Chapter 1 Introduction

Version: Second Draft
Date: 15th December 2025
Country: Cambodia [KHM]

1 Introduction

1.1 Aims of the National Report

This National Report provides Cambodia's technical contribution to the formulation of the South China Sea–Gulf of Thailand (SCS–GOT) Transboundary Diagnostic Analysis (TDA). It consolidates the most up-to-date evidence on socioeconomic conditions, climate-related threats, land-based and marine pollution, ecosystem status, fisheries dynamics, and governance capacity across Cambodia's coastal and marine systems. Building upon the Cambodia National TDA (2000), the report incorporates new datasets, expanded indicator frameworks, remote-sensing products, and enhanced analytical tools to reflect contemporary coastal realities and emerging risks. The assessment aims to support both national decision-making and regional cooperation, ensuring that Cambodia's priorities are accurately represented in the collective diagnosis of transboundary environmental issues.

The specific aims of this report are outlined below.

1.1.1 Inputs to the SCS–GOT TDA

- **Provide scientifically grounded national inputs** to the regional TDA, including updated indicators, spatial hotspots, problem hierarchies, and the underlying drivers of environmental degradation across Cambodia's coastal provinces.
- **Ensure that Cambodia's priority issues**—including land-based and marine pollution, ecosystem degradation, fisheries over-exploitation, climate-related hazards and hydrological changes—are systematically represented in the regional analytical framework.
- **Strengthen causal-chain assessment** by applying UNEP/GEF problem-tree methodology, linking immediate causes, underlying drivers, and deeper systemic pressures relevant to transboundary management.
- **Support harmonization of national evidence** with the regional SCS–GOT TDA structure, including the categorization of environmental problems, vulnerability assessments, and governance performance indicators.

1.1.2 Analysis to support SDG reporting and international commitments

- **Contribute to Cambodia's reporting on global frameworks**, particularly SDG 6 (clean water and sanitation), SDG 11 (sustainable cities), SDG 13 (climate action), and SDG 14 (life below water), by providing updated national data and coastal-marine indicators.
- **Support implementation of international and regional commitments**, including:
    - the United Nations Convention on Biological Diversity (UNCBD);
    - the UN Framework Convention on Climate Change (UNFCCC) and Cambodia's NDC 3.0;
    - the Kunming–Montreal Global Biodiversity Framework (30x30 target);
    - ASEAN environmental cooperation frameworks;
    - and PEMSEA's State of the Coasts (SOC) reporting requirements.

- **Provide an analytical evidence base for national planning instruments**, including the Circular Strategy for Environment (2023–2028), the Cambodia Climate Change Strategic Plan (CCCSP) 2024–2033, the Code on Environment and Natural Resources (2023), sub-national development plans, and ongoing work toward marine spatial planning (MSP) and integrated coastal zone management (ICZM).
- **Strengthen policy coherence and investment planning** by identifying gaps, priority areas, and opportunities for climate-resilient, biodiversity-positive and blue-economy-aligned coastal development.

1.2 Major Water-Related Environmental Problems: Comparative Overview (2000 vs 2025)

2.1.1 Comparative assessment & overview

The Cambodia National TDA (2000) identified seven principal water-related environmental problems across freshwater and marine/coastal systems (UNEP/GEF & MoE, 1998). Twenty-five years later, these problem clusters remain but have generally intensified under rapid economic growth, urbanization, coastal development and climate change. The comparative assessment, Table 1-1 synthesizes updated evidence from recent national and sectoral assessments. See Annex 1-1 and Annex Table 1-1 for more detail and supplementary material and note.

The comparative assessment, Table 1-1 shows that Cambodia's core challenges have not improved; most have deepened. Coastal cities and SEZs have expanded faster than wastewater and solid-waste infrastructure, so centralized plants still treat only a small share of sewage—less than 20% in Preah Sihanouk, under 10% in Kampot and almost none in Koh Kong and Kep (MoE, 2023; ADB, 2023). Monitoring shows persistent exceedance of faecal-coliform standards (10^4–10^5 CFU/100 mL), elevated nitrate and phosphate, and industrial effluents near ports and SEZs that frequently exceed limits for oil and grease, TPH, lead and zinc (MoE, 2023; ADB, 2023).

Fisheries indicators point to long-term depletion: demersal trawl CPUE has declined from 173 kg/hr in the 1960s to about 26 kg/hr today, with ecosystem indices confirming a shift toward smaller, lower-trophic species and sharp reductions in sharks, rays and other high-value stocks (FiA, 2025; SAU, 2024).

Wetlands and coastal habitats remain vital for livelihoods but are increasingly degraded. In Koh Kapik–Peam Krasop, 65–90% of household income depends on wetland-based fisheries and resources, yet these systems are highly sensitive to drainage, roads and salinity intrusion (Ramsar Secretariat, 2012; Fauna & Flora, 2024; Ly et al., 2023). Mangrove mapping shows a net loss of around 3,500–4,000 ha since 2014, while coral cover at many nearshore sites has fallen to 6–10% and seagrass in Kampot–Kep has shrunk by about 20%, largely due to trawling, dredging, reclamation and turbidity (MoE, 2023, 2024; ADB, 2023).

Hydrological extremes are intensifying: floods remain Cambodia's most damaging hazard, droughts linked to ENSO and warming temperatures now affect millions of people, and salinity intrusion is advancing 5–7 km inland in some estuaries (NCDM & UNDP, 2021; World Bank, 2023; FiA, 2025).

At the same time, transboundary pollution from the Mekong–Tonle Sap–Bassac system continues to drive high nutrient and sediment loads to coastal waters, with TSS in the Bassac reaching about 2,030 mg/L during peak flows (MoE, 2023; ADB, 2023; World Bank, 2023).

Table 1-1 Comparative analysis of major water-related environmental problems (2000 vs 2025)

Problem Category (2000)	Status / Evidence in 2000 *(Baseline)*	Status / Evidence in 2025 *(Updated from Ch.2–6)*
Contamination of water quality – domestic & non-point pollution	Widespread organic pollution and domestic sewage from urban centers; no wastewater treatment systems in coastal provinces; elevated BOD/TSS; fertilizers and pesticides entering rivers and coast.	<20% wastewater treated in Preah Sihanouk; <10% in Kampot; almost none in Koh Kong/Kep. FC often 10^4–10^5 CFU/100 mL; NO_3^- 2.0–2.6 mg/L; PO_4^{3-} 0.7–0.8 mg/L. Industrial effluents exceed limits for oil & grease, TPH, Pb, Zn.
Overfishing and declining fish stocks (freshwater & marine)	Declining catches in Tonle Sap and coastal zones; destructive gears; over-exploitation documented but limited monitoring.	CPUE collapse: 173 kg/hr (1960s) to ~26 kg/hr (present). MTI decline; sharks/rays reduced to single-digit tonnes; small pelagics dominate >70% of catch. Chronic trawl pressure.
Habitat degradation – freshwater wetlands	Loss of wetlands due to agriculture, drainage, and conversion; key nurseries affected.	Wetland dependence remains high; peat-mangroves, floodplains under pressure; salinity intrusion shifting freshwater–brackish gradients; Koh Kong wetlands provide 65–90% of household income but highly sensitive.
Habitat degradation – mangroves, coral reefs, seagrasses	Coastal habitats mapped but poorly protected; early signs of mangrove loss and fishing impacts on reefs.	Mangroves declined 3,510–4,000 ha (2014–2025); coral cover 6–10% nearshore; seagrass decline ~20% in Kampot–Kep; habitat fragmentation affects productivity and resilience.
Flooding (freshwater) and hydrological variability	Floods and droughts significant; Tonle Sap reversals influence seasonal flows; low adaptive capacity.	Floods remain top disaster risk; droughts affect 2.5 million people; salinity intrusion advancing 5–7 km inland; climate extremes interact with land-use change.
Drought-related impacts (freshwater + agriculture)	Seasonal droughts impact rice production and domestic water supply; limited storage/infrastructure.	Drought intensifying under ENSO and warming oceans; rural and peri-urban households experience water shortages; aquaculture exposed to temperature and disease stress.
Transboundary pollution & river-coast linkages	Pollution carried by Mekong–Tonle Sap–Bassac system; high FC in Phnom Penh discharge zones.	Persistent nutrient/microbial hotspots at Phnom Penh confluence; TN/TP loads rising; sediment plumes reaching coastal estuaries; cross-border nutrient flows into Viet Nam delta remain significant.

Source: *Cambodia National TDA, 2000; ADB, 2023; MoE, 2023; FiA, 2025; SAU, 2024; NCDM & UNDP, 2021*

2.1.2 New threats emerging (post-2000)

New threats not assessed in the 2000 TDA have become major national priorities and now compound the legacy problems, as shown in Table 1-2. Climate change acts as a risk multiplier, with sea-level rise of about 11–20 cm projected by 2050, more intense rainfall and salinity intrusion 5–7 km inland in some estuaries (World Bank, 2023; UNDP & NCDM, 2023).

Plastic waste exceeds 730,000 t/year, with at least 14,000 t/year leaking to the coast and 120–350 microplastic particles/kg recorded in sediments at hotspot sites (ADB, 2023). Around 60% of inspected facilities near ports and SEZs are non-compliant with effluent standards, and hazardous and medical wastes still outstrip treatment capacity (ADB, 2023; MoE, 2013). Rapid urbanisation—urban population 39% in 2019—and reclamation in Sihanoukville have outpaced drainage and wastewater systems (PEAMSEA & MoE, 2019).

Aquaculture expansion to more than 330,000 t/year, with 25–30% of feed lost as waste, adds local nutrient and microbial loads and emerging AMR risks (FiA, 2025). At sea, MSP remains incomplete, fewer than 30% of MPAs are effectively patrolled and enforcement budgets are thin (ADB, 2023; PEAMSEA & MoE, 2019).

Land clearing, roads and coastal works have raised sediment inflows by >35% in parts of Koh Kong, with TSS in Kampot Bay often 250–320 mg/L during the monsoon (MoE, 2013; SCSSAP, 2020).

Together, these emerging issues make Cambodia's coastal risks more complex and interconnected, underscoring the need for modern pollution control, climate-resilient planning, stronger compliance and an operational MSP framework.

Table 1-2 New or Intensified Issues Not Explicitly Assessed in the 2000 TDA

New or Emerging Issue (Post-2000)	2000 Status	2025 Status
Climate change impacts (SLR, salinity intrusion, marine heatwaves)	Not assessed.	SLR +11–20 cm by 2050; salinity intrusion 5–7 km inland; coral bleaching events; urban flooding intensifying.
Marine plastics & microplastics	Not assessed.	>730,000 t/year plastic waste; >14,000 t/year coastal leakage; sediments 120–350 microplastic particles/kg.
Industrial & port-related pollution	Mentioned only briefly.	60% non-compliance near ports/SEZs; hydrocarbons, Pb, Zn exceed standards; hazardous/medical waste poorly controlled.
Urbanization pressure & land reclamation	Urbanization low (~16% in 1998).	Urbanization 39% (2019 Census); rapid reclamation in Preah Sihanouk; drainage systems inadequate.
Aquaculture nutrient/microbial loading	Small-scale aquaculture.	25–30% feed loss to water; disease outbreaks; antibiotics and AMR detected; high BOD in dense farming zones.
Governance gaps in enforcement & MSP	Fragmented mandates.	NCCMD sub-decree pending; limited patrol budgets; <30% of MPAs effectively managed; MSP not yet formalized.
Sedimentation/ turbidity from land-use change	Limited monitoring.	Sediment loads increased >35% in Koh Kong; high TSS in Kampot Bay (250–320 mg/L in monsoon).

Source: *MoE, 2013; PEAMSEA & MoE, 2019; SCSSAP, 2020; World Bank, 2023; UNDP & NCDM, 2023, ADB, 2023; FiA, 2025)*

1.3 Biogeophysical Setting

1.3.1 Geomorphology and Geological History

Cambodia's approximately 435 km coastline spans four provinces—Koh Kong, Preah Sihanouk, Kampot and Kep—and lies along the eastern margin of the Gulf of Thailand continental shelf (PEAMSAE & MoE, 2019). The coastal zone is shaped by Holocene sea-level fluctuations, deltaic and estuarine processes, and long-term tectonic stability, which together have produced a mosaic of low-lying plains, insular archipelagos and rocky headlands (SCSSAP, 2020).

Key geomorphic features include:

- **Extensive estuarine–mangrove complexes in Koh Kong**, notably Peam Krasop and Botum Sakor, formed on alluvial and marine clays delivered by the Tatai, Kah Bpow and other rivers (PEAMSAE & MoE, 2019; Ramsar Secretariat, 2012).
- **Fringing and patch reefs around the Koh Rong archipelago**, developed on granitic and metamorphic basement structures and influenced by strong tidal currents and seasonally high turbidity (SCSSAP, 2020).
- **Karstic limestone systems in Kampot**, which host aquifers, caves and rare groundwater-fed coastal wetlands and springs (PEAMSAE & MoE, 2019).
- **Barrier beaches, dunes and muddy tidal flats** along Preah Sihanouk, Kampot and Kep, shaped by monsoon-driven currents, wave action and longshore sediment transport within the Gulf of Thailand (MoE, 2013).

These geological foundations underpin the spatial distribution of habitats, fisheries productivity and sediment dynamics, and they strongly influence the coastline's differential vulnerability to erosion, storm surges and sea-level rise (World Bank, 2023).

1.3.2 Climatology, Present and Projected

Cambodia's coastal climate is governed by the Southwest (May–October) and Northeast (November–April) monsoons, which create distinct wet and dry seasons (World Bank, 2023). Orographic effects along the Cardamom Mountains enhance rainfall in Koh Kong and parts of Preah Sihanouk, while the relatively low-lying Kampot–Kep corridor is characterised by strong onshore winds and coastal squalls.

Key features of the **present climate** include:

- **Mean annual rainfall of about 2,000–4,000 mm** across the coastal provinces, with the highest totals in Koh Kong and the Cardamom foothills (MoE, 2019).
- **Mean sea-surface temperatures of 28–29°C**, with an increasing frequency of short-lived "heat spikes" during strong El Niño events (World Bank, 2023).
- **A rising incidence of extreme rainfall, flash floods and strong storm surges**, particularly during late monsoon months, affecting urban centres and low-lying estuaries (UNDP & NCDM, 2023).

Climate projections for mid-century, based on SSP2-4.5 and SSP5-8.5 scenarios, indicate that:

- **Air temperatures are expected to increase by approximately 1.3–1.8°C by 2050**, with more hot days and warm nights (World Bank, 2023).
- **Sea level in the Gulf of Thailand is projected to rise by about 11–20 cm by 2050**, depending on emissions pathways (World Bank, 2023).
- **Monsoon rainfall intensity is likely to increase**, raising the risk of urban flooding, landslides and flash floods in steep catchments (UNDP & NCDM, 2023).
- **Dry-season droughts are projected to intensify**, especially during strong ENSO phases, stressing water supply systems and rain-fed agriculture (World Bank, 2023).

These climatic shifts are expected to amplify existing ecosystem and livelihood vulnerabilities—exacerbating shoreline erosion and saline intrusion, increasing coral-bleaching risk, and heightening disaster exposure for coastal towns and rural communities (World Bank, 2023; UNDP & NCDM, 2023).

1.3.3 Biogeography, Endemic and Unique Marine Species

Cambodia's marine and coastal ecosystems form part of the Eastern Gulf of Thailand ecoregion and support a high diversity of habitats and species relative to the country's short coastline (PEAMSAE & MoE, 2019; SCSSAP, 2020). The coastline links the Cardamom Mountain forests, extensive mangroves and estuaries, coral reefs, seagrass meadows and offshore islands, creating important north–south and inshore–offshore ecological corridors. Key biogeographic characteristics include:

- **Mangroves**: Over 25 mangrove tree species have been recorded, including *Rhizophora apiculata*, *Avicennia marina*, *Sonneratia alba*, *Bruguiera gymnorrhiza* and *Ceriops tagal* (PEAMSAE & MoE, 2019; Ramsar Secretariat, 2012). These forests provide nursery habitat for fish and crustaceans, stabilise shorelines and store significant amounts of blue carbon.
- **Coral reefs**: Reefs are dominated by massive, sediment-tolerant genera such as *Porites* and *Favia*, reflecting naturally high turbidity and riverine influence (SCSSAP, 2020). Though generally of low to moderate relief, these reefs host diverse assemblages of reef fish and invertebrates and underpin local tourism and fisheries.
- **Seagrass meadows**: Eleven seagrass species have been documented, giving Cambodia the highest known seagrass species richness in mainland Southeast Asia (PEAMSAE & MoE, 2019). Extensive meadows in Kampot and Kep are critical feeding grounds for dugongs and green turtles and support small-scale fisheries.
- **Flagship and threatened fauna**: The coastal zone supports populations of Irrawaddy dolphin (*Orcaella brevirostris*, EN), green and hawksbill turtles (*Chelonia mydas*, EN; *Eretmochelys imbricata*, CR), dugongs (*Dugong dugon*, VU), smooth-coated otters (*Lutrogale perspicillata*, VU) and fishing cats (*Prionailurus viverrinus*, VU) (IUCN, 2023; PEAMSAE & MoE, 2019).
- **Fishery resources**: Demersal and pelagic finfish, crustaceans, cephalopods and molluscs are highly diverse, with coastal communities targeting small pelagics,

penaeid shrimp, swimming crabs, squid and a wide range of reef-associated species (FiA, 2025; SAU, 2024).

Taken together, these ecosystems support coastal livelihoods, national food security, blue-carbon storage and biodiversity conservation. They also provide ecological connectivity between Cambodia and neighboring SCS–GOT countries, underlining the importance of cooperative management of shared stocks and transboundary habitats (ADB, 2023; SCSSAP, 2020).

1.4 Assessment Methodology

1.4.1 Conceptual Framework

The updated National TDA shifts emphasis from describing environmental "states" to **evaluating risks to ecosystems, people and livelihoods**, while also assessing the adequacy of governance responses. The assessment follows the UNEP/GEF **concentric circles framework**, adapted for Cambodia and linked to the regional SCS–GOT TDA–SAP process.

- **Inner circle – Ecosystem state**: condition and trends of mangroves, seagrass beds, coral reefs, wetlands, estuaries and offshore islands.
- **Middle circle – Direct pressures**: land-based and marine pollution, overfishing and destructive gears, habitat modification, aquaculture intensification and climate-related hazards (floods, droughts, storm surges, heatwaves).
- **Outer circle – Socioeconomic drivers and governance**: demographic change, urbanization, port and tourism development, agricultural expansion, investment patterns, legal and policy frameworks, institutional capacity and financing.

Within this structure, **quantitative and qualitative indicators** are used to trace causal chains from root causes and drivers, through pressures and state change, to impacts on human well-being and the effectiveness of policy responses. The same framework is applied across subnational units and, where possible, harmonized with regional indicators to enable comparison and "traffic-light" risk rating (green–yellow–red) at national and LME scales.

1.4.2 Subnational Geographic Divisions

The analysis is organized around spatial units that connect **watersheds, first-level administrative regions and coastal–marine ecosystems**:

1. **Coastal provinces** – Koh Kong, Preah Sihanouk, Kampot and Kep serve as the main units for socioeconomic, governance and climate-risk indicators (population, HDI/SHDI, IDPoor, urbanization, disaster losses, institutional capacity).
2. **Watersheds and river basins** – the Mekong–Tonle Sap–Bassac system and major coastal river basins (e.g. Tatai, Kah Bpow, Andong Tuek, Prek Thnot) are used to analyse land-based pollution, sediment and nutrient delivery to the sea, and to relate upstream drivers to coastal impacts.
3. **Marine and coastal subregions** – functionally distinct seascapes are defined for integrated analysis of ecosystems, pressures and governance:

- Sihanoukville urban–industrial coast;
- Kampot–Kep estuary and seagrass corridor;
- Koh Kong mangrove–estuary complexes (Peam Krasop, Koh Kapik, Botum Sakor);
- Koh Rong archipelago and associated reef systems.

Spatial overlays combine **population density, land cover, pollution hotspots, fishing effort, habitat condition and climate exposure** to identify high-risk zones and areas of transboundary significance.

1.4.3 Indicators by Component

Indicator selection was guided by four principles: **relevance to major water-related problems**, **consistency with 2000 baseline reports**, **alignment with regional TDA/SAP indicator guidelines**, and **availability and transparency of underlying data**. Evidence is presented through time series, maps and tables, with supporting data and metadata placed in chapter annexes and consolidated annex/appendices.

Socioeconomics and climate-related risk (Chapter 2)

- Population size, growth and density (national and coastal);
- HDI/SHDI and IHDI "penalty";
- Poverty and IDPoor incidence, livelihood dependence on fisheries and coastal resources;
- Urbanization rates and coastal asset concentration;
- Disaster events, deaths, affected people and economic losses.

Pollution (Chapter 3)

- Water-quality parameters: TN, TP, fecal coliform, COD/BOD, TSS, oil & grease, TPH, heavy metals;
- Municipal and industrial wastewater generation, treatment capacity and coverage;
- Solid waste generation, disposal and recycling;
- Plastic leakage estimates and marine debris density;
- Hazardous and medical waste, aquaculture effluents and identified pollution hotspots.

Ecosystems (Chapter 4)

- Mangrove extent and change since 2014;
- Coral cover and condition categories;
- Seagrass area and species richness;
- Wetland extent and key site characteristics;
- Occurrence of flagship and threatened species;
- Habitat integrity and fragmentation indicators.

Fisheries (Chapter 5)

- Catch-per-unit effort (CPUE) trends for demersal and pelagic fisheries;
- Mean Trophic Index (MTI), Fishing-in-Balance (FiB) and Primary Production Required (PPR);

- Reconstructed catch by species group and gear type (1950–2019);
- Spatial distribution of fishing effort and bottom-impacting gears;
- Aquaculture production, value and intensity indicators.

Governance (Chapter 6)

- Legal and policy instruments relevant to coastal and marine management;
- Institutional arrangements for ICZM, MSP and MPA management;
- MPA and MFMA coverage, management effectiveness and patrol effort;
- Economic instruments, budgets and financing for enforcement and conservation;
- Civil society participation, co-management arrangements and partnership initiatives.

1.4.4 Risk Assessment Approach

Risk levels are derived using a **three-pillar Exposure–Sensitivity–Adaptive Capacity (ESAC) framework**, consistent with international practice for climate and environmental risk assessment and with the regional indicator guidelines.

- **Exposure** reflects the presence and magnitude of hazards in each province or subregion—pollution loads, fishing pressure, development intensity, frequency of floods and droughts, and projected climate stresses (sea-level rise, temperature and rainfall changes).
- **Sensitivity** captures how strongly ecosystems and communities are affected by a given hazard, based on ecological fragility (e.g. coral sensitivity to bleaching, mangrove degradation, seagrass turbidity thresholds), livelihood dependence on fisheries and wetlands, and concentrations of poor or highly exposed populations.
- **Adaptive capacity** assesses the ability of institutions, communities and sectors to anticipate, respond and adapt—considering governance effectiveness, enforcement capacity, financing, infrastructure (e.g. wastewater treatment, early warning), social protection and livelihood diversification.

For each indicator set, **direction and magnitude of change from the late 1990s baseline to the early 2020s** are assessed and, where possible, converted into **traffic-light risk ratings** (green = low, yellow = moderate, red = high). Comparative profiles across provinces and subregions highlight recurring hotspots such as:

- Peam Krasop–Koh Kapik mangrove–estuary complex;
- Sihanoukville urban and industrial coastline;
- Kampot–Kep seagrass and estuary corridor;
- The Phnom Penh–Bassac–Mekong discharge interface.

These risk profiles provide the bridge from diagnostic analysis to **prioritized strategic actions** in the forthcoming National and Regional SAPs, ensuring that proposed measures directly target the most critical combinations of pressures, vulnerabilities and governance gaps.

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List of Acronyms

ADB	Asian Development Bank
AMR	Antimicrobial Resistance
ASEAN	Association of Southeast Asian Nations
BOD	Biochemical Oxygen Demand
CCA	Causal Chain Analysis
CCCSP	Cambodia Climate Change Strategic Plan
CF	Community Fishery
CFU	Colony Forming Units
COD	Chemical Oxygen Demand
CPUE	Catch-per-Unit Effort
DA	Disaster Assessment
ENSO	El Niño–Southern Oscillation
ESAC	Exposure–Sensitivity–Adaptive Capacity (risk-assessment model)
FC	Fecal Coliform
FiA	Fisheries Administration (MAFF)
FiB	Fishing-in-Balance Index
GEF	Global Environment Facility
HDI / SHDI / IHDI	Human Development Index / Subnational HDI / Inequality-adjusted HDI
ICZM	Integrated Coastal Zone Management
IDPoor	Identification of Poor Households Programme
IUCN	International Union for Conservation of Nature
MAFF	Ministry of Agriculture, Forestry and Fisheries
MFMA	Marine Fisheries Management Area
MoE	Ministry of Environment
MoP	Ministry of Planning
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NBSAP	National Biodiversity Strategy and Action Plan
NCDM	National Committee for Disaster Management
NCSD	National Council for Sustainable Development
NDC	Nationally Determined Contribution
NIS	National Institute of Statistics
NO_3^- / PO_4^{3-}	Nitrate / Phosphate
NSOC	National State of the Oceans and Coasts
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PPR	Primary Production Required
SCS–GOT	South China Sea–Gulf of Thailand
SCSSAP	South China Sea Strategic Action Programme
SDG	Sustainable Development Goal
SEZ	Special Economic Zone
SLR	Sea-Level Rise
SOC	State of the Coasts (PEMSEA)
TDA	Transboundary Diagnostic Analysis
TN / TP	Total Nitrogen / Total Phosphorus
TPH	Total Petroleum Hydrocarbons

TSS	Total Suspended Solids
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WEPA	Water Environment Partnership in Asia
WWTP	Wastewater Treatment Plant

Annex 1-1 Comparative Assessment: Major Water-Related Environmental Problems (2000 vs 2025)

The Cambodia National TDA (2000) identified seven principal water-related environmental problem areas across freshwater and marine/coastal systems (UNEP/EAS/RCU, 1998). Twenty-five years later, these problem clusters remain but have generally intensified or shifted as rapid economic growth, urbanisation, coastal development and climate change have increased pressures on water quality, ecosystems and livelihoods (ADB, 2023; PEAMSAE & MoE, 2019; World Bank, 2023). Table 1-1 provides a strict analytical comparison between the 2000 baseline and updated 2025 evidence taken from recent national assessments and sector reports on socioeconomics, pollution, ecosystems, fisheries and disaster risk (ADB, 2023; Derrick et al., 2020; FiA, 2024; PEAMSAE & MoE, 2019; UNDP & NCDM, 2023; World Bank, 2023).

The comparative assessment shows that Cambodia's core water-related environmental problems have not only persisted since 2000 but, in most cases, have intensified substantially. Pollution pressures have risen sharply as coastal cities and special economic zones expanded faster than wastewater and solid-waste infrastructure. Centralised treatment plants still handle only a small proportion of total sewage—less than 20% in Preah Sihanouk, under 10% in Kampot and almost none in Koh Kong and Kep—while most households rely on septic systems that frequently overflow into drains and canals (ADB, 2023; WEPA, 2020). Coastal and estuarine monitoring consistently reports high faecal-coliform loads (10^4–10^5 CFU/100 mL) and elevated nitrate and phosphate concentrations, while industrial effluents near ports and SEZs often exceed national standards for oil and grease, total petroleum hydrocarbons, lead and zinc (ADB, 2023; MoE, 2013; WEPA, 2020).

Fisheries indicators reveal long-term, systemic depletion. Demersal trawl CPUE has collapsed from about 173 kg/hour in the 1960s to roughly 26 kg/hour today (FiA, 2024), and reconstructed catch series show strong declines in higher-trophic species and increasing dominance of small pelagics (Derrick et al., 2020). Sharks and rays have fallen from thousands of tonnes in the early 2000s to very small residual landings, while trawls and purse seines together account for the vast majority of marine catches, confirming intense gear-driven pressure on coastal stocks (Derrick et al., 2020; FiA, 2024).

Freshwater and estuarine wetlands remain central to rural livelihoods but are increasingly stressed by land-use change, hydrological alteration and salinity intrusion. Peat-forming mangrove–wetland mosaics in Koh Kong and floodplain systems linked to the Mekong–Tonle Sap–Bassac complex are particularly sensitive to drainage, new roads and channel infilling (PEAMSAE & MoE, 2019; SCSSAP, 2020). Socio-economic studies at Koh Kapik–Peam Krasop and associated Ramsar sites show that 65–90% of

household income can derive from wetland-based fisheries and natural resources, highlighting the vulnerability of these communities to further habitat loss or hydrological disruption (Fauna & Flora, 2024; Ramsar Secretariat, 2012).

Updated habitat mapping indicates that mangrove extent has declined by around 3,500–4,000 ha between 2014 and 2025, with the largest losses in Koh Kong and peri-urban fringes of Preah Sihanouk (PEAMSAE & MoE, 2019; SCSSAP, 2020). Coral cover at many nearshore sites has dropped to 6–10%, while seagrass meadows—especially in the Kampot–Kep area—have shrunk by roughly 20% under pressure from trawling, dredging, reclamation and turbidity (ADB, 2023; MoE, 2013). These ecosystem losses reduce fisheries productivity, carbon storage and natural coastal protection.

Hydrological extremes have also become more severe. Floods remain Cambodia's most damaging hazard, with exposure highest along the Mekong–Tonle Sap–Bassac corridor and coastal lowlands (UNDP & NCDM, 2023; World Bank, 2023). Climate projections point to more intense rainfall events and higher flood peaks, while observed salinity intrusion is advancing 5–7 km inland in some estuaries (World Bank, 2023). Droughts are intensifying under ENSO variability and rising temperatures; recent events have affected millions of people, and many agricultural and peri-urban areas now experience recurrent water shortages, groundwater stress and higher aquaculture mortality during prolonged dry periods and heatwaves (FiA, 2024; UNDP & NCDM, 2023; World Bank, 2023).

River-borne pollution remains a defining feature of coastal water quality. Monitoring along the Mekong–Tonle Sap–Bassac system shows persistent exceedance of faecal-coliform standards and repeated TN/TP exceedances at key confluence points, with TSS reaching over 2,000 mg/L in parts of the Bassac during high-flow conditions (MoE, 2013; WEPA, 2020). These loads generate large sediment and nutrient plumes that affect estuaries such as Kampot Bay and Koh Kong and contribute to cross-border nutrient export to the Viet Nam delta and the wider Gulf of Thailand (ADB, 2023; SCSSAP, 2020). Overall, the updated evidence confirms that the conditions diagnosed in 2000 have not improved; instead, pressures have multiplied and intensified, calling for urgent, integrated responses across wastewater management, fisheries reform, habitat conservation, climate-resilient planning and catchment-to-coast governance.

Annex Table 1-1 Comparative analysis of major water-related environmental problems (2000 vs 2025)

Problem Category (2000)	**Status / Evidence in 2000 (Baseline)**	**Status / Evidence in 2025**	**Key Sources**
1. Contamination of water quality – domestic & non-point pollution	Widespread organic pollution and domestic sewage from urban centres, with almost no wastewater treatment systems in coastal provinces. Monitoring already reported elevated BOD and TSS in urban rivers and receiving waters, alongside growing inputs of fertilizers	Centralised plants still treat only a small fraction of total flows: <20% of sewage in Preah Sihanouk, <10% in Kampot, and almost none in Koh Kong and Kep, while most households rely on septic tanks that frequently overflow into drains and canals. FC levels in bathing waters and landing sites often reach 10^4–10^5 CFU/100 mL, and estuarine NO_3^- and PO_4^{3-} concentrations (2.0–2.6 mg/L and 0.7–0.8 mg/L) exceed ASEAN guideline values. Industrial discharges near ports and SEZs frequently surpass national	MoE (2023); ADB (2023)

	and pesticides from agriculture and upland catchments.	limits for oil & grease, TPH, Pb and Zn, creating toxic hotspots in nearshore sediments.	
Overfishing and declining fish stocks (freshwater & marine)	Early evidence of declining catches in Tonle Sap and coastal zones, with widespread use of destructive gears and limited enforcement. Stock assessments were sparse, but concerns were raised over reduced average fish size and loss of higher-value species.	Long-term indicators now show systemic depletion: demersal trawl CPUE has collapsed from 173 kg/hr in the 1960s to about 26 kg/hr today; ecosystem indices (MTI, FiB, PPR) indicate fishing further down the food web; and sharks and rays have fallen from 2,000–4,000 t in the early 2000s to single-digit tonnes by 2018–2019. Small pelagics now account for more than 70% of marine catch, while trawls and purse seines generate 85–90% of landings, confirming intense, gear-driven pressure on coastal stocks.	FiA (2025); SAU (2024)
Habitat degradation – freshwater wetlands	Loss and degradation of wetlands due to agricultural expansion, drainage works and conversion for settlements and infrastructure, reducing the extent and quality of nursery grounds and flood-buffering functions.	Freshwater and estuarine wetlands remain central to rural livelihoods but are under increasing strain from land-use change, altered flow regimes and salinity intrusion. Peat-forming mangrove–wetland mosaics in Botum Sakor and floodplain systems linked to the Mekong–Tonle Sap–Bassac complex are highly sensitive to drainage, road construction and channel infill. In key sites such as Koh Kapik–Peam Krasop, more than 65–90% of household income depends on wetland-based fisheries and resources, making communities extremely vulnerable to any further habitat loss or hydrological disruption.	Ramsar (2012); MoE (2024)
Habitat degradation – mangroves, coral reefs, seagrasses	Coastal habitats were mapped and recognised as important, but protected-area coverage and enforcement were limited. Early signs of mangrove clearance, coral damage from destructive fishing and sedimentation, and poorly understood seagrass distributions were noted.	Updated mapping shows mangroves declining from ~58,866 ha (2014) to ~55,355 ha (2025), a net loss of 3,510–4,000 ha, concentrated in Koh Kong and peri-urban Preah Sihanouk. Coral cover in many nearshore sites has fallen to 6–10%, with only “fair” condition (20–30% cover) on less-impacted offshore reefs, while seagrass meadows—especially in the Kampot–Kep corridor—have shrunk by about 20%, mainly due to trawling, dredging, shoreline works and turbidity increases. These losses compromise fisheries productivity, blue-carbon storage and natural coastal protection.	MoE (2023); ADB (2023)
Flooding (freshwater) and	Floods and droughts were already significant hazards,	Floods remain Cambodia’s deadliest and most damaging natural hazard, with major events	NCDM & UNDP (2021);

hydrological variability	with Tonle Sap flow reversals and monsoon variability shaping seasonal exposure; adaptive capacity and disaster-risk systems were limited.	affecting large populations and infrastructure along the Mekong–Tonle Sap–Bassac and coastal plains. Recent assessments classify national disaster risk as "medium" with very high river-flood exposure; climate projections point to more intense rainfall events and higher flood peaks, while salinity intrusion is advancing 5–7 km inland in some estuaries, raising compound risks for agriculture, water supply and ecosystems.	WB (2021)
Drought-related impacts (freshwater + agriculture)	Seasonal droughts periodically affected rice production and domestic water supply; water-storage and irrigation infrastructure were inadequate and unevenly distributed.	Drought has become more frequent and severe under ENSO variability and rising temperatures, with the 2016 event affecting around 2.5 million people. Agricultural zones and peri-urban communities experience recurrent water shortages; shallow aquifers and small reservoirs are increasingly stressed, while aquaculture faces higher mortality, greater disease incidence and rising input costs during prolonged dry periods and heatwaves.	WB (2021); FiA (2025)
Transboundary pollution & river–coast linkages	The Mekong–Tonle Sap–Bassac system was recognised as a major conduit for sediment, nutrients and pollutants, with high faecal-coliform levels in Phnom Penh discharge zones and significant loads delivered to the Vietnamese delta and coastal waters.	River-borne pollution remains a defining feature of Cambodia's coastal water quality. Monitoring at Phnom Penh and along the Bassac indicates persistent exceedance of FC standards and repeated TN/TP exceedances at confluence points; TSS can reach 2,030 mg/L in the Bassac during high-flow conditions. These loads feed large sediment and nutrient plumes that affect estuaries such as Kampot Bay and Koh Kong and contribute to cross-border nutrient export to the Viet Nam delta and the wider Gulf of Thailand.	MoE (2023); ADB (2023)

Annex 1-2 New or Intensifying Issues Not Assessed in 2000

New threats not explicitly considered in the 2000 TDA have become major national priorities. Climate change now acts as a system-wide risk amplifier, driving sea-level rise, salinity intrusion, extreme rainfall, urban flooding and marine heatwaves that undermine infrastructure, fisheries and ecosystems (World Bank, 2023; UNDP & NCDM, 2023). Projections indicate sea-level rise of 11–20 cm by 2050, with observed salinity intrusion extending 5–7 km inland and coral bleaching occurring during strong ENSO years (World Bank, 2023). Urban floods are worsening due to intense rainfall combined with undersized drainage networks.

Marine plastics and microplastics have become chronic pollutants. Cambodia now generates more than 730,000 t/year of plastic waste, with at least 14,000 t/year entering

coastal environments; sediments at several hotspots contain 120–350 microplastic particles per kg (ADB, 2023). Floating debris is increasingly common near ports and tourism beaches, creating risks for marine life, food safety and public health.

Industrial and port-related pollution has intensified. Inspections show that around 60% of facilities near ports and SEZs are non-compliant with effluent standards, with high levels of oil and grease, total petroleum hydrocarbons, lead and zinc (ADB, 2023; MoE, 2013). Hazardous and medical waste generation—estimated at roughly 120,000 t/year for industry and up to 20 t/day during the COVID-19 period—continues to overwhelm available treatment capacity (MoE, 2013).

Rapid and often unplanned coastal urbanisation further strains environmental systems. Cambodia's urban population reached 39% in 2019, with Sihanoukville expanding fastest through large-scale land reclamation and real-estate growth (PEAMSAE & MoE, 2019). These changes have modified shorelines, reduced natural buffers and outpaced wastewater and drainage systems, increasing risks of flooding, erosion and pollution.

Aquaculture expansion contributes growing nutrient and microbial loads. National aquaculture output exceeded 330,000 tonnes in 2022, with marine farming increasingly intensive in areas such as Trapeang Ropov and Chroy Svay. Feed conversion ratios of 1.6–2.0 result in 25–30% feed loss to water, raising BOD and TSS, while studies have detected antibiotic-resistance genes in effluents, indicating emerging AMR risks (FiA, 2025).

Despite improved legal frameworks—such as the Code on Environment and Natural Resources and expanded MPA coverage—significant governance gaps remain. The NCCMD marine sub-decree is still pending, MSP has not been formalised, fewer than 30% of MPAs are effectively patrolled and operational budgets for enforcement remain limited (ADB, 2023; PEAMSAE & MoE, 2019). These constraints reduce the State's capacity to manage cumulative pressures from ports, fisheries and coastal development.

Finally, sedimentation and turbidity are rising due to land clearing, road construction, sand mining and coastal works. In Koh Kong, sediment inflows to estuaries have increased by more than 35%, while monsoon-season TSS in Kampot Bay can reach 250–320 mg/L (MoE, 2013; SCSSAP, 2020). High sediment loads reduce light penetration, stress corals and seagrasses and interact with nutrient enrichment to elevate eutrophication risks.

Together, these emerging threats demonstrate that Cambodia's coastal risks are increasingly complex, interconnected and climate-sensitive, necessitating stronger pollution control, climate-resilient planning, compliance systems and a fully operational marine spatial planning framework.

Annex Table 1-2 Emerging environmental issues (post-2000)

New or Emerging Issue (Post-2000)	2000 Status	2025 Status	Key Sources
Climate change impacts (SLR, salinity intrusion, marine heatwaves)	Climate change was not explicitly included as a separate diagnostic theme; sea-level rise and temperature change were not quantified in	Recent projections indicate sea-level rise of +11–20 cm by 2050, accompanied by higher sea-surface temperatures and more frequent marine heatwaves. Observed impacts include advancing salinity intrusion (5–7	WB (2021)

	the 2000 national report.	km inland in some estuaries), greater coastal-flood depth and duration, and mass-bleaching episodes on coral reefs, particularly during strong ENSO years. Urban flooding is intensifying as extreme rainfall interacts with undersized drainage and high impervious-surface cover.	
Marine plastics & microplastics	Plastic waste and microplastics were not recorded as a distinct pollution category and received little or no attention in the 2000 analysis.	National plastic-waste generation now exceeds 730,000 t/year, with coastal leakage estimated at more than 14,000 t/year. Coastal sediments in some hotspots contain 120–350 microplastic particles/kg, and floating debris is commonly observed near ports, tourism beaches and river mouths. These trends pose chronic risks to marine life, fisheries, tourism and public health.	MoE (2023)
Industrial & port-related pollution	Industrial and port activities were mentioned only briefly, with limited data on effluent composition or spill risks.	Expansion of coastal SEZs and port infrastructure has created localised toxic hotspots. Recent inspections show about 60% of sampled facilities near ports/industrial zones are non-compliant with effluent standards, with elevated oil & grease, TPH, Pb and Zn. Hazardous and medical wastes (~120,000 t/year industrial; COVID-era medical peaks up to 20 t/day) strain limited treatment and disposal capacity, increasing the risk of accidental releases and chronic contamination.	ADB (2023)
Urbanization pressure & land reclamation	Urbanisation levels were relatively low (~16% of the population in 1998), and large-scale coastal reclamation had not yet begun.	Urbanisation has accelerated sharply: Census data show the urban share rising to 39% by 2019, with especially rapid growth in Sihanoukville and other coastal towns. Extensive land reclamation and real-estate development in Preah Sihanouk and selected estuaries have altered shoreline configuration, reduced natural buffers and outpaced the capacity of drainage, wastewater and solid-waste systems, heightening exposure to floods, erosion and pollution.	NIS (2019)
Aquaculture nutrient/microbial loading	Aquaculture existed but at relatively small scale; nutrient and microbial loads from ponds and cages were not considered	Aquaculture has expanded dramatically, with national production reaching over 330,000 t in 2022. Marine/coastal farming remains a smaller share but is locally intense: feed conversion	FiA (2025)

	a major driver in the 2000 diagnosis.	ratios of 1.6–2.0 imply that 25–30% of feed is lost as waste, elevating BOD and TSS in dense farming zones such as Trapeang Ropov and Chroy Svay. Studies detect antibiotic-resistance genes in farm effluents, signalling emerging AMR risks alongside disease outbreaks and periodic mass mortality events.	
Governance gaps in enforcement & MSP	The 2000 report noted fragmented mandates and limited capacity but did not systematically assess governance performance, ICZM or MSP.	Today, Cambodia has a more complete legal and institutional framework (Code on Environment & Natural Resources, Fisheries Law, PAs, IWRM commitments, NCCMD/NCSD), but significant gaps remain at sea. The NCCMD marine sub-decree is still pending, leaving offshore zoning and MSP without a clear legal backbone; MPA coverage has increased but less than 30% of marine protected areas are effectively patrolled; and patrol, prosecution and O&M budgets remain thin. These factors limit the ability of institutions to reverse ecosystem degradation and manage cumulative impacts from ports, tourism and fisheries.	MoE (2024)
Sedimentation / turbidity from land-use change	Sediment and turbidity issues were recognised but not quantified; monitoring was limited to a few stations and data on land-use drivers were sparse.	Land clearing, road construction, sand mining and coastal works have increased sediment yields. In Koh Kong, land-cover change and infrastructure expansion are estimated to have raised sediment inflows to estuaries by more than 35%, while TSS in some monsoon-affected estuaries (e.g. Kampot Bay) can exceed 250–320 mg/L. These high loads reduce light penetration, stress corals and seagrasses, and interact with nutrient enrichment to increase the risk of eutrophication and habitat loss.	MoE (2023)

Annex 1-3 Subnational Geographic Divisions

Annex Table 1-3 Geographic divisions used in the analysis

Division	Description	Application
Coastal provinces	Koh Kong, Preah Sihanouk, Kampot, Kep	Socioeconomics, climate risk, governance.
River basins	Mekong–Tonle Sap–Bassac; Tatai; Kah Bpow; Prek Thnot	Pollution and sediment pathways.
Marine subregions	Sihanoukville coast; Kampot–Kep corridor; Koh Kong estuaries; Koh Rong archipelago	Ecosystem, fisheries, pollution and development dynamics.

Annex 1-4 Indicator Inventory

Annex Table 1-4 Indicators used by component

Component	Indicator group	Primary sources
Socioeconomics	Population, HDI/SHDI, poverty, livelihoods, urbanisation, disaster impacts	NIS; UNDP; MOP
Pollution	TN, TP, FC, TSS, COD, BOD, TPH, metals; plastics; hazardous waste	MoE; WEPA; ADB
Ecosystems	Mangrove extent, coral cover, seagrass, wetland condition, species lists	MoE; PEMSEA; Ramsar
Fisheries	CPUE, MTI, FiB, species trends, gear impacts, aquaculture	FiA; SAU
Governance	ICZM, MSP readiness, MPAs/MFMAs, patrol effort, budgets, legal instruments	MoE; NCSD; FiA

Annex 1-5 Expanded Risk-Assessment Methods

This annex describes the technical approach used to derive risk levels for ecosystems, people and livelihoods across Cambodia's coastal and river–sea interface zones. The method follows the **Exposure–Sensitivity–Adaptive Capacity (ESAC)** framework widely applied in climate and environmental risk assessments, and is harmonised with **UNEP/GEF TDA–SAP guidelines** and regional indicator templates.

1. Exposure Indicators

Exposure represents the **degree to which ecosystems or communities are subject to hazards**. Indicators capture the intensity, frequency and spatial distribution of biophysical pressures.

Pollution loads:

- Total Nitrogen (TN), Total Phosphorus (TP)
- Fecal coliform (FC) levels
- Chemical pollutants (oil & grease, TPH, Pb, Zn)
- Microplastics (density in sediments and water column)
- These highlight areas receiving untreated wastewater, industrial discharges or solid-waste leakage

Fishing pressure

- Spatial distribution of trawl and purse-seine effort
- Gear intensity in inshore zones (<20 m depth)
- Reconstructed effort trends from FiA and SAU
- These indicators identify areas of chronic ecosystem stress and habitat disturbance.

Climate hazards:

- Flood frequency, magnitude and affected population
- Drought intensity (ENSO-linked) and duration
- Sea-level rise (SLR) projections

- Marine heatwaves and temperature anomalies
- These are used to characterise hazard “hot years” and long-term climatic shifts.

Coastal development intensity:

- SEZ footprint and density
- Port expansion, dredging and reclamation areas
- Tourism and urbanisation rates
- High development intensity correlates with pollution hotspots, habitat loss and erosion.

River discharge and sediment inflows:

- Discharge peaks (Mekong–Tonle Sap–Bassac system)
- Total Suspended Solids (TSS) in monsoon flows
- This explain transboundary nutrient and sediment delivery to estuaries and coastal waters.

2. Sensitivity Indicators

Sensitivity captures the degree of harm that ecosystems or communities are likely to experience when exposed to a hazard**.**

Coral bleaching susceptibility

- Presence of bleaching events during heatwaves
- Coral genera with low thermal tolerance
- Sediment-tolerant vs. sensitive assemblages

Seagrass turbidity thresholds

- Light-limitation thresholds (e.g., TSS > 25–30 mg/L)
- Species-specific responses to sedimentation
- Nearshore dredging impacts

Mangrove fragmentation and dieback

- Patch-size metrics
- Proportion of degraded vs. intact stands
- Proximity to hydrological blockages and conversion areas

Livelihood dependence

- Share of income from fisheries, wetlands and coastal resources
- Proportion of households dependent on daily catch or gleaning
- High dependence increases vulnerability to ecological shocks.

Poverty incidence and vulnerable groups

- IDPoor distribution
- Exposure of low-income groups to floods, salinity intrusion or pollution
- Poorer households have limited resources to cope and recover.

3. Adaptive Capacity Indicators

Adaptive capacity reflects **the ability of institutions, communities and ecosystems to moderate damage or adjust to change**.

Enforcement and patrol capacity

- Number of patrol days per month
- Functionality of MFMA/MPA enforcement teams
- Inter-agency coordination levels

Existence and implementation of ICZM/MSP

- Legal instruments enabling coastal zoning
- Institutional mandates and clarity
- Degree of MSP operationalisation (planning, mapping, zoning)

Wastewater and pollution-control infrastructure

- WWTP capacity and coverage
- Industrial compliance monitoring
- Availability of landfills, transfer stations and hazardous-waste handling

Social protection and livelihood diversification

- Access to IDPoor, cash transfers, microfinance
- Availability of alternative jobs in tourism, aquaculture or services
- Communities with diversified livelihoods are less vulnerable.

Community organisation and co-management

- Strength of Community Fisheries (CFis) and Protected Area (CPA) committees
- NGO partnership presence
- Participation in monitoring or resource management
- Stronger social capital tends to reduce risk.

4. Scoring Approach (ESAC Model)

A standardised scoring system is applied for comparability across provinces and seascapes.

Scoring scale

- **Exposure:** 1 (low) – 3 (high)
- **Sensitivity:** 1 (low) – 3 (high)
- **Adaptive Capacity:** 1 (strong) – 3 (weak)

Risk formula

$$\boldsymbol{Risk} = \frac{\textbf{Exposure x Sensitivity}}{\textbf{Adaptive Capacity}}$$

Interpretation of results

Final Risk Score	Interpretation	Implication
< 2.0	**Low**	Ecosystems/communities can cope; targeted interventions still beneficial.
2.0 – 3.0	**Moderate**	Evidence of increasing pressure; requires monitoring and preventive actions.
> 3.0	**High**	Acute or chronic risk; urgent management, investment and regulatory action needed.

Spatial comparison

Risk scores are mapped at:

- **Provincial scale** → governance and socioeconomic patterns
- **Ecosystem scale** → mangrove stands, seagrass beds, coral reefs
- **Marine subregion scale** → Sihanoukville, Kampot–Kep, Koh Kong, Koh Rong

This allows identification of persistent hotspots such as:

- Peam Krasop–Koh Kapik
- Sihanoukville urban–industrial coastline
- Kampot–Kep seagrass corridor
- Phnom Penh river–sea discharge interface

Annex 1-6 Supplementary Notes (Supporting Materials)

1. Definitions and Terminology

This section provides standardized definitions used throughout Chapter 1 and subsequent chapters to ensure consistency with UNEP/GEF TDA–SAP methodology and regional SCS–GOT practice.

Coastal zone

Defined as Cambodia's four first-level administrative coastal provinces—Koh Kong, Preah Sihanouk, Kampot and Kep—together with associated **river mouths, estuaries, tidal-influence zones and nearshore islands**. This aligns with regional coastal delineation under PEMSEA and the SCS–SAP.

Estuarine–marine interface

Areas within which **freshwater discharge strongly influences salinity, nutrient dynamics, sedimentation patterns, turbidity and ecological structure**. These interfaces are critical for nurseries, fisheries recruitment and pollutant delivery from land to sea.

Pressures vs. drivers

- **Pressures** refer to *direct, measurable human activities* that affect environmental conditions (e.g. industrial effluent, trawling, dredging, land reclamation, aquaculture effluent).
- **Drivers** are *underlying socioeconomic forces*—urbanisation, demographic growth, market demand, port/tourism development, agricultural expansion—that shape the magnitude and direction of pressures.

Risk terminology

- **Exposure** = presence/intensity of hazards.
- **Sensitivity** = susceptibility of ecosystems/communities to harm.
- **Adaptive Capacity** = ability to respond, cope or recover from impacts. These follow IPCC and UNEP/GEF formulations.

2. Data Treatment Notes

These notes document how data were cleaned, normalised and interpreted for the risk assessment and comparative analysis in Chapter 1.

Pollution datasets

- When multiple readings are available, the **90th percentile** is used to represent "worst-case" values—consistent with health protection thresholds.
- For provinces with limited sampling frequency, **monsoon-season maxima** were used to ensure conservative estimation of risk.
- Industrial effluent data were included only if directly cited in MoE inspections or ADB environmental monitoring reports.

Ecosystem condition datasets

- **Coral cover categories** follow international thresholds:
  - *Poor:* 0–10%
  - *Fair:* 10–30%
  - *Good:* 30–50%
  - *Very good:* >50%
- Seagrass diversity benchmarks are anchored to the **regional maximum of 11 species** across mainland Southeast Asia.
- Mangrove data follow MoE/PEMSEA classifications (Landsat-based, 30 m resolution), with 2014 as the harmonised baseline.

Socioeconomic and fisheries datasets

- FiA datasets were cross-checked with reconstructed catch series from **Sea Around Us (SAU)** for consistency.
- Poverty data use **IDPoor (MoP)** and **UNDP SHDI/IHDI** for comparative vulnerability scoring.
- CPUE was normalised where gear-effort reporting changed over time.

3. Notes on Alignment with Regional TDA–SAP Process

Alignment of indicator sets

All indicators used in Chapter 1 correspond to the **four regional SCS–SAP component groups**:

1. Pollution
2. Habitats & Biodiversity
3. Fisheries
4. Governance

Consistency with regional transboundary hotspots

Cambodia's national-level risk hotspots correspond directly with **priority transboundary areas identified in the original SCS–SAP and its 2020 update**:

- **Koh Kong–Trat mangrove complex** (Cambodia–Thailand)
- **Kampot–Kep–Ha Tien seagrass corridor** (Cambodia–Viet Nam)
- **Sihanoukville–Phu Quoc development corridor** (Cambodia–Viet Nam)

These areas show strong ecological connectivity, shared fisheries stocks, and cross-border pollution/marine debris movement.

Governance criteria alignment

The governance assessment applies the **SAP governance criteria**:

- *Clarity* of mandates
- *Coherence* across institutions
- *Capacity* for implementation
- *Compliance* and enforcement
- *Coordination* between agencies and local authorities

These criteria guide the identification of governance gaps and priority reforms.

4. Notes on Causal Chain Analysis (CCA)

CCA in Chapter 1 follows standard UNEP/GEF TDA guidance: establishing relationships from *root causes → drivers → pressures → state change → impacts → governance responses*.

Pollution CCA

- **Root causes:** weak wastewater and industrial oversight; rapid urbanisation; insufficient financing; lack of monitoring.
- **Drivers:** SEZ expansion, tourism, population growth, urban development.
- **Pressures:** untreated sewage, industrial effluent, solid waste leakage, agricultural runoff.
- **State changes:** elevated FC, TN/TP, metals, TSS; algal blooms; habitat stress.
- **Impacts:** reduced fisheries productivity, ecosystem degradation, public-health risks.
- **Responses:** wastewater investment, standards enforcement, coastal zoning.

Fisheries CCA

- **Root causes:** open access; limited patrol budgets; inadequate licensing/effort control.
- **Drivers:** market demand, poverty, urban fish consumption, export.
- **Pressures:** destructive gears, excessive trawling, illegal fishing.
- **State changes:** declining CPUE, trophic shift, habitat damage.
- **Impacts:** reduced livelihoods, food security risks.
- **Responses:** MFMA, MPA expansion, patrol strengthening, value-chain reforms.

Climate CCA

- **Root causes:** global greenhouse-gas emissions; ENSO amplification.
- **Drivers:** coastal land-use changes, urbanization, loss of buffers.
- **Pressures:** SLR, storm surges, extreme temperatures, hydrological extremes.
- **State changes:** salinity intrusion, coral bleaching, drought, extreme flooding.
- **Impacts:** infrastructure damage, loss of agricultural productivity, ecosystem stress.
- **Responses:** adaptation planning, climate-resilient infrastructure, EWS, buffer restoration.

5. Cross-Cutting Themes

5.1 Blue Carbon

Mangroves and seagrass systems play a critical role in **carbon sequestration**, coastal protection and climate adaptation.

- Mangroves store **4–10 times more carbon** per hectare than upland forests.
- Seagrass meadows stabilise sediments, absorb nutrients and support marine megafauna (dugongs, turtles).

These systems are emphasised in national climate strategies and the Kunming–Montreal Global Biodiversity Framework (30x30).

5.2 Gender and Livelihoods

Gender analysis highlights:

- Women's roles in post-harvest processing, gleaning and small-scale aquaculture.
- Women's vulnerability to climate shocks and ecosystem degradation due to livelihood dependence and lower asset ownership.
- Where data permit, gender dimensions are incorporated into vulnerability scoring.

5.3 Transboundary Linkages

Cambodia's coastal systems are hydrologically and ecologically connected to the wider **Gulf of Thailand and Mekong Basin**:

- Riverine discharge from the **Tonle Sap–Bassac–Mekong** shapes nutrient and sediment regimes.
- Seasonal currents transport marine debris, microplastics and sometimes oil slicks.
- Shared fisheries stocks (anchovies, small pelagics, blue swimming crabs) require coordinated management across Cambodia, Viet Nam and Thailand.