project scores overall medium geological risk if 1 individual risk topic scores high. A project scores overall low geological risk if none of the individual risk topics score high.

Historical Climate Data

A.1 KAMPONG CHAM

Mean Monthly and Annual Temperature, 1991-2015

Mean Monthly Temperature (^{O}C)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
27.17	27.75	29.10	29.94	29.65	29.00	28.54	28.59	28.38	27.98	27.51	26.86
Mean annual temperature for 1991-2015											28.37

Source: Climate Change Knowledge Portal. The World Bank Group. (http://sdwebx.worldbank.org)

Mean Monthly, Total Annual and Mean Annual Rainfall, 1992-2016

No.of Years	Year	Monthly Rainfall (mm)												Total Annual Rainfall (mm)
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1	1992	26.6	-	-	14.9	122.9	283.8	190.6	277.8	339.7	218.4	48.0	12.4	1,535.1
2	1993	30.0	-	78.8	19.1	213.0	165.3	318.8	103.0	245.0	-	-	-	1,173.0
3	1994	-	-	81.3	166.6	178.7	423.7	108.1	102.3	318.5	147.9	-	32.2	1,559.3
4	1995	-	-	114.6	11.3	241.1	182.2	181.5	126.2	470.5	255.5	38.9	1.5	1,623.3
5	1996	62.6	8.5	1.8	45.7	330.7	298.6	147.1	245.1	420.1	483.8	111.5	8.8	2,164.3
6	1997	-	27.4	3.0	185.8	153.3	131.1	146.9	136.4	146.2	264.3	23.2	0.2	1,217.8
7	1998	-	-	-	33.6	192.0	66.0	62.2	237.2	394.2	-	1.8	36.7	1,023.7
8	1999	48.1	130.5	154.2	335.3	143.7	200.0	221.2	267.2	272.3	126.0	18.7	63.6	1,980.8
9	2000	13.5	247.5	191.2	204.0	165.0	114.7	120.7	217.8	100.3	30.5	-	-	1,405.2
10	2001	5.9	0.2	200.1	75.2	121.7	107.1	53.8	206.7	147.7	379.3	14.5	12.1	1,324.3
11	2002	-	-	5.7	85.8	51.2	294.0	80.2	253.1	116.1	89.5	94.0	63.7	1,133.3
12	2003	-	-	135.9	45.3	286.5	130.0	151.8	260.8	532.0	385.0	31.0	-	1,958.3
13	2004	1.4	-	0.5	104.5	103.3	249.0	128.6	190.6	210.3	162.4	32.2	-	1,182.8
14	2005	6.8	-	7.0	83.8	85.2	122.4	323.4	101.9	361.0	185.6	102.8	26.8	1,406.7
15	2006	19.1	35.9	84.9	138.2	197.0	181.5	162.7	281.2	246.0	218.1	12.7	13.8	1,591.1
16	2007	-	-	10.0	71.8	250.5	177.4	293.8	162.6	284.4	256.5	52.4	-	1,559.4
17	2008	52.3	1.3	72.0	103.7	147.5	71.3	150.7	125.3	275.1	259.6	224.5	12.1	1,495.4
18	2009	T	19.2	68.7	150.3	233.5	152.7	376.2	265.1	336.9	259.9	3.9	-	1,866.4
19	2010	21.2		38.2	70.9	43.7	316.7	182.9	204.9	145.3	282.4	65.6	-	1,371.8
20	2011	0.2		57.3	122.8	375.4	139.5	216.0	187.0	189.2	94.0	77.0	20.1	1,478.5
21	2012	21.0	0.6	29.4	148.0	264.3	136.9	308.7	141.8	401.2	115.6	132.0	-	1,699.5
22	2013	2.2	-	46.1	70.5	257.1	153.0	289.8	199.8	293.5	69.0	64.7	18.4	1,464.1
23	2014	-	-	54.2	225.5	27.3	181.9	298.2	70.2	119.8	210.8	65.3	28.1	1,281.3
24	2015	-	2.0	1.6	122.6	109.2	175.6	173.8	224.1	230.8	203.2	136.4	5.1	1,384.4
25	2016	-	-	T	3.5	34.4	179.7	146.8	134.7	443.4	335.5	169.5	77.5	1,525.0
Mean monthly		12.4	18.9	57.5	105.5	173.1	185.4	193.4	188.9	281.6	201.3	60.8	17.3	
Mean annual rainfall														1,496.2

Source: Second Integrated Urban Environmental Management in he Tonle Sap Basin Project. ADB.

" T " Rained but less than 0.1 mm

" - " No rain

No rain or minimum monthy rainfall for the year

Maximum monthly rainfall for the year

Year with the most rainfall (1996)

Year with the least rainfall (1998)

A.2 KRATIE

Mean Monthly and Annual Temperature, 1991-2015

Mean Monthly Temperature (^{O}C)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
26.16	27.10	28.24	29.66	28.93	28.40	27.92	28.09	27.78	27.29	26.83	26.03
Mean annual temperature for 1991-2015											27.70

Source: Climate Change Knowledge Portal. The World Bank Group. (http://sdwebx.worldbank.org)

Mean Annual Rainfall

Year	Rainfall (mm)		
	Min	Max	Annual
1998	-	469.1	1,696.0
1999	-	423.5	**2,549.7**
2000	6.0	419.4	2,212.4
2001	-	441.6	1,964.4
2002	-	375.3	1,847.2
2003	-	331.2	1,665.5
2004	-	403.7	1,751.8
2005	-	384.7	1,430.7
2006	1.2	384.4	1,717.8
2007	-	409.2	1,910.6
2008	-	333.2	1,706.2
2009	-	456.4	2,050.9
2010	-	283.5	1,342.1
2011	-	386.4	1,989.9
2012	-	**538.6**	2,224.0
2013	-	450.8	1,982.7
2014	-	462.6	1,735.2
2015	-	245.4	**1,209.3**
2016	-	453.6	1,920.5
Mean annual rainfall			**1,837.2**

Source: DOWRAM, Kratie Province.

A.3 STUNG TRENG

Mean Annual Temperature

Mean Monthly Temperature (^{O}C)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
25.66	27.69	29.72	30.50	29.17	28.36	27.74	27.82	27.63	27.25	26.80	25.46
Mean annual temperature for 1991-2015											**27.82**

Source: Climate Change Knowledge Portal. The World Bank Group. (http://sdwebx.worldbank.org)

Mean Annual Rainfall

Mean Monthly Rainfall (mm)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-	10.87	27.13	79.68	181.29	239.48	346.53	313.15	347.27	201.86	67.53	6.71
Mean annual rainfall for 1991-2015											**1,821.50**

Source: Climate Change Knowledge Portal. The World Bank Group. (http://sdwebx.worldbank.org)

Estimating GHG Emissions

A. Wastewater Treatment Plant

The formula used in estimating came from "Greenhouse Gas Emissions Estimation Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal Wastewater Treatment Ethanol Fermentation", 2010, December 14, RTI International (Research Triangle Institute).

3.2.1 Estimating CH_4 and CO_2 Emissions from Wastewater and Sludge Treatment Units

Aerobic wastewater treatment systems produce primarily CO_2, whereas anaerobic systems produce a mixture of CH_4 and CO_2. Equations 3-1 and 3-2 provide a general means of estimating the CO_2 and CH_4 emissions directly from any type of wastewater treatment process assuming all organic carbon removed from the wastewater is converted to either CO_2, CH_4, or new biomass.

$$CO_2 = 10^{-6} \times Q_{WW} \times OD \times Eff_{OD} \times CF_{CO2} \times \left[\left(1 - MCF_{WW} \times BG_{CH4}\right)\left(1 - \lambda\right)\right] \quad (3\text{-}1)$$

$$CH_4 = 10^{-6} \times Q_{WW} \times OD \times Eff_{OD} \times CF_{CH4} \times \left[\left(MCF_{WW} \times BG_{CH4}\right)\left(1 - \lambda\right)\right] \quad (3\text{-}2)$$

where:

CO_2 = CO_2 emission rate (Mg CO_2/hr)
CH_4 = CH_4 emission rate (Mg CH_4/hr)
10^{-6} = Units conversion factor (Mg/g)
Q_{WW} = Wastewater influent flow rate (m^3/hr)
OD = Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD5 or COD (mg/L = g/m^3)
Eff_{OD} = Oxygen demand removal efficiency of the biological treatment unit
CF_{CO2} = Conversion factor for maximum CO_2 generation per unit of oxygen demand = 44/32 = 1.375 g CO_2/ g oxygen demand
CF_{CH4} = Conversion factor for maximum CH_4 generation per unit of oxygen demand = 16/32 = 0.5 g CH_4/ g oxygen demand
MCF_{WW} = methane correction factor for wastewater treatment unit, indicating the fraction of the influent oxygen demand that is converted anaerobically in the wastewater treatment unit (see **Table 3-1**)
BG_{CH4} = Fraction of carbon as CH_4 in generated biogas (default is 0.65)
λ = Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process).

The biomass yield, λ, in Equations 3-1 and 3-2 should be determined based on the net sludge generation from the process. For example, for an activated sludge tank, the sludge wastage rate would be used. Commonly, the mixed liquor volatile suspended solids (MLVSS) value is used as a measure of the biomass concentration. The flow rate of the sludge waste stream multiplied by the MLVSS concentration of the sludge waste stream provides a mass generation rate of biomass. Using the general cell composition from **Figure 3-2**, carbon accounts for 53% of the biomass weight (dry basis). The carbon consumed in the wastewater treatment process is estimated based on the BOD removal rate. Thus, the biomass yield, λ, can be calculated using Equation 3-3. When the biomass generation rate cannot be assessed, default values for the biomass yield provided in **Table 3-1** should be used.

$$\lambda = \frac{Q_S \times MLVSS_S \times CF_S}{Q_{WW} \times OD \times Eff_{OD} \times CF_C} \quad (3\text{-}3)$$

where:

λ = Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process)
Q_S = Waste sludge stream flow rate (m^3/hr)
Q_{WW} = Wastewater influent flow rate (m^3/hr)
$MLVSS_S$ = Mixed liquor volatile suspended solids concentration of the waste sludge stream (mg/L = g/m^3)

OD = Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD5 or COD (mg/L = g/m^3)
Eff_{OD} = Oxygen demand removal efficiency of the biological treatment unit
CF_S = Correction factor for carbon content of the biomass (i.e., MLVSS$_S$)
= 0.53 g C/g MLVSS (default)
CF_C = Conversion factor for maximum C consumption per unit of oxygen demand
= 12/32 = 0.375 g C/ g oxygen demand.

Table 3-1. Default Values for Methane Correction Factor and Biomass Yield

Treatment System	MCF[a]	λ
Wastewater Treatment Processes		
Aerated treatment process (e.g., activated sludge system), well managed	0	0.65 [b]
Aerated treatment process, overloaded (anoxic areas)	0.3	0.45 [b,c]
Anaerobic treatment process (e.g., anaerobic reactor)	0.8	0.1 [c,d]
Facultative lagoon, shallow (< 2 m deep)	0.2	0
Facultative lagoon, deep (≥ 2 m deep)	0.8	0
Sludge Treatment Processes		
Aerobic sludge digestion	0	Use λ from wastewater treatment process
Anaerobic sludge digestion	0.8	

[a] Source: IPCC (2006).
[b] Source: Choubert et al. (2009), Muller et al. (2003), and Munz (2008); λ reported in g-COD in produced biomass/g-COD consumed; equivalent to λ in g-C in produced biomass/g-C consumed when using default CF_c in Equation 3-3.
[c] Source: Ammary (2004); λ reported in g-VSS produced/g-COD degraded; converted to λ in g-C in produced biomass/g-C consumed using default CF_s and CF_c in Equation 3-3 as λ = λreported × (CF_s / CF_c).
[d] Source: Low and Chase (1999); λ reported in g-VSS produced/g-COD degraded; converted to λ in g-C in produced biomass/g-C consumed using default CF_s and CF_c in Equation 3-3 as λ = λreported × (CF_s / CF_c).

Equation 3-8 presents a methodology to estimate N_2O emissions for both aerobic and anaerobic processes using an average value for the percent of influent TKN emitted as N_2O from Chandran (2010):

$$N_2O_{WWTP} = Q_i \times TKN_i \times EF_{N2O} \times \frac{44}{28} \times 10^{-6} \quad (3\text{-}8)$$

where:

N_2O_{WWTP} = N_2O emissions generated from WWTP process (Mg N_2O/hr)
Q_i = Wastewater influent flow rate (m^3/hr)
TKN_i = Amount of TKN in the influent (mg/L = g/m^3)
EF_{N2O} = N_2O emission factor (g N emitted as N_2O per g TKN in influent),
= 0.0050 g N emitted as N_2O/g TKN (Chandran, 2010)
44/28 = Molecular weight conversion, g N_2O per g N emitted as N_2O
10^{-6} = Units conversion factor (Mg/g).

Inputted data:

		KC	K	ST
Households served		43,221	,45,410	29,890
Total WWtr generation		7,700	6,953	4,892
BOD removal from anaerobic pond	60%			
BOD contribution per capita	45 gal/cap/day			

Results:

Town/Activity	GHG Emissions (Mg CO_2/hr)			Total
	CO_2	CH_4	N_2O	(tpy CO_2)
Kampong Cham				
Anaerobic	0.0202	0.1676	-	1,810.36
Facultative	0.0190	0.0217	-	392.48
Maturation	-	-	0.0273	263.55
Total				**2,466.39**

Procedures used in calculating emissions were obtained from:
Research Training Institute International. 2010. Greenhouse Gas Emissions Estimation. Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal, Wastewater Treatment, Ethanol Submitted to US Environmental Protection Agency.

Town/Activity	GHG Emissions (Mg CO_2/hr)			Total
	CO_2	CH_4	N_2O	(tpy CO_2)
Kratie				
Anaerobic	0.0212	0.1754	-	1,894.89
Facultative	0.0199	0.0227	-	411.20
Maturation	-	-	0.0247	237.99
Total				**2,544.08**

Procedures used in calculating emissions were obtained from:
Research Training Institute International. 2010. Greenhouse Gas Emissions Estimation. Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal, Wastewater Treatment, Ethanol Fermentations. Submitted to US Environmental Protection Agency.

Stung Treng				
Anaerobic	0.0139	0.1153	-	1,245.85
Facultative	0.0131	0.0150	-	270.35
Maturation	-	-	0.0174	167.44
Total				**1,683.65**

Procedures used in calculating emissions were obtained from:
Research Training Institute International. 2010. Greenhouse Gas Emissions Estimation. Methodologies for Biogenic Emissions from Selected Source Categories: Solid Waste Disposal, Wastewater Treatment, Ethanol Fermentation. Submitted to US Environmental Protection Agency.

B. Controlled Landfill

The tool used was "Estimation Tool for Greenhouse Gas (GHG) Emissions from Municipal Solid Waste (MSW) Management ia Life Cycle Perspective". Nirmala Menikpura. Janya Sang-Arun. Institute for Global Environmental Strategies (IGES).

Inputted data:

	KC	**K**	**ST**
Solid waste generated (tonnes per month)	1,663	1,514	1,017
Collection vehicle capacity (m3)	15	15	15
Diesel consumption per trip including collection	12L round	12L round	8L round
Diesel consumption of landfill equipment, per month	25% of that of collection truck	25% of that of collection truck	25% of that of collection truck
Waste composition	(See Table 1)		
Recyclable at the landfill	(See Table 2)		

Table 1 Adopted Waste Composition of Battambang

Source: JICA. 2004. The Study on Solid Waste Management in the Municipality of Phnom Penh. Kokosai Kogyo Co. Ltd.

Please enter the compostion of landfilling waste	
Component	**Percentage (%)**
Food waste	71.88
Garden waste	0.00
Plastics	8.61
Paper	2.72
Textile	2.88
Leather/rubber	0.00
Glass	5.40
Metal	1.06
Hazardous waste	0.00
Others	7.45
Total	**100.00**

Table 2 Composition of Recyclables at Dumpsite*

Type of recyclable	Percentage (%)
Paper	15.58
Plastic	74.13
Aluminium	1.90
Steel	0.00
Glass	8.40
Total	**100.00**

*Based on: Composition of Municipal Solid Waste at Dumpsite

Source: Waste Management and Activities of Cambodia in the Application of Basel Convention.
A PPt presentation prepared by:
Mr. Chin Sothun
Department of Environmental Pollution Control, MOE, Cambodia.
Workshop 2010 of Asian Network of Prevention of Illegal Transboundary Movement of Hazardous Waste. 29 November-02 December 2010.
Allson Paradise Angkor Hotel, Siem Reap, Cambodia.

Results: GHG Emissions from Controlled Landfill Operations

Kampong Cham

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	1.79	0.00	1.79	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	747.84	0.00	747.84	kg of CO2-eq/tonne of mix waste
Composting	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**948.54**	**408.51**	**540.03**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**1,753,583.97**	**755,476.39**	**998,107.58**	**kg of CO2-eq/monthly managed waste**

Kratie

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	1.84	0.00	1.84	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	747.85	0.00	747.85	kg of CO2-eq/tonne of mix waste
Composting	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**948.61**	**408.51**	**540.10**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**1,926,279.25**	**829,826.45**	**1,096,452.80**	**kg of CO2-eq/monthly managed waste**

Stung Treng

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	2.12	0.00	2.12	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	747.92	0.00	747.92	kg of CO2-eq/tonne of mix waste
Composting	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**948.94**	**408.51**	**540.43**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**1,178,257.27**	**507,431.64**	**670,825.63**	**kg of CO2-eq/monthly managed waste**

Climate Mitigation Calculations

Results: Simulation of GHG Emissions from Controlled Landfill Operations with Mitigation Measures in Place

Mitigation Measures:

- Waste to be collected is reduced by 15% due to active recycling at source.
- Waste collection frequency is every other day except for market waste.
- Composting of about 20% of the waste collected (about 200- 300 tonnes per month at the landfill site.

Kampong Cham

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	2.70	0.00	2.70	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	748.07	0.00	748.07	kg of CO2-eq/tonne of mix waste
Composting	177.00	892.50	-715.50	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**891.37**	**445.13**	**446.24**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**1,177,083.04**	**588,243.65**	**588,839.38**	**kg of CO2-eq/monthly managed waste**

Kratie

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	1.70	0.00	1.70	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	747.82	0.00	747.82	kg of CO2-eq/tonne of mix waste
Composting	177.00	892.50	-715.50	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**887.37**	**446.91**	**440.46**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**1,117,934.47**	**563,293.97**	**554,640.50**	**kg of CO2-eq/monthly managed waste**

Stung Treng

Activity	Direct GHG Emissions	Indirect GHG Savings	Net GHG Emissions	Unit
Transportation	1.74	0.00	1.74	kg of CO2-eq/tonne of waste
Landfilling of mix MSW	747.83	0.00	747.83	kg of CO2-eq/tonne of mix waste
Composting	177.00	892.50	-715.50	kg of CO2-eq/tonne of organic waste
Anaerobic digestion	0.00	0.00	0.00	kg of CO2-eq/tonne of organic waste
Mechanical Biological Treatment (MBT)	0.00	0.00	0.00	kg of CO2-eq/tonne of waste
Recycling	1844.79	2252.79	-408.00	kg of CO2-eq/tonne of mixed recyclables
Incineration	0.00	0.00	0.00	kg of CO2-eq/tonne of incinerated waste
Open burning	0.00	0.00	0.00	kg of CO2-eq/tonne of open burned waste
GHG emission from whole system	**862.38**	**462.65**	**399.73**	**kg of CO2-eq/tonne of collected waste**
Total GHG emissions per month	**770,523.93**	**413,595.88**	**356,928.05**	**kg of CO2-eq/monthly managed waste**

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