Impact Indicators of key questions

Aquatic systems
- Productivity of aquatic habitats in the Mekong
- Biodiversity of aquatic habitats in the Mekong
- The capacity of the Mekong’s ecosystem regulating services – purification and water quality
- Value of Mekong River’s cultural ecosystem services – inspiration, recreation and tourism

Terrestrial systems and agriculture
- Habitat loss and degradation, forest cover and protected areas
- Changes to patterns of agriculture
- Value of paddy agriculture in each zone
- Changes to agricultural and land use patterns along the mainstream especially river bank gardens
Summary of existing situation and trends without mainstream dams - *Aquatic*

- **Habitat Diversity** - Relatively natural at the moment
  - High diversity and productivity of aquatic habitats - rapids, deep pools, sandbars - dependent upon flood pulse

- **Biodiversity** Very high
  - Development of upstream dams in China and tributaries alter the hydrology and patterns of sediment discharge,
  - River morphology and habitats beginning to change and will continue.

- **Water quality** - River is relatively clean and in good ecosystem health at present,
  - Increasing point and dispersed sources of pollution
  - Mitigated by the large dilution effect of the river flow.
  - Existing signs of decreasing water quality
  - Water quality expected to decrease in the future with growth of population.

- **Cultural ecosystem services** - immense cultural value for Mekong communities and tourism
  - Inspirational and religious values
  - Festivals and Recreation values
  - Tourist attraction of a large, dramatic, near-natural river, expected to continue to increase
  - Feature of the GMS tourism strategy
Summary of existing situation and trends

without mainstream dams - Terrestrial

- **Forest cover**: extensive forest cover in Zones 1 and 2, decreasing markedly as the river passes through zones 3, 4, 5 and 6
  - But riparian forests generally degraded
- **Agricultural land use**: progressively higher percentage, especially in NE Thailand, southern Laos, and below Kratie in Zone 5 and in the Delta.
  - Government policies - intensification of agriculture, with increased irrigation in Laos and Cambodia.
  - In NE Thailand water for further irrigation is a limiting factor,
  - Availability of suitable land is a limiting factor in the Vietnam Delta.
- **Terrestrial biodiversity**: The terrestrial ecosystems recognized as globally important for biodiversity
  - Of 2600 km of the Lower Mekong, lengths of over 1000 km are considered as Key Biodiversity Areas,
  - BUT only about 100 km of the river actually lies within a nationally protected area.
- **River bank gardens** recognized as an important part of riparian livelihoods,
  - RBG contribution in each zone ranges from 10 - 60 million US per year.
Critical Aspects

DAM CONSTRUCTION – 2015 to 2030

- **Increased release of sediment**
  - Construction activities, earth moving, tunneling, road construction along the river bank

- **Increased risk of pollution** with consequent kills of fish and other aquatic animals.
  - Construction camps, stores and construction activities, including organic waste from sewage,
  - Spillage of oil and fuel,
  - Accidental release of toxic construction materials,

- **Changes in flow**
  - Diversions past coffer dams and tunnels,
  - During the filling of the reservoirs,

- **Changes in water quality** as a result of breakdown of vegetation in the reservoirs

- **Blockage of key sections of the river for fish movement and migration,**
  - Physical barriers, such as temporary and permanent dams,
  - Chemical barriers from declining water quality

- **Blockage of key sections of the river for navigation** – especially in the reaches between Vientiane and Chiang Saen
Critical aspects of

**DAM OPERATION – 2020 onwards**

- **Seasonal changes in flow:**
  - Very little active storage capacity. The total storage capacity of mainstream dams is something over 2,553 m$^3$.m
  - The average yearly flow down the Mekong is 14,150 cu.m/ sec. Flow into the Delta delayed by about 2 days.
  - First flushes wet season flushes at Kratie delayed by up to 10 days.

- **Landscape,** reservoirs appear throughout the year like the river at the height of the flood season, with the channel full.
  - Velocity through the reservoirs same as at present in the wet season.
  - But much slower in the dry season.
Critical aspects of DAM OPERATION – 2020 onwards

- **Daily changes in flow:**
  - Operational rules not yet clear; peaking vs continuous flow
  - Dams with little peaking - Little change in daily flows
    - e.g Pak Chom, Ban Koum and Latsua -
  - In peaking mode, downstream flows increased by several times during generation.
  - Reservoir levels may change by up to 2 m during the day
    - e.g Pak Beng, Xayaburi and Stung Treng.
  - More significant during dry season,

- **Sediment movement and trapping:** Run-of-river dams generally trap less sediment than storage dams;
  - Sediment will tend to build up at top of reservoirs in the dry season
  - Washed down into the main body of the reservoir with the flood waters.
  - Deep pools at the top ends of the reservoirs operate as before,
  - Further down the reservoirs the deep pools will fill up with sediment.
Critical aspects of dam operation – 2020 onwards

- **Scour of bed** Immediately downstream of the dams
  - Scour will extend for several kilometers downstream as the channel realigns itself.
  - Deep pools downstream of the dams will continue to operate as they have, but with less sediment passing through them.

- **Delays to start and duration of the transition periods between dry and wet seasons**
  - With the mainstream dams delays are more extreme.
  - In Zone 2 - one month delay in transition from dry to wet
  - In Zones 3 and 4, onset is less delayed by about 2 weeks
  - Overall in the delta delay of about 3 weeks.
Critical aspects of dam operation – 2020 onwards

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  - Overall in the delta delay of about 3 weeks.

- **Ecological implication** is complex.
  - Hydrological changes provide triggers for spawning
  - Close linkage between breeding and availability of food,
  - If the timing is disturbed, breeding success may be very limited
  - Possible crash in populations of affected species.
### Mekong Productivity

**Changes in aquatic habitats.**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Length of river</th>
<th>Converted to reservoir</th>
<th>% Area of Habitats inundated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km</td>
<td>%</td>
<td>Deep pools</td>
</tr>
<tr>
<td>1</td>
<td>2120</td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>795</td>
<td>87</td>
<td>70</td>
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<tr>
<td>3</td>
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<td>330</td>
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<tr>
<td>5</td>
<td>364</td>
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<td>0</td>
</tr>
<tr>
<td>6</td>
<td>225</td>
<td>No change</td>
<td>0</td>
</tr>
<tr>
<td>Overall (LMB)</td>
<td>2427</td>
<td>41</td>
<td>48</td>
</tr>
</tbody>
</table>

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ICEM | MRC SEA of mainstream hydropower | Impacts Assessment Workshop 19-20 May 2010
Impacts on net primary productivity

- Primary productivity due to dry season exposed river channel – 0.6 – 1.4 kg/m²/yr

<table>
<thead>
<tr>
<th>Zone</th>
<th>Area of wet season channel (sq km)</th>
<th>Area of dry season channel (sq km)</th>
<th>Area exposed in dry season (sq km)</th>
<th>% lost due to inundation dry season channel</th>
<th>% loss in NPP (low)</th>
<th>% loss in NPP (high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2513</td>
<td>1757</td>
<td>755</td>
<td>48</td>
<td>12</td>
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<tr>
<td>2</td>
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<td>238</td>
<td>221</td>
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<td>27</td>
<td>53</td>
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<tr>
<td>3</td>
<td>697</td>
<td>576</td>
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<td>42</td>
<td>6</td>
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<tr>
<td>4</td>
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<td>530</td>
<td>276</td>
<td>58</td>
<td>15</td>
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<td>5</td>
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<td>413</td>
<td>137</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Overall (LMB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ICEM | MRC SEA of mainstream hydropower | Impacts Assessment Workshop 19-20 May 2010
Reservoirs lose habitat diversity –
- rapids, riffles and sand bars lost
- deep pools filled in or less dynamic.

Downstream of the dams – habitats will change because:
- Variable and unpredictable flows
- Trapping of sediment upstream reduces sandbars downstream
- Deep pools may still provide a dry season refuge.

Loss of key spawning and feeding areas within the Mekong mainstream
- Riffles, sandbars and in-channel wetlands

Barriers to fish movement and migration

Isolation and loss of connectivity of river sections.

Reservoirs tend to be less biodiverse than rivers,

Construction activities change sediments, water quality and flows
- drive fish away,
- smother important downstream habitats, or
- cause mortality of aquatic organisms.
Even in narrow reservoirs, large areas of seasonally exposed in channel wetlands will be inundated

Xayaburi Dam
Changing Aquatic Biodiversity in the zones

- **Zone 1:**
  - Affected by changing flow and sediment from Chinese dams,
  - Isolation from the rest of the Lower Mekong. No long distance migrations of fish.

- **Zone 2:** high biodiversity impacts.
  - Zone cut up into isolated segments,
  - Few major tributaries entering the Mekong
  - Species diversity will fall in most of these segments, since spawning grounds will be inundated or inaccessible.
  - The major in-channel wetlands from Pak Chom to Pak Lay are important breeding areas and refuges
  - Species richness lost in both Zones 2 and 3.

- **Zone 3:**
  - Ban Koum is located at an area of high habitat diversity,
  - Ban Koum reservoir could have an impact upon the species diversity of the zone.
• Pak Chom in-channel wetlands are important spawning grounds for fish in Zones 2 and 3

• Also important for water birds
Diversity of wetland habitats – Pak Chom

Dry season

Wet season
Changing Aquatic Biodiversity in the zones

Zone 4:
- Very high habitat diversity,
- Richest biodiversity of the Mekong mainstream
- Upper part of Siphandone may be adversely affected by flows from Latsua,
- Don Sahong dams only channel used by migrating fish throughout year
- Reduced diversity and productivity of fish above and below Khone Falls
- Cambodian dams flood larger areas,
  - reduce diversity of habitats with loss of many fish, reptile and mammal species.
- Even with fish passages, prevent the large fish migrations in the zone.

Zone 5 and 6:
- No dams - no major changes of habitat.
- Reduced access to upstream areas for fish migrations by Sambor dam
- Significant declines in migratory species in Tonle Sap and the Delta
Changes in fisheries biodiversity

- Difficult to predict exact numbers of species lost
- Few species would become extinct, but would have reduced range
- Numbers of fish species in reservoirs would decrease, perhaps by 30%, because:
  - No suitable spawning grounds in reservoir
  - Few tributaries available and may not be suitable
  - No long distance migratory (white) fish, only resident or short distance migrants (grey and black species)
Charismatic and endangered species

- **Irrawaddy dolphin** - Zone 4,
  - Construction - massive disturbance
  - Operation
    - Separation of family groups
    - Changes in availability of fish as their main food source
  - Final threat to extinction of sub-population.

- **Giant Mekong Catfish**
  - Migrates out of Tonle Sap and into the Mekong mainstream for spawning
  - Migrates past Khone Falls (Hou Sahong)
  - Found near at top end of Zone 2 where spawning takes place.
  - Mainstream dams prevent long distance migration
  - Extinct in the wild

- **Siamese crocodile**
  - Stung Treng Ramsar site - only remaining location on mainstream
  - Construction and inundation of the Stung Treng dam - local loss
Charismatic and endangered species

- **Siamese crocodile**
  - Stung Treng Ramsar site - only remaining location on mainstream
  - Construction and inundation of the Stung Treng dam - local loss

- **Turtles**
  - Found throughout the Mekong, although increasingly rare and threatened
  - Zone 4 is globally significant for Cantor’s Giant Softshell Turtle
  - All turtles are threatened by loss of sandbars for breeding habitat

- **Otters**
  - Hairy-nosed otter, Smooth coated otter, Oriental small-clawed otter found in the Tonle Sap system and Zone 4.
  - Throughout river where there are diverse aquatic habitats
  - Dams limit habitat diversity - an additional threat to otters

- **Water birds**
  - Loss of habitat for breeding – sandbars, flooded forests
  - Some large water birds increasingly endangered
Inundation of Stung Treng Ramsar site – loss of rare and endangered species

- Dolphins
- Siamese crocodile
- Turtles
- Otters
- Large water birds, especially those using sand bars, and flooded forests
Mekong ecosystem regulating services – Purification and Water quality

**Construction phase**

- Increase in sediment as a result of rock blasting and earthmoving.
  - Increased sediment may deposit & smother gravel beds and riffles important for fish spawning.

- Increase in organic matter from wastes from construction camps.
  - Local issue significant at times of low flow.
  - Controlled by adequate waste treatment and disposal by contractors.

- Accidental spillage of construction materials, concrete, toxic compounds and fuel and oils.
  - Discharge of used engine oils from construction vehicle maintenance into water courses

- Increase in organic matter/oxygen demand during the impoundment
  - Limited in the case of mainstream dams because of small land inundation.
  - Cambodian dams flood larger areas of land and may need to clear vegetation

**Operation Phase**

- Run-of river dams rarely cause water quality issues
- Except during sediment flushing - high sediment releases
- May make water pollution conditions resulting from increased navigation worse
- With climate change, dams may contribute to falling water quality
Cultural ecosystem services –
Inspiration, Recreation and Tourism

- Spiritual and inspirational
  - Naga myths linked to specific locations e.g. deep pools and rapids
  - If the dams are built, many sites will experience changes and lose unique character.
  - Naga myths will decline.

- Festivals - loss of relevance
  - Giant Mekong catfish festival in Chiang Khong dependent upon the presence of the endangered fish.
  - The fireball festival near the confluence with the Nam Ngum river may be affected by the changes in the seasonal flow patterns.
  - Boat racing festivals all along the Mekong celebrate the end of the flood season - communities along banks of new reservoirs experience little seasonal change.
Cultural ecosystem services –
Inspiration, Recreation and Tourism

- **Recreation depends upon landscape value**
  - River channel, banks, sandbars and exposed rocks used for recreation
  - Lower sediment and higher dry season flows - less free recreational space loss of value.
  - The mainstream dams will contribute in this decline.

- **Mekong Tourism will change**
  - Tourism value of the river - Each zone has unique features
    - Irrawaddy dolphin and landscape features below Khone Falls,
    - attraction of “wild” river, passing through magnificent landscapes
  - Construction of the mainstream dams will impact upon tourism attractiveness,
    - Boat tourism between Louangprabang and Chiang Khong disrupted for 10 years.
  - With navigation locks past dams in Zone 2, tourism experience very different.
  - Don Sahong and Thakho HPP around Khone Falls will have impacts on tourism
  - Loss of Dolphins will reduce Cambodian and Lao tourism attractions

- **Predictions**
  - Boom in “last chance to see” type tourism on the Mekong over next few years
  - At least a decade of disruption during construction.
  - Once dams built, tours will adapt to take advantage of dams and reservoirs,
  - More attractive to domestic tourists - loss of higher value tourism
Endangered species?

Giant catfish festival at Chiang Khong

Tourists watching dolphins at Kampi, Cambodia
Tourism boats disrupted during construction

Between Louangprabang and Houay Xai
Impacting Key Biodiversity Areas

- **Direct Impacts** - Key Biodiversity Areas cover 1,100 km of Mekong River
  - About 860 km - about 80% directly affected by reservoirs,
  - Change terrestrial habitat of the flora and fauna using these areas,
  - Protected areas affected:
    - Ban Koum HPP changes landscape of Pha Taem and Phou Xiang Thong NPA
    - Stung Treng Ramsar site may have to be de-designated

- **Indirect Impacts**
  - In Tonle Sap, with mainstream dams - an additional 2% in dry season area flooded
  - At end of wet season, the surface area likely to increase dramatically - an additional 7% due to mainstream dams
  - Ramsar sites and flooded forests around Tonle Sap will be “squeezed”
    - No expansion on land side because of existing agriculture,
    - On water side, forests no longer viable because they will be inundated for longer.

**Note:** Key Biodiversity Areas (KBAs) are areas that have been recognised internationally as important for biodiversity. They may or may not be nationally protected.
Landscape changes in protected areas

Ban Koum – Permanent bank-full reservoir

Pha Taem and Phou Xiang Tong Protected areas
Land use changes due to 12 Mainstream HPPs

- Create over 151,000 ha of reservoir,
  - 29% lie in Zone 2,
  - 16% in Zone 3
  - 55% lie in Zone 4.

- 92,000 ha of existing river channel will be inundated (61% of the total reservoir area)
  - 59% in Zone 2,
  - 84% in Zone 3
  - 55% in Zone 4

- Outside of the river channel,
  - 23,000 ha of forest land (mostly degraded forest) will be inundated
  - 13,500 ha of agricultural land.
  - Only a total of 829 ha of irrigated land will be inundated.
Irrigation potential associated with Mekong mainstream dams

- Pak Chom
  - 11 irrigation schemes, covering a total of 2,706 ha
  - 1 scheme (217 ha) in Laos
  - 10 schemes (2,489 ha) in Thailand

- Ban Koum plans for irrigation of 7,870 ha
  - 8 schemes are in Laos and 14 in Thailand.

- Latsua –
  - Irrigation plan for 7,300 ha in Laos
  - 3 crops per year
Losses and gains in irrigation

- Value of lost annual productivity of agricultural land due to dams:
  - 1.15 million USD in Zone 2,
  - 1.17 Million USD in Zone 3
  - 1.77 million USD in Zone 4.

- With proposed irrigation schemes, the annual value of the increased productivity is:
  - 1.89 million USD per year in Zone 2 and
  - 13.65 million USD per year in Zone 3.
- No figures are available for irrigation potential from the Cambodian dams.

- Even with just three dams being used for irrigation, gains outweigh losses in each zone.
Transmission lines and Access roads

- Using estimates for 7 dams, over 1,500 km of transmission line will be required to connect to regional power grids
- With 70m wide corridor, this covers over 10,800 ha
  - 7,886 ha of forest land and
  - 2,286 ha of cultivated land would be affected
- Access roads will be mainly local, since existing road network passes close by
- Roads near some dam sites have already been upgraded
Regional Power grid and mainstream dams
Land use changes in context of 50 km corridor along Mekong

- **Total area** - 1,371 sq km inundated by the reservoirs
- **Wetlands** - 54% of the area inundated
  - 735 sq km river channel modified into reservoirs
    - 52% of wetlands in 50 km corridor of Zone 2
    - 6% in Zone 3 and
    - 17% in Zone 4
- **Forest** - 544 sq km inundated (about 40%).
  - Mostly evergreen and deciduous
  - This is about 0.5% of the forest land cover in the 50 km corridor.
- **Agricultural land** inundated is relatively small, making up about 64 sq km (under 5%)
  - This is less than 0.1% of the agricultural land in the 50 km corridor.

**Conclusion**

- The different land uses inundated are relatively small in comparison to the wider area.

**Note:** Land use has been measured using 2003 GIS land use maps in a corridor 50 km on each side of the Mekong for each zone.
River bank gardens

Losses due to reservoirs

- River bank gardens lost due to inundation
  - Zone 2, 1,891 ha of RBGs lost
  - Zone 3, 1,872 ha of RBGs lost
  - Zone 4, 554 ha of RBGs lost

- The annual value of vegetable production estimated at USD 20.72 million per year within zones 2, 3 and 4.

- Most significant in Zone 2 and 3, with losses of about USD 9 million per year each.
  - In Zone 2, about 80% of the length of the river converted to reservoir - River bank households will lose this livelihood
  - In Zone 3, higher density of households using river bank gardens, although the length of river bank affected is smaller.
River Bank Gardens under threat

Siphandone

Latsua Dam site
Other terrestrial impacts

- **Pumped irrigation**
  - Increased efficiency of pumped irrigation due to higher water levels.
  - Variable water levels downstream of dams - more complicated pumping for irrigation.
  - Increased ground water levels around dams - Reduced costs of pumping from wells.

- **Contaminated ground water**
  - Increased ground water levels around dams, may mobilise contaminants in the soil.
  - Arsenic - contamination of ground water sources.
  - High arsenic levels have been recorded in Cambodia, especially in Sambor area.

- **In the Delta**, decrease in the flooded area, duration of flood and depth of flooding.
  - Slight decrease in these changes with the mainstream dams compared to without.
  - Little difference in wet season cultivation in the flood plain.

- **The increased dry season flows**
  - May reduce saline intrusion and acid sulphate release from soils in Delta.
  - But uncertain how the balance between increased flows but decreased sedimentation may influence these.

- **Fertility of floodplains**
  - The fertility of the floodplains depends on the nutrients carried on fine sediments.
  - The mainstream dams may reduce fine sediments reaching the floodplains and lead to reduced fertility.