



Aquatic and terrestrial systems

SEA of Mekong mainstream dams
Regional workshop on SEA Baseline
Assessment

Purpose of the baseline

- The baseline is geared towards answering the key questions for two theme papers:
 - ▣ Aquatic systems
 - ▣ Terrestrial systems and agriculture
- The baseline is therefore focused on the information that will help us to answer these questions.

BDP Key environmental indicators

Table 2-2 Development objectives and key environmental indicators

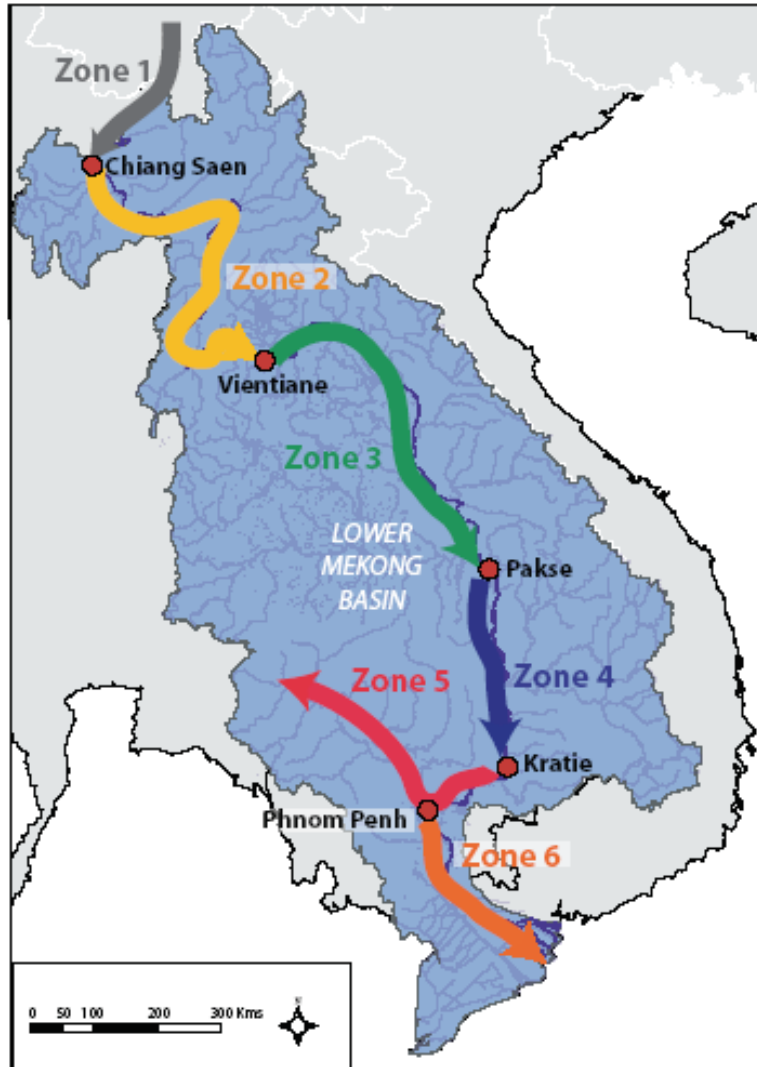
Specific development objectives	Key environmental indicators	Unit
Maintain water quality and acceptable flow conditions	Water quality incl. sediment transport in the mainstream	Trend
	Key flow characteristics	Trend
	Forest flooded for specified depth and duration at Tonle Sap	'000 ha
	Net incremental economic values	US\$ million
Maintain wetland productivity and ecosystem services	Incremental wetlands with required depth duration	'000 ha
	Net incremental economic value	US\$ million
Manage salinity intrusion in the Mekong Delta	Area in the delta within thresholds of salinity	'000 ha
	Net incremental economic value	US\$ million
Minimize channel effects on bank erosion	Incremental area at risk to erosion	'000 ha
	Vulnerability to bank erosion	'000 ha
	Net incremental economic value	US\$ million
Conservation of biodiversity	Incremental area of suitable habitats	'000 ton
	Estimated number of species affected	No.
	Incremental net economic value to tourism	US\$ million

Source: BDP Technical note v3.1: Scoping and Planning of the Assessment of Basin-Wide Development Scenarios, March 2009

Key issues

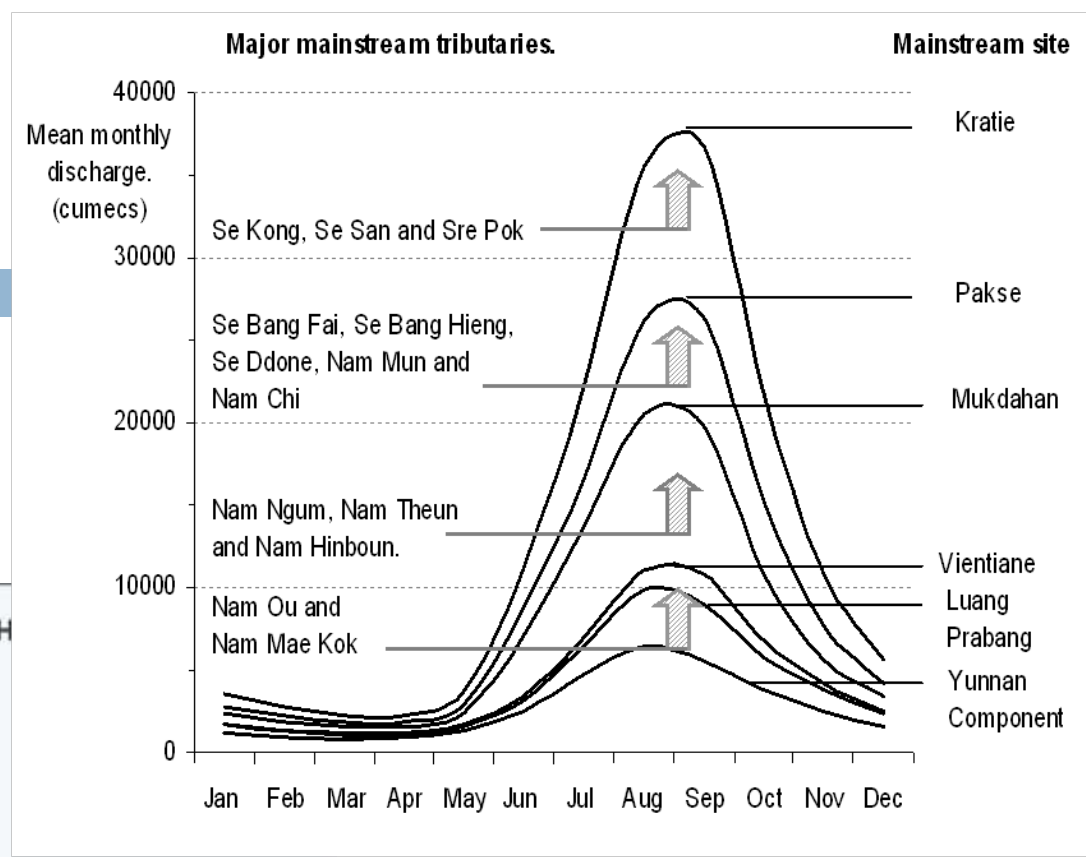
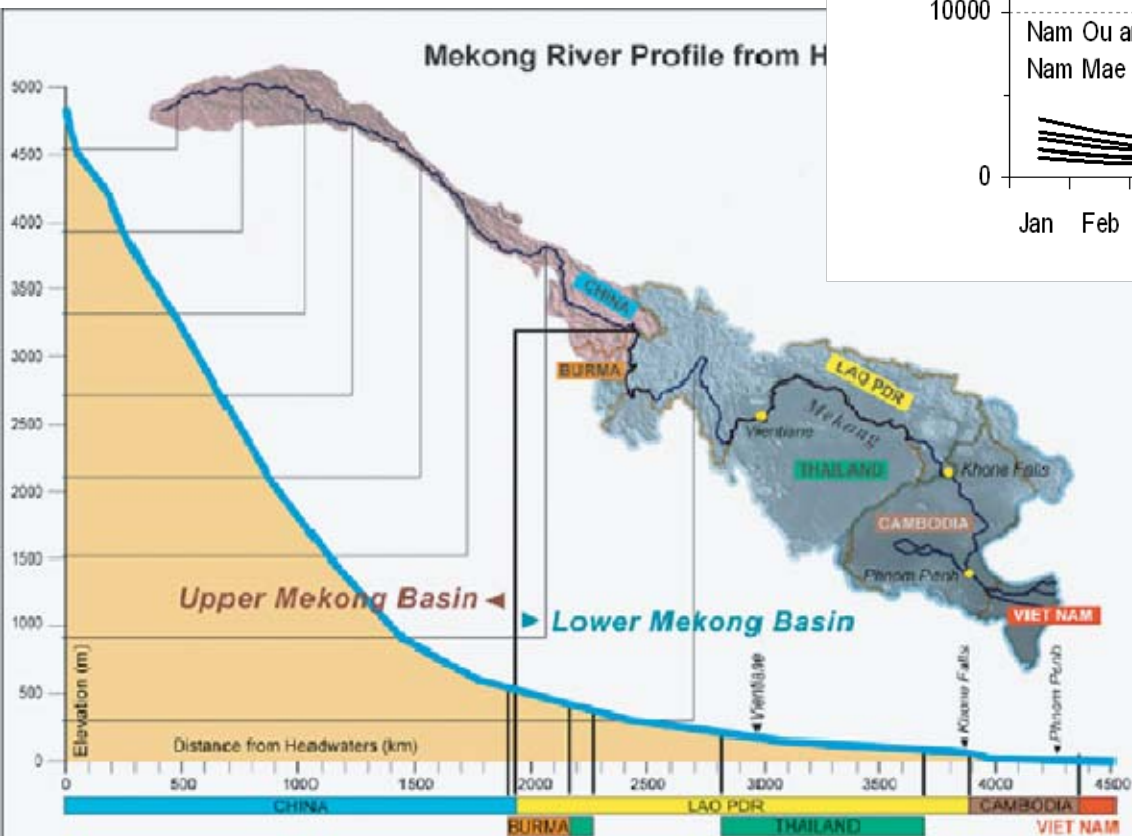
- **Mekong aquatic productivity and biodiversity –**
 - Will changes in aquatic habitats caused by the construction of the mainstream dams reduce the productivity and biodiversity of the Mekong aquatic systems?
- **Mekong aquatic ecosystem services –**
 - Will other ecosystem services provided by the Mekong River and its floodplain be changed by the mainstream dams?
- **Terrestrial ecosystems and biodiversity:**
 - Will there be significant changes in terrestrial ecosystems and biodiversity associated with the hydropower projects on the mainstream?
- **Land use patterns and Agriculture:**
 - How will the mainstream dams influence land use patterns and agriculture along the mainstream?

Ecological zones considered

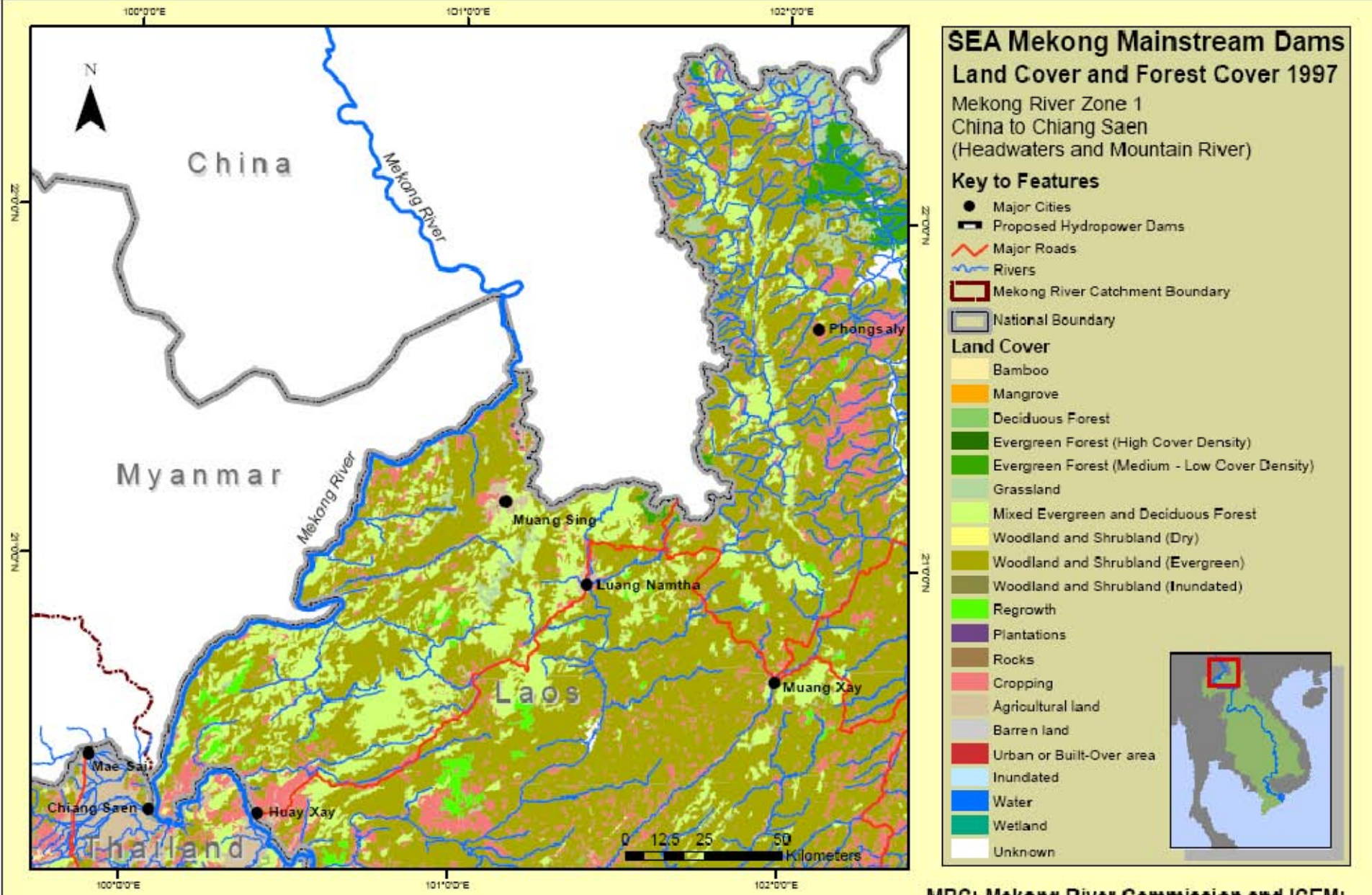


- **Zone 1** – China to Chiang Saen – headwaters and mountain river
- **Zone 2** – Chiang Saen to Vientiane – upland river in steep narrow valley
- **Zone 3** – Vientiane to Pakse – the Thai/Lao midstream section and tributaries
- **Zone 4** – Pakse to Kratie, including wetlands of Siphandone, Khone Falls, Stung Treng and Kratie, including a number of significant tributaries
- **Zone 5** – Kratie to Phnom Penh and the Tonle Sap - Floodplains and the Great Lake
- **Zone 6** – Phnom Penh to the sea – Mekong delta, tidal zone

Basic hydrology of the Mekong



Zone 1 – Headwaters and mountain river



Note: MRC Land Cover mapping only available for the Mekong River Catchment

MRC: Mekong River Commission and ICEM:
International Centre for Environmental Management

Zone 1 – Key features and status

- Aquatic
 - ▣ Fast flowing mountain river,
 - ▣ Massive rocky outcrops and rapids, deep pools and sand bars
 - ▣ Excellent water quality in Laos, but concerns over water and sediments quality coming from China
 - ▣ Sediments reaching Chiang Saen, halved in 1992, after construction of Manwan dam
 - ▣ 162 fish species in China
 - ▣ Annual fish production probably limited by low numbers of fishers
- Terrestrial
 - ▣ Largely forested – mixed deciduous, some primary forest, but mostly secondary due to logging
 - ▣ Swidden agriculture on valley sides
 - ▣ Considered part of the Upper Lao Mekong IBA – but no protection status

Zone 1 – Pressures, Trends, Predictions

□ Aquatic

- Chinese dams influence hydrology and sediment flows of this area dramatically, and will increase
 - BUT Mengsong dam cancelled because of impacts on fish migration
- Water pollution from industrial wastes in China
- Increased navigation, resulting from channel improvements
 - Increased Access, Pollution risks, Bank erosion
- Increased fishing pressure

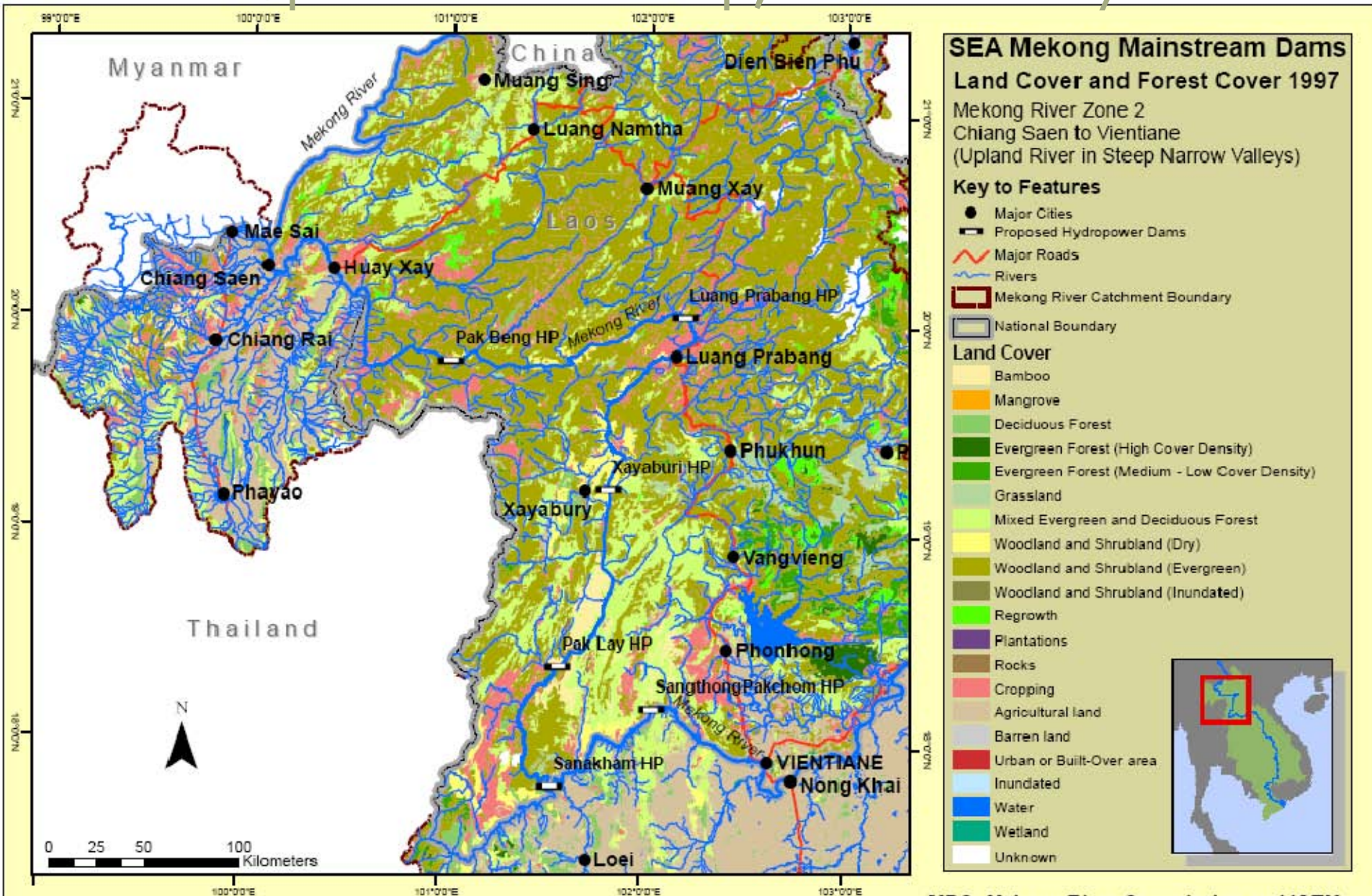
River morphology and aquatic ecology will change significantly over next 20 years

□ Terrestrial

- Increased access, hunting and wildlife trade
- Continued logging pressure
- Continued swidden agriculture

Pressure on terrestrial environment will be increased due to increased access and populations, with continued degradation

Zone 2 – Upland river – steep, narrow valley



Note: MRC Land Cover mapping only available for the Mekong River Catchment

MRC: Mekong River Commission and ICEM:
International Centre for Environmental Management

Zone 2 – Key features and status

□ Aquatic

- Steep narrow valley, except near Chiang Saen, Louangprabang, and Vientiane
- Largely natural river morphology, with many exposed rocks, rapids and riffles and some extensive wetland areas exposed in dry season river channel
- Water quality and ecological health largely good, except around Vientiane and Louangprabang
- 140 species of fish, including important migratory species, and Giant Mekong catfish fishery around Chiang Kong
- Subsistence fishing near riparian communities
- Collection of Mekong riverweed

□ Terrestrial

- Largely forested hillsides – evergreen and mixed deciduous
- Significant logging activities, e.g. around Pak Lay
- Agriculture mainly swidden on hillsides, but with cropping areas on flat land around tributaries – especially Louangprabang
- River bank gardens
- Biodiversity areas –
 - Chiang Saen basin IBA and Ramsar site, IBAs Mekong valley above Vientiane, Mekong Channel at Pak Chom
 - Protected areas in Thailand and Laos adjacent to catchment, but only one touches Mekong

Zone 2 – Pressures, Trends, Predictions

□ Aquatic

- Hydrological and sediment changes from Chinese dams, and on tributaries – e.g. Nam Ou
 - Dry season flows possibly 1 m higher, change in habitats e.g. sandbars and wetland areas reduce
- Possible extension of navigation channel improvement to Louangprabang – increase in commercial and tourist traffic – increase in pollution risk
- Pollution from urban areas and industry – e.g. sawmills

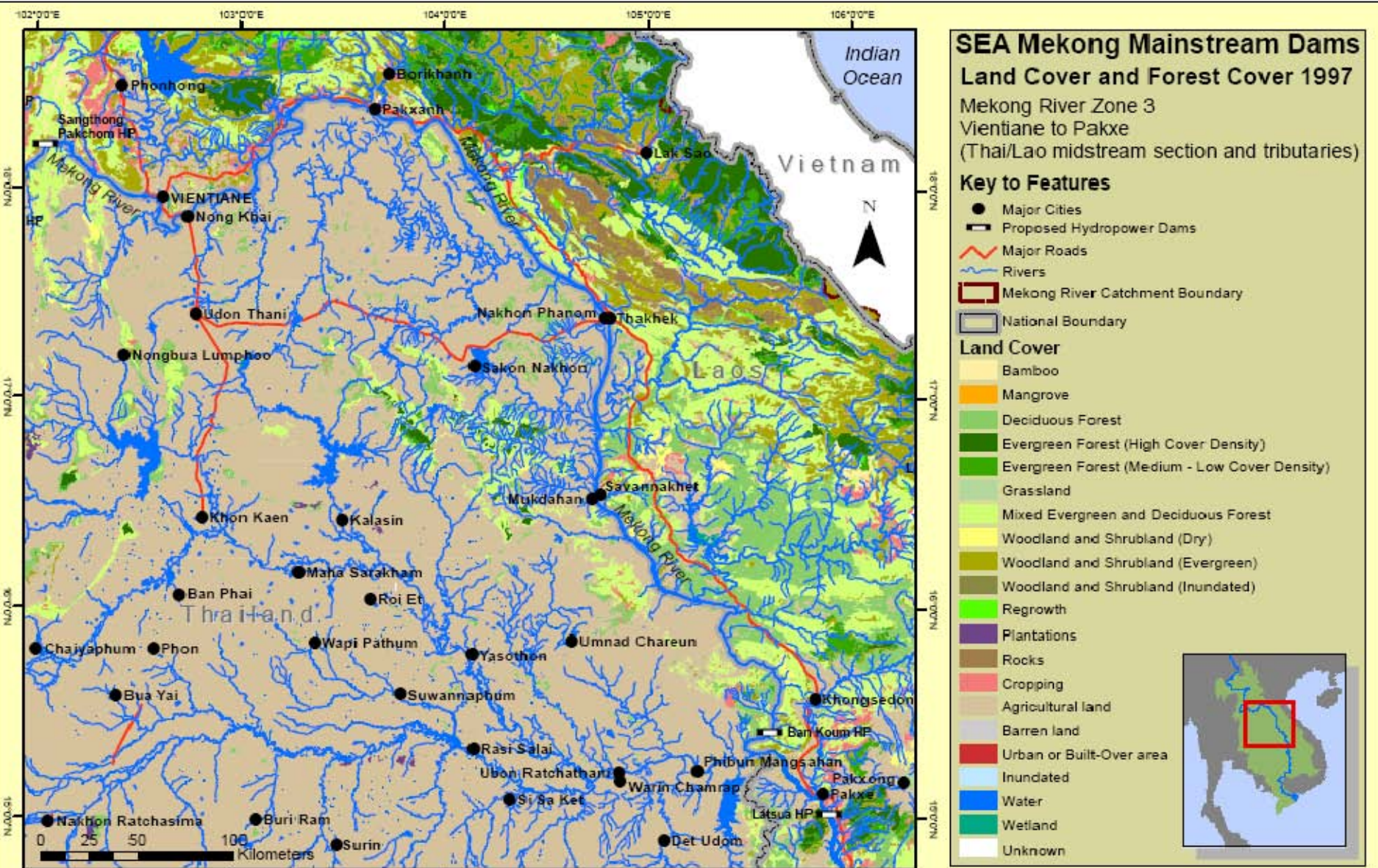
Continued gradual degradation of the river, loss of fish diversity and production, reduction in river weed

□ Terrestrial

- Population growth
- Increased access
- Pressures from logging,
- Hunting and wildlife trade

Pressure on terrestrial environment will be increased with continued degradation of natural habitats and biodiversity

Zone 3 – Thai/Lao midstream



Note: MRC Land Cover mapping only available for the Mekong River Catchment

Zone 3 – Key features

□ Aquatic

- Significant hydrological contributions from left bank tributaries, and Songkhram and Mun/Chi rivers
- Wide channel through deep cut banks, slower moving
- Few deep pools and rapids between Vientiane and Mukdahan, more afterwards in rocky valley to Pakse
- Water quality and ecological health generally good after Vientiane
- Fishing activities more significant

□ Terrestrial

- Flood plain areas receive fertile sediments and flood water
- River bank gardens feature regularly around communities
- Most natural vegetation has been removed, giving way to agriculture – more intense in Thailand
- Some original forest remains in protected areas south of Mukdahan – mainly Dry deciduous dipterocarp forest
- Protected Areas on both sides of Mekong above Mun confluence – Phou Xiang Thong (Lao) and Pha Taem and Kaeng Tana NPs (Thailand)

Zone 3 – Pressures, Trends, Predictions

□ Aquatic

- Hydrological influence of hydropower on tributaries and from China
 - Dry season flows at Savannakhet may increase by 135% - 1.2 m rise in water level; wet season peaks reduced by 20%
- Loss of habitat diversity, less exposure of sandbars and river banks in dry season
- Localised pollution around urban centres
- Increase in fishing pressure and use of illegal methods

General further degradation of the habitat and biodiversity

□ Terrestrial

- Increased access to protected areas, esp. on Laos side from new roads
- Reduction in area of river bank gardens
- Increased water availability in dry season due to raised flows from China – possibilities for irrigation

Potentially increased agriculture production from new irrigated areas.
Some degradation of the protected areas

Zone 4 – Complex braided river



SEA Mekong Mainstream Dams

Land Cover and Forest Cover 1997

Mekong River Zone 4
Pakxe to Kratie
(Wetlands)

Key to Features

- Major Cities
- ▭ Proposed Hydropower Dams
- Major Roads
- Rivers
- ▭ Mekong River Catchment Boundary
- ▭ National Boundary

Land Cover

- Bamboo
- Mangrove
- Deciduous Forest
- Evergreen Forest (High Cover Density)
- Evergreen Forest (Medium - Low Cover Density)
- Grassland
- Mixed Evergreen and Deciduous Forest
- Woodland and Shrubland (Dry)
- Woodland and Shrubland (Evergreen)
- Woodland and Shrubland (Inundated)
- Regrowth
- Plantations
- Rocks
- Cropping
- Agricultural land
- Barren land
- Urban or Built-Over area
- Inundated
- Water
- Wetland
- Unknown



Note: MRC Land Cover mapping only available for the Mekong River Catchment

Zone 4 – Key features

□ Aquatic

- Multiple braided channels, many islands, water falls, rapids, deep pools – diversity of habitats – largely unmodified
- 3S confluence at Stung Treng – contributes >20% of flow and 50% of sediment to Mekong
- Water quality good, ecological health good
- Very important for fish diversity and major migration route for fish
- Aquatic biodiversity extremely high
- Stung Treng Ramsar site – but little protection – possible isolated populations of Siamese crocodile
- Kratie to border has remaining population of dolphins, but concerns over high mortality rate

□ Terrestrial

- Some remnant forests away from the river – dry deciduous dipterocarp.
- Islands with riverine forest
- River bank gardens feature significantly
- Mostly rainfed agriculture, with some small-scale pumped irrigation from the river
- Area of high terrestrial biodiversity – 5 IBAs from Mun river to Siphandone to Stung Treng to Kratie, but little protection

Zone 4 – Pressures, Trends, Predictions

□ Aquatic

- Hydrological and sediment changes resulting from dams on tributaries become more important, especially on 3S rivers
- Increase in blooms of filamentous algae and invasion by *Mimosa pigra*
- Increased fishing pressure, leading to declines in fish catches
- Possible bioaccumulation of heavy metal and POPs
- Mortality of dolphins may lead to local extirpation within 10 yrs

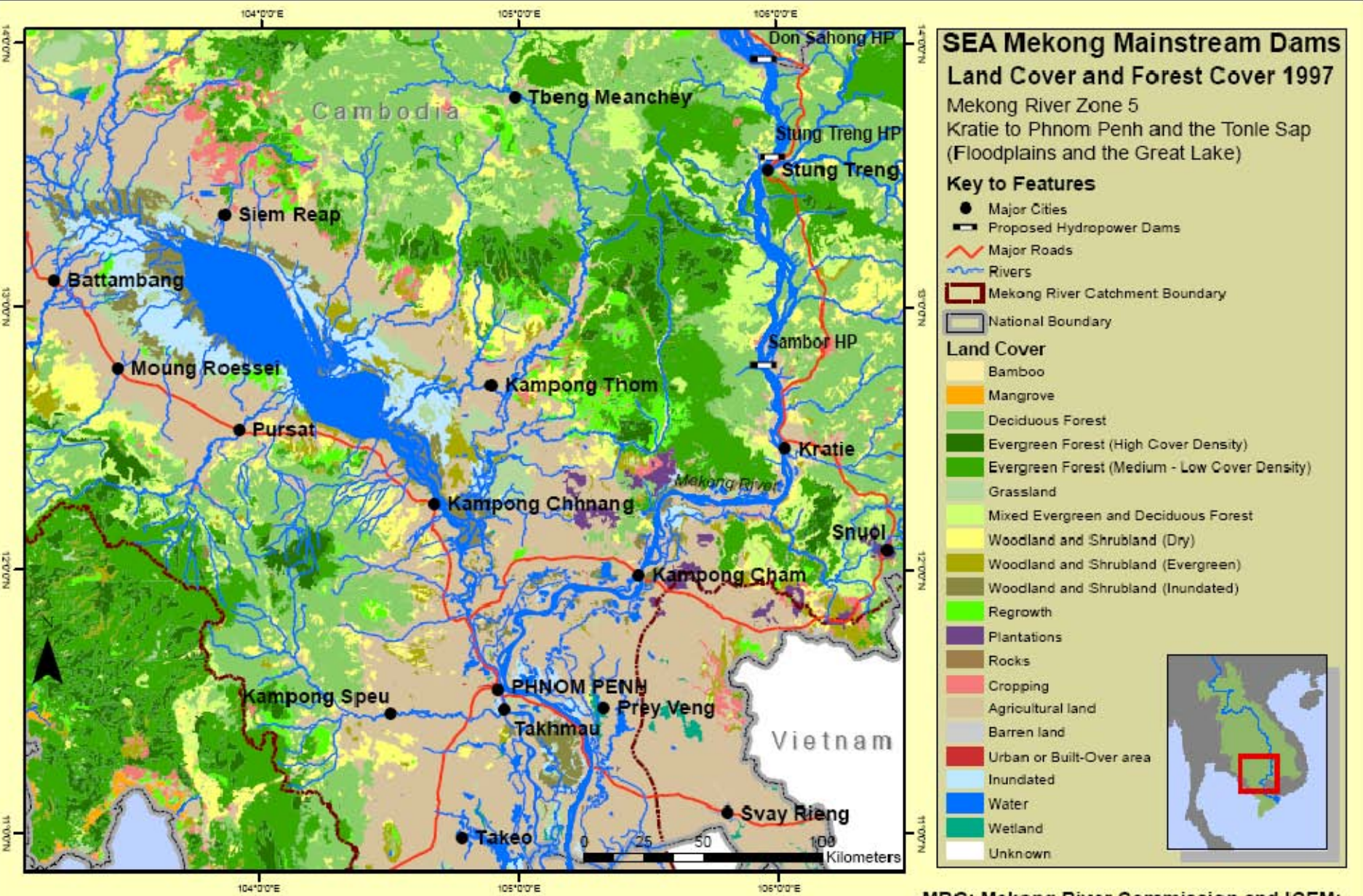
Indicators of environmental degradation are present – loss of habitat, loss of biodiversity, decline in fish production

□ Terrestrial

- Deforestation of riparian and dipterocarp forest for agriculture
- Land use change - Concessions for agroforestry
- Land use change – commercial and resort developments e.g. around Khone Falls
- Continued pressure on wildlife from hunting and wildlife trade

Rapid rate of development with much land use change, risk of loss of vegetation cover, loss of biodiversity and pollution

Zone 5 – Floodplains & the Great Lake



Note: MRC Land Cover mapping only available for the Mekong River Catchment

Zone 5 – Key features

□ Aquatic

- Hydrology changes at Kratie –
 - Very complex because of low gradient
 - Water levels, overbank storage and flooding
- Water quality considered to be good, except around Phnom Penh and in Tonle Sap river
- Ecosystem depends upon seasonal flooding and recession
- Fish biodiversity very high - 282 species
- High water snake biodiversity and harvest
- Fish migrations as water quality conditions in Tonle Sap worsen as water levels drop

□ Terrestrial

- Much of land converted to agriculture – rainfed and with irrigation
- Most of natural forested vegetation has gone, except for areas of flooded forest around Tonle Sap
- Protected areas/habitats – especially for birds
 - Flooded forest in Tonle Sap – Biosphere reserve, Prek Toal IBA (40,000 ha)
 - Boeung Chhmar Ramsar site (39,000 ha) – seasonally inundated grasslands
 - Stung Sen/Santuk/Baray IBA (109,000 ha)

Zone 5 – Pressures, Trends, Predictions

□ Aquatic

- Hydrological changes, tending to reduce the wet season flows and flooding
- Industrial and municipal wastes from urban areas and floating villages tending to increase pollution levels
- Agricultural run-off with increased nutrients and chemicals
- Overfishing and non-sustainable harvest of water snakes

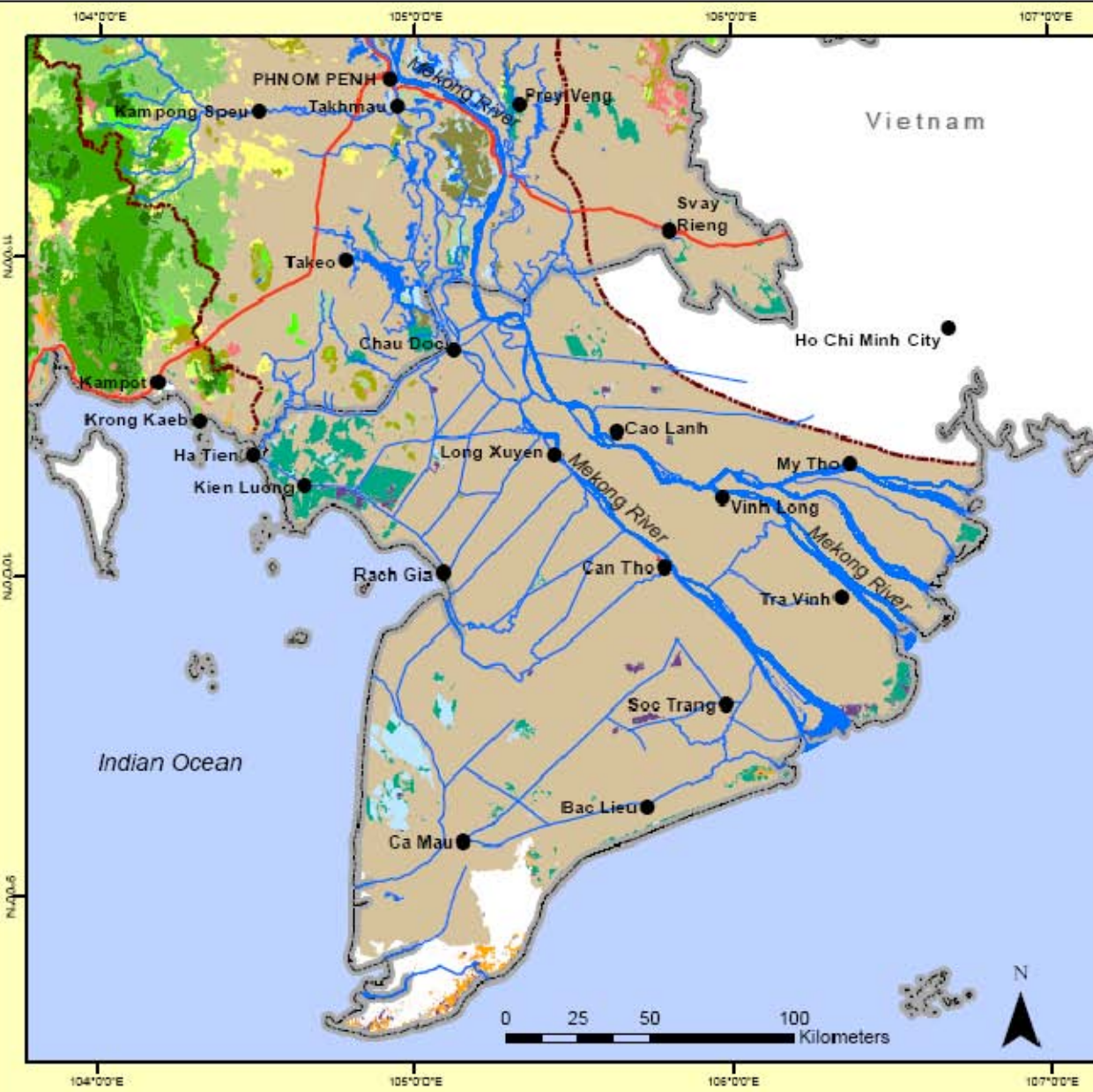
Increased pressure on the ecosystem from hydrology, extent of flooding, pollution, harvests exceed productivity base

□ Terrestrial

- Extent of flooding threatens survival flooded forests and seasonally inundated grasslands
- Intensification of agriculture

Pressure on land use and terrestrial natural resources from changing flooding patterns

Zone 6 – The Delta



SEA Mekong Mainstream Dams Land Cover and Forest Cover 1997

Mekong River Zone 6
Phnom Penh to Mekong Delta
(Mekong delta, tidal zone)

Key to Features

- Major Cities
- ▭ Proposed Hydropower Reservoirs
- Major Roads
- Rivers
- ▭ Mekong River Catchment Boundary
- ▭ National Boundary

Land Cover

- Bamboo
- Mangrove
- Deciduous Forest
- Evergreen Forest (High Cover Density)
- Evergreen Forest (Medium - Low Cover Density)
- Grassland
- Mixed Evergreen and Deciduous Forest
- Woodland and Shrubland (Dry)
- Woodland and Shrubland (Evergreen)
- Woodland and Shrubland (Inundated)
- Regrowth
- Plantations
- Rocks
- Cropping
- Agricultural land
- Barren land
- Urban or Built-Over area
- Inundated
- Water
- Wetland
- Unknown

Zone 6 – Key features

□ Aquatic

- Floodplains and delta below Phnom Penh – 35 – 50% of area is flooded annually during wet season
- Increasing tidal influence and saltwater intrusion
- River has been significantly modified, canals, embankments
- Water quality generally moderate to poor,
 - some good isolated sites, e.g. Plain of Reeds/Tram Chim
 - Evidence of toxicity due to heavy metals and dioxins
 - Mekong water quality tends to be worse than Bassac
- Fish diversity highest (481 species)
- Aquaculture very intensive and productive - Floating cages, especially for catfish, Shrimp farms along the coast

□ Terrestrial

- Conversion of most of natural wetlands to intensive agriculture, very productive (3 crops per year)
- Some remnants of Plain of Reeds – Tram Chim NP and Lang Sen with natural *Melaleuca* forests
- High biodiversity areas remain – 3 IBAs in Cambodia and five in Vietnam associated with Mekong
- Coastal mangrove areas

Zone 6 – Pressures, Trends, Predictions

□ Aquatic

- Pollution from urban areas,
 - Especially Phnom Penh, Chau Doc
 - Boat traffic – oils and grease
 - Floating fish farms – organic matter, chemicals
 - Agricultural run-off – nutrients and agrochemicals
- Changes in infrastructure – roads, coastal flood embankments alter movement of flood water
- Large irrigation schemes proposed in Cambodia
- Loss of mangrove and coastal areas to shrimp farms

Increasing population pressure adds to pollution load, changing hydrology alters delta dynamics

□ Terrestrial

- Changes in hydrology – increased dry season flows may alter effects of saline intrusion
- Changes in sediment reaching delta –
 - Delta no longer continues to grow
 - Loss of nutrients and reduced fertility of the flood plains, more intensive use of fertilisers
- Climate change and sea level rise, may lead to loss of land area
- Pressure to convert remaining natural wetland areas to agricultural land, with loss of biodiversity

Agricultural production affected by changing conditions – saline intrusion, erosion of the delta

Other ecosystem issues

- Longitudinal changes – water quality and ecological health assessments
- IBFM assessments of the zones
- High Biodiversity and Protected Areas
- Fish species diversity
- Assessing productivity of the river and its wetlands
- Ecosystem services of the zones

Longitudinal trends – Water quality

- Temperature of the water tends to increase from upstream to downstream stations,
 - ▣ average values for Chiang Saen 23.4°C to 26.9 °C at Pakse
- Total Suspended Solids
 - ▣ increases down to Vientiane, (average 400 mg/l).
 - ▣ Downstream of Vientiane TSS drops to 200 mg/l with dilution from tributaries.
 - ▣ TSS from 3S rivers raises the overall TSS levels (over 50% of the Mekong sediments from the Central Highlands).
- Total phosphorus content tends to increase downstream
 - ▣ gradual increase in total phosphorus over the past decade.
- The nitrate concentrations do not appear to follow the same trend downstream,
 - ▣ tendency for nitrate levels to be increasing slightly with time.
- The COD and Dissolved Oxygen show a longitudinal trend
 - ▣ with increasing COD and
 - ▣ decreasing Dissolved Oxygen with passage downstream,
 - pollution sources entering the river,
 - lower aeration capacity in the downstream slower moving river

Longitudinal trends – Water quality

- Mineralisation tends to decrease from Chiang Saen to Pakse, falling from average values of 2402 to 1873 $\mu\text{S}/\text{cm}$, caused by the dilution effect.
 - High mineralized water from the Mun/Chi basin due to natural salt deposits in the Khorat plateau and irrigated agriculture are diluted by the time Pakse is reached.
 - The concentration of ions in the water tends to decline with passage downstream
- Heavy metal concentrations and toxicity of sediments has shown concern
 - **arsenic** and **mercury** which have reached TEC (Threshold Effect Concentration) levels at some stations, including high levels in some tributaries.
- Multi-criteria analysis of several different parameters, including heavy metals, pH, PCDD/PCDF (Dioxins and furans) and toxicity bioassays showed high values at
 - Chinese/Lao border,
 - Prek Kdam and Neak Leang in Cambodia and
 - at Chau Doc in the Delta.
 - Recognized areas in or downstream of heavily polluted areas.
- The importance of the Mekong River system in diluting pollution recognized.

MRC Water quality assessments

Zone	Locality	Organic Matter	Nitrogenous matter	Nitrates	Phosphorous matter	Mineralisation	Acidification
Zone 1	Chiang Saen	Green	Green	Green	Green	Yellow	Blue
Zone 2	Louangprabang	Green	Blue	Green	Green	Green	Green
Zone 3	Vientiane	Yellow	Green	Green	Green	Yellow	Yellow
	Nakhon Phanom	Yellow	Green	Green	Green	Green	Yellow
	Khong Chiam	Yellow	Green	Green	Green	Green	Yellow
Zone 4	Pakse	Green	Green	Green	Blue	Green	Yellow

Blue = very good, Green = good, Yellow = fair, Red = bad)

MRC Ecological health assessment

Excellent	A
Good	B
Moderate	C
Poor	D

Ecological Health from Card	Sample site	2004	2005	2006	2007	2008
Zone 1	LXT	C				D
	TCS					B
Zone 2	LPB	A	A			B
	LVT	C			B	C
Zone 3	TSM				C	A
	TNP					C
Zone 4	LDN				A	A
	CMR		B	A	B	B
	CKT	A		A		A
Zone 5	CSK			C		B
Zone 6 Bassac	CKL			B		C
	VKB					B
	VDP					C
	VLX			C		B
	VCT			C		B
Zone 6 Mekong	VTP					C
	VTT					C
	VCL			C		C
	VVL					C

IBFM assessments - 2005

Discipline	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Geomorphology (channel form)	B+	B+	A	B+	C
Water Quality (chemical only)	B	B	B	B	B-E
Vegetation - In Channel/River bank		C*	B*	D*	C-D
	C	D [#]	C [#]	B-E [#]	
Invertebrates	B	B	B+	B-	C
Fish	C	C	C	C	D
Water Birds	C	C	D+	D+	D+
Frogs/Reptiles	C	C	D+	D+	D+
	B-	B-	C+	C+	C+

A Excellent. *Unmodified, natural.* Close to the probable condition in the absence of human intervention in the catchment.

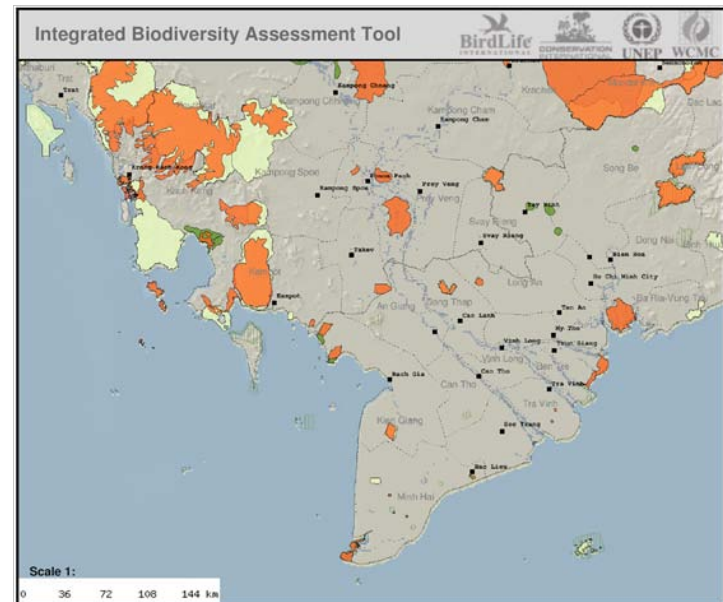
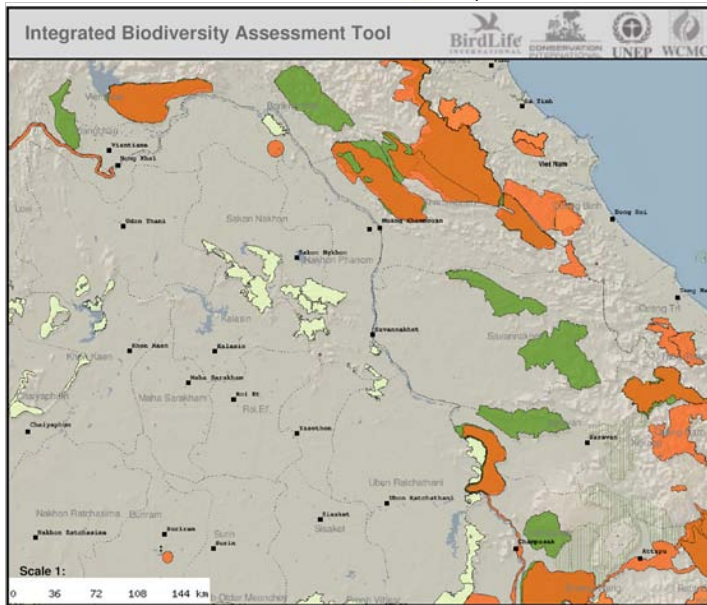
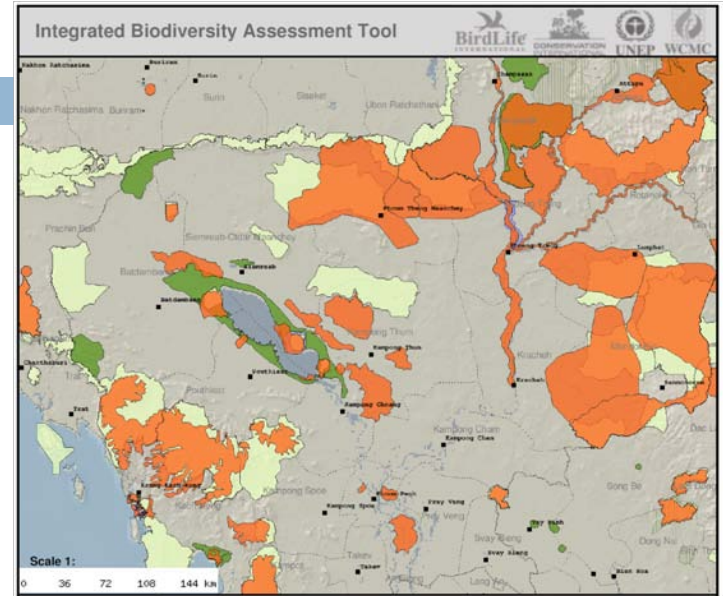
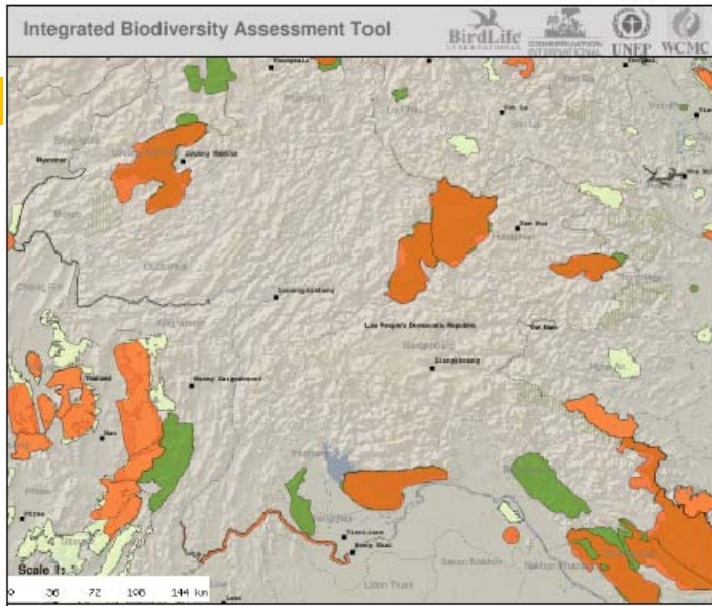
B Good. *Largely natural.* Modified from the original natural condition but not sufficiently to have produced measurable change in the nature and functioning of the ecosystem.

C Satisfactory. *Moderately modified.* Changed from the original condition sufficiently to have measurably altered the nature and functioning of the ecosystem, although the difference may not be obvious to a casual observer. Efforts should be made to ensure that no further deterioration occurs.

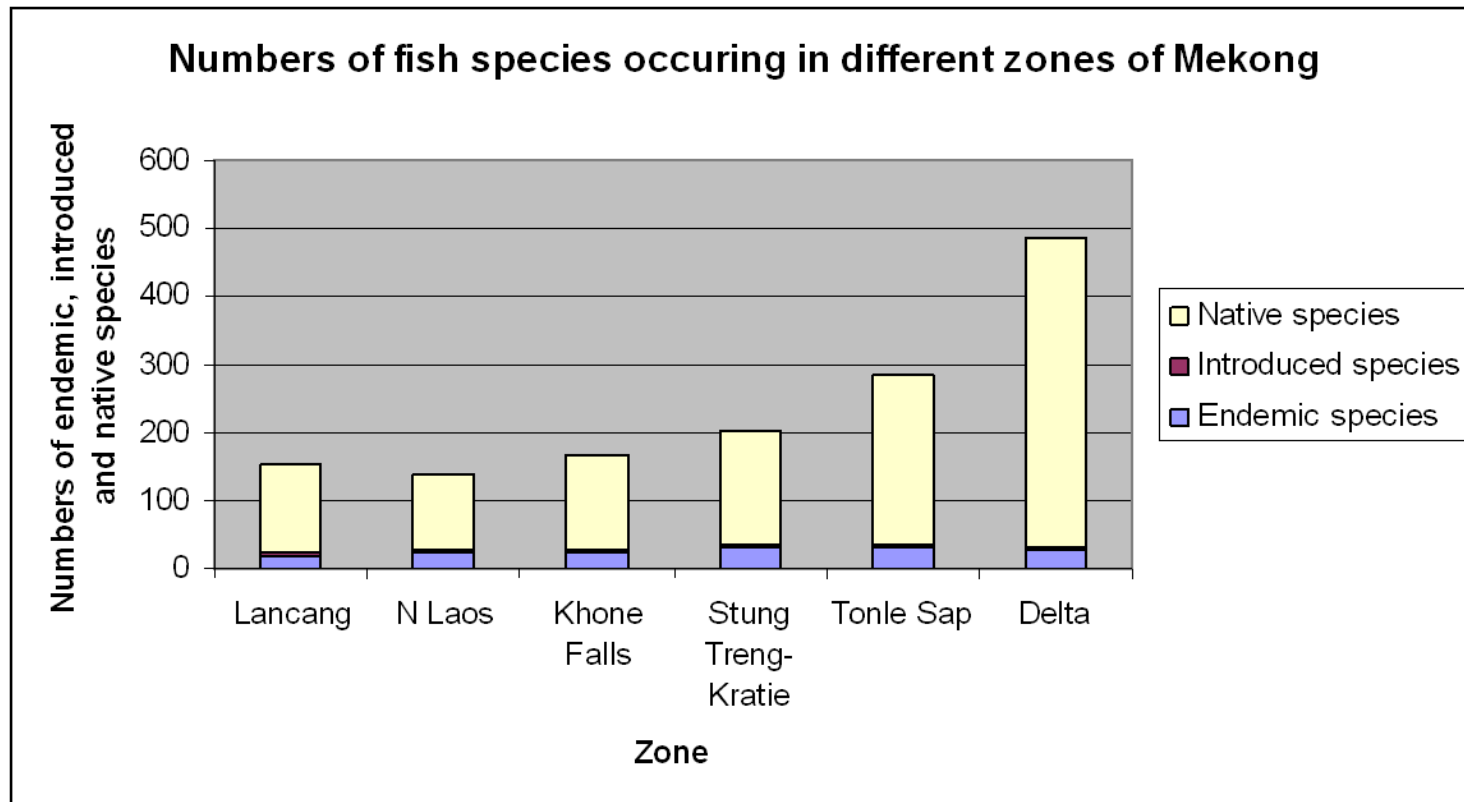
D Room for Improvement. *Largely modified.* Sufficiently altered from natural for obvious impacts on ecosystem nature and functioning to have occurred. Management agencies should be developing strategies to improve the conditions.

E Improvement Necessary. *Seriously to critically modified.* Important aspects of the original nature and functioning of the ecosystem are no longer present. The area is heavily impacted by human interventions.

High Biodiversity/Protected areas



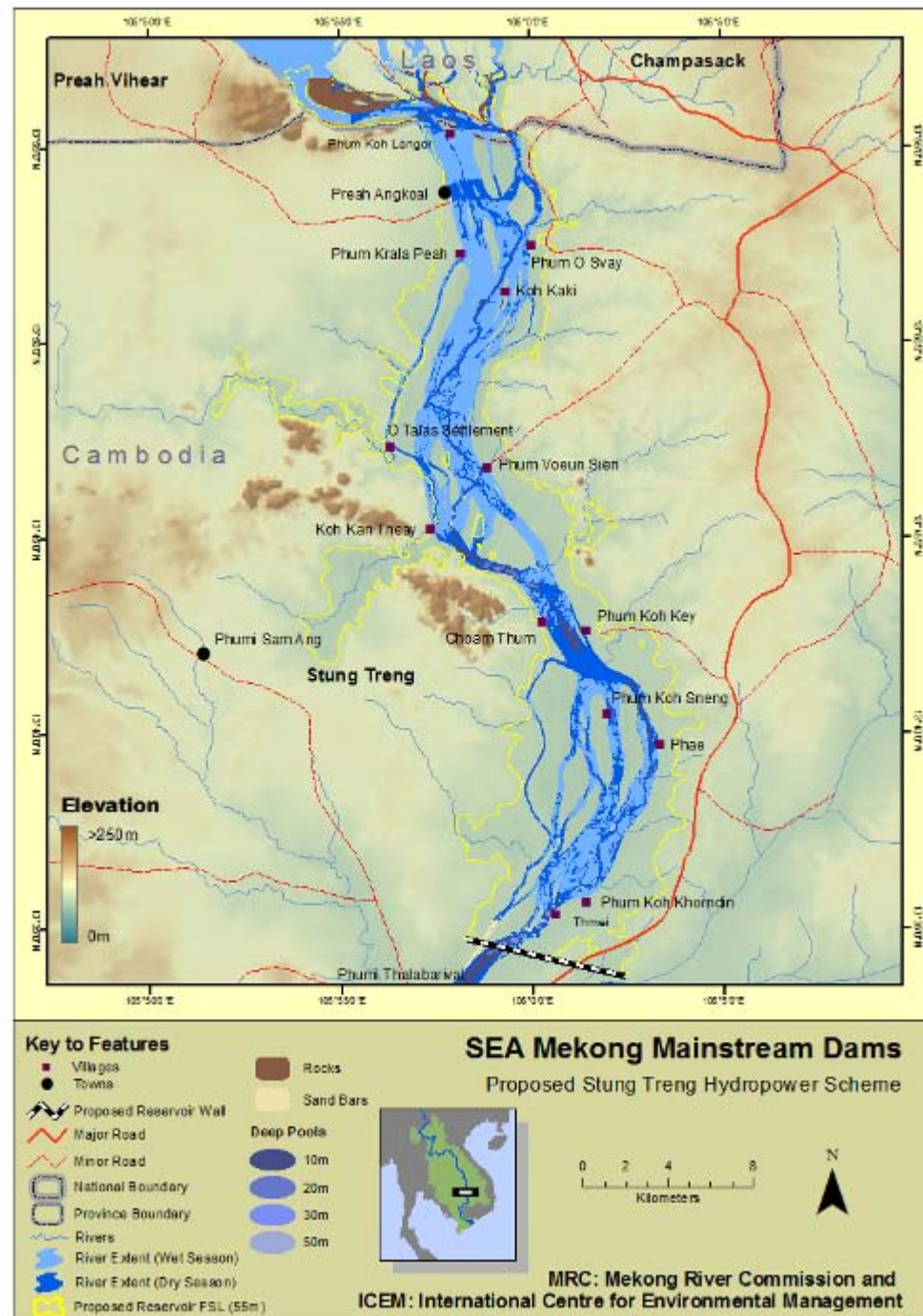
Longitudinal changes – Fish species diversity



Example – Stung Treng

- Dry season channel – 48.5 sq km
- Wet season channel – 116.3 sq km
- Exposed channel – 67.8 sq km
- Deep pools – 85 over 10 m deep,
- Area of deep pools – 5.94 sq km
- Area of rocks and rapids – 3.25 sq km
- Area of plain sand bars – 2.1 sq km
- Diversity of habitat very high
- Biodiversity amongst highest in Mekong

- Primary productivity of exposed channel = 41,000 – 95,000 tC/yr
- If covered by water all year round productivity = 20,000 – 34,000 tC/yr
- Lost productivity = 20,000 – 61,000 tC/yr



Changes in ecosystem services

Ecosystem services	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5a		Zone 5b		Zone 6	
	Present	Future	Present	Future	Present	Future	Present	Future	Present	Future	Present	Future	Present	Future
Provisioning														
Food production of fish, wild game, fruits, and grains	Low	↓	Medium	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Fresh water storage and retention of water for domestic, industrial, and agricultural use	Low	↑	Low	↑	Medium	↑	High	↑	High	↑	High	↑	High	↓
Fiber and fuel production of logs, fuelwood, peat, fodder	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Biochemical extraction of medicines and other materials from biota	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Genetic materials genes for resistance to plant pathogens, ornamental species, and so on	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→	Low	→
Regulating														
Climate regulation source of and sink for greenhouse gases; influence local and regional temperature, precipitation, and other climatic processes	High	→	High	→	High	→	High	→	High	→	High	→	High	→
Water regulation (hydrological flows) groundwater recharge/discharge,	High	↓	High	↑	High	↑	High	↑	High	↑	High	↑	High	↑
Water purification and waste treatment retention, recovery, and removal of excess nutrients and other pollutants	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Erosion protection and retention of soils and sediments	High	↓	High	↓	High	→	High	→	High	→	High	→	High	↓
Natural hazard regulation, flood control, storm protection	High	↑	High	↑	High	↑	High	↑	High	↑	High	↑	High	↑
Ecosystem services														
Cultural														
Spiritual and inspirational source of inspiration; many religions attach spiritual and religious values to aspects of wetland ecosystems	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Recreational opportunities for recreational activities	Low	→	High	→	Medium	→	High	→	Medium	→	High	→	Medium	→
Aesthetic - appreciation of natural features	High	→	High	→	High	→	High	→	Medium	→	High	→	Medium	→
Educational opportunities for formal and informal education and training	Low	→	Medium	→	Low	→	Medium	→	Low	→	Medium	→	Low	→
Supporting														
Biodiversity - habitats for resident or transient species	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓	High	↓
Fish spawning and nursery areas	Medium	↓	Medium	↓	Medium	↓	High	↓	High	↓	High	↓	Medium	↓
Soil formation sediment retention and accumulation of organic matter	High	↓	Medium	↓	Medium	↓	High	↓	Medium	↓	Medium	↓	High	↓
Nutrient cycling storage, recycling, processing, and acquisition of nutrients	High	↓	Medium	↓	Medium	↓	High	↓	Medium	↓	Medium	↓	High	↓
Pollination habitat for pollinators	Low	→	Low	→	Low	→	Medium	→	Medium	→	Medium	→	Low	→