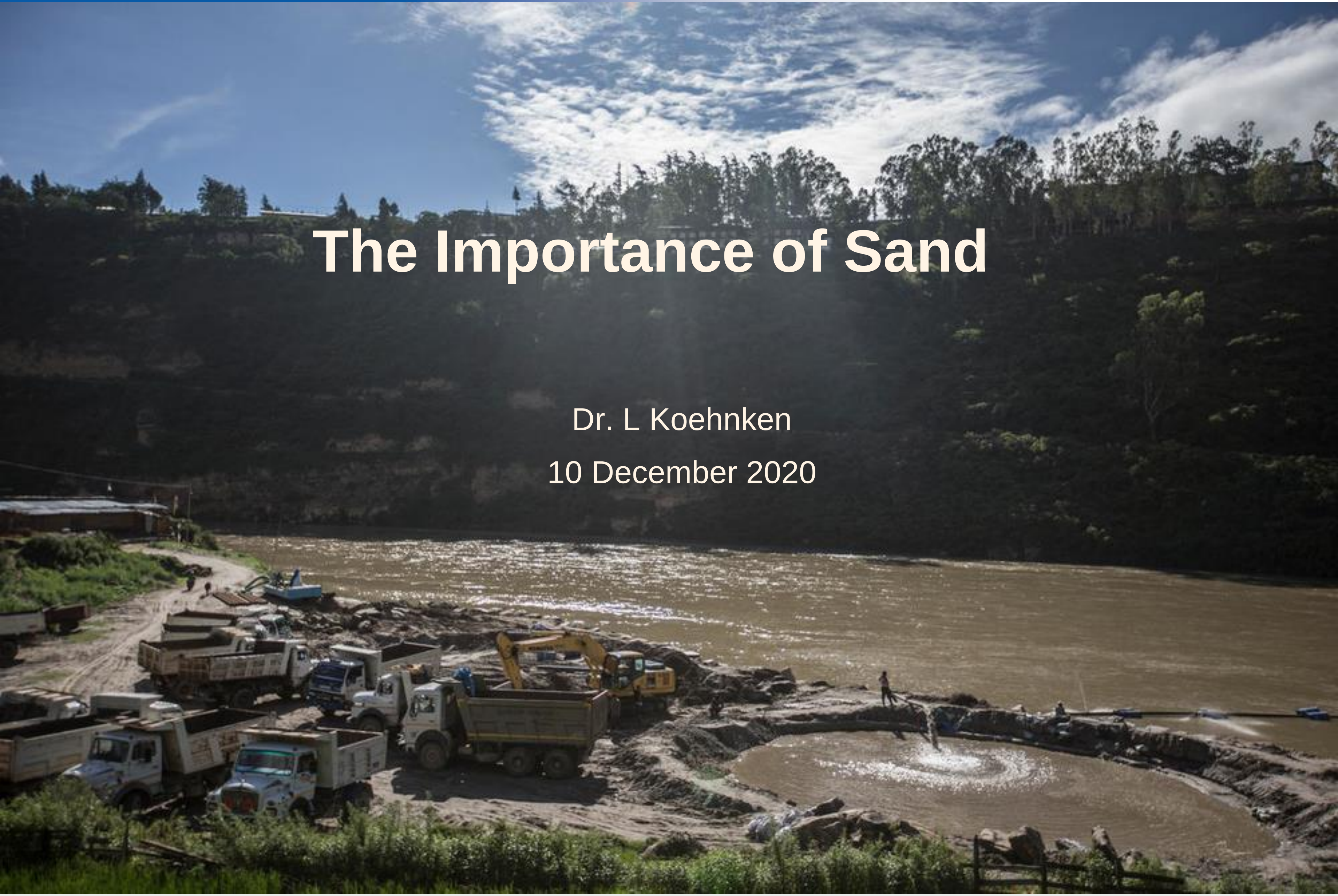

The Importance of Sand

Dr. L Koehnken

10 December 2020

Overview

- Why is sediment important & how rivers respond to changes
- Sand mining trends & impacts
- Hydropower trends & impacts
- Mitigation & management approaches to reduce impacts from river developments

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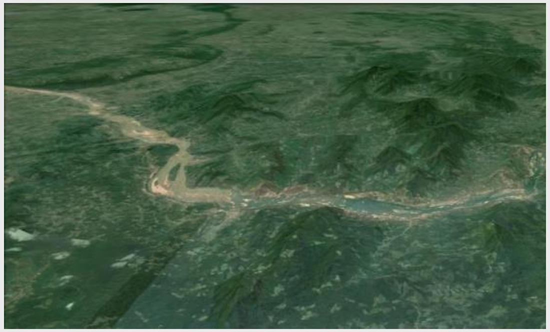
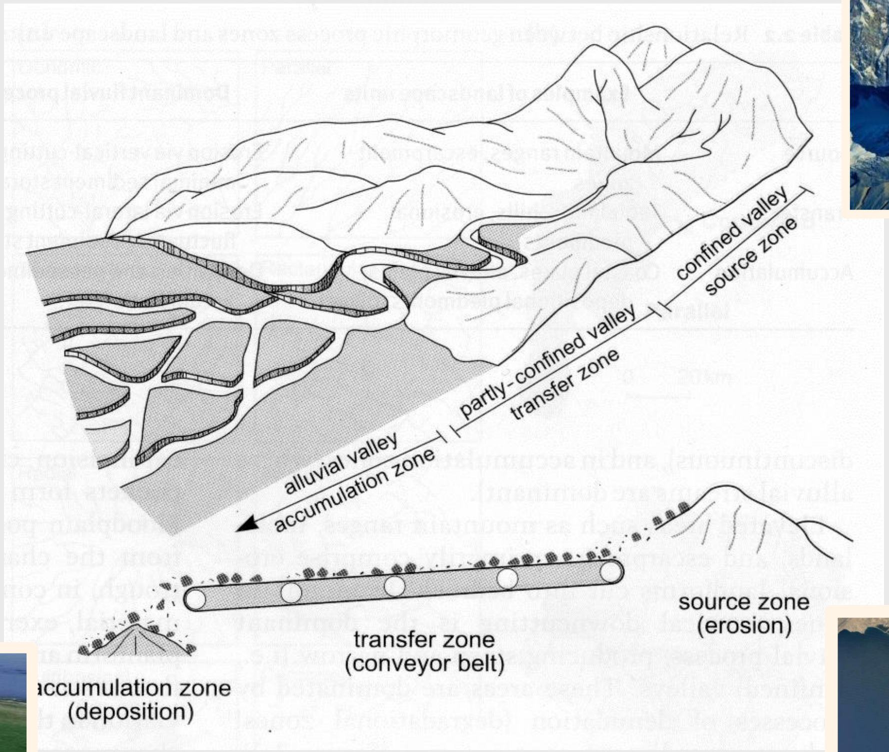
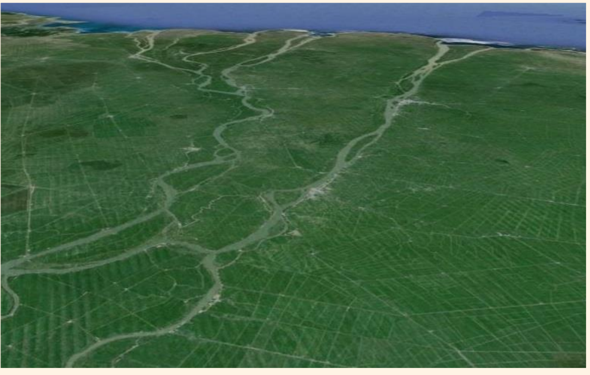
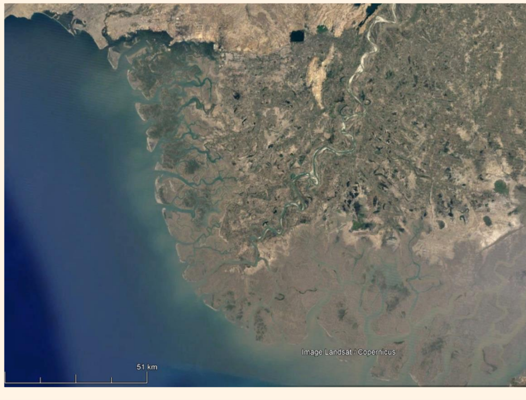
Why is Sediment Continuity Important?
Rivers Carve Landscapes and Transport Sediments





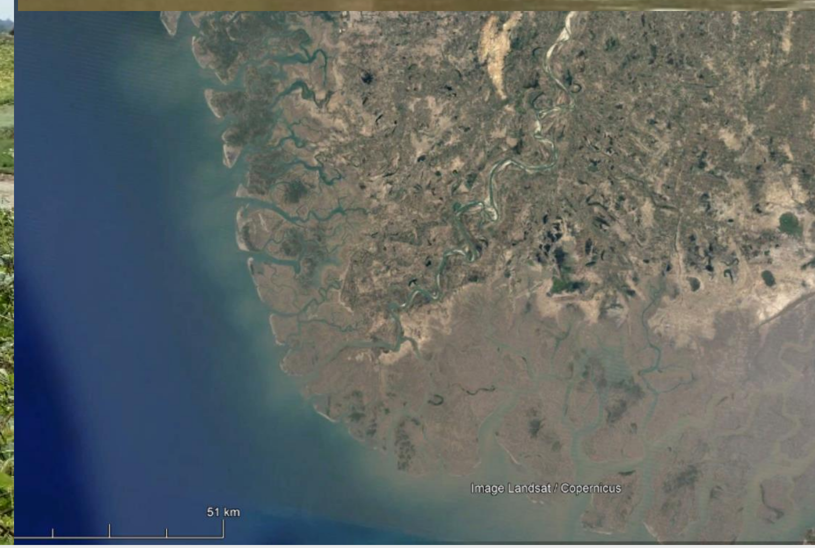




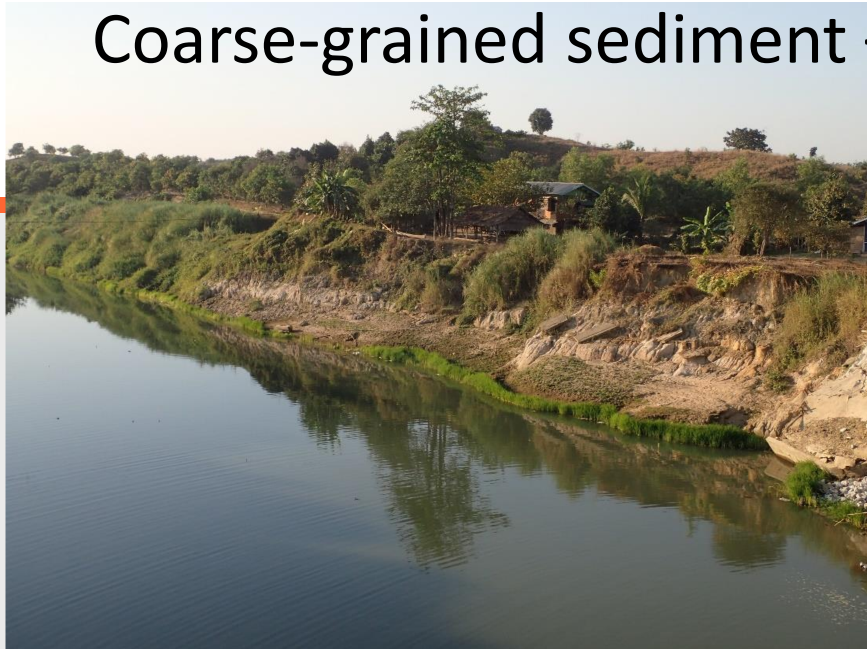
Importance of Hydrologic & Sediment Transport Processes

- **Distribution and quality of habitats**
  - Geomorphology & vegetation are closely linked
  - Vegetation responds to flow & sediment changes, which alters bank stability
- **Stability of the river channel & deltas**
- **Social dependence on river systems**
  - Flood plains agriculture
  - Navigation
  - Water availability
  - Energy production
- **Need to be understand how rivers will change when developed**
  - *Rivers will 'adjust' to any change to hydrology or sediment processes*

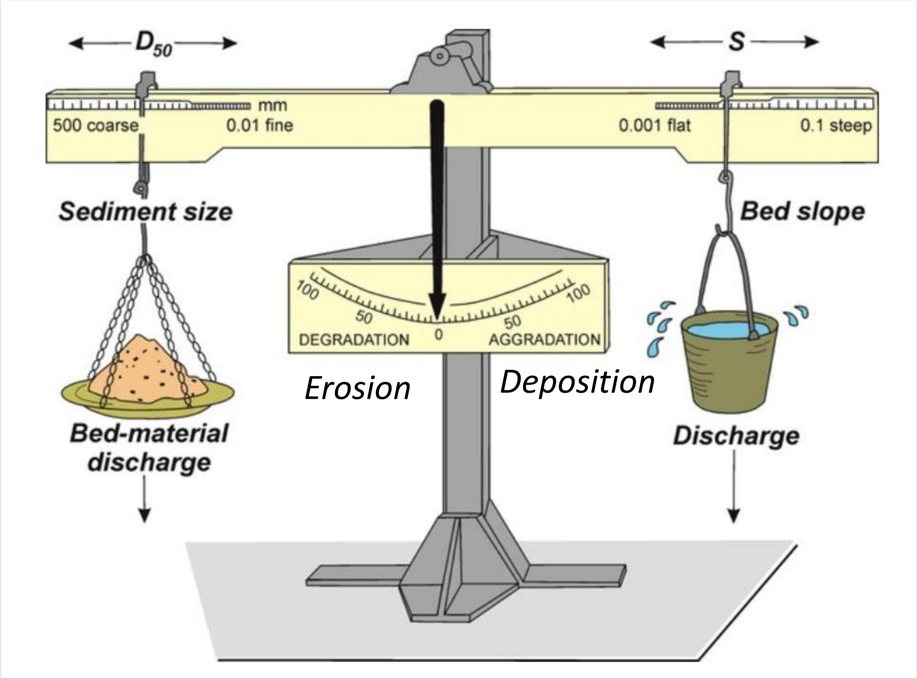
Fine-grained Sediment



Coarse-grained sediment – sand, gravel, cobbles



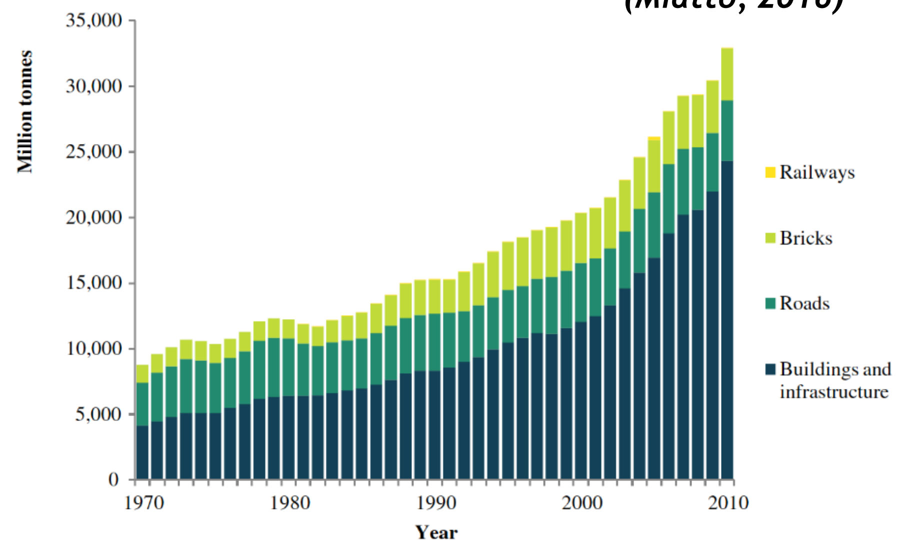
Channel shape respond to flow, sediment & slope changes



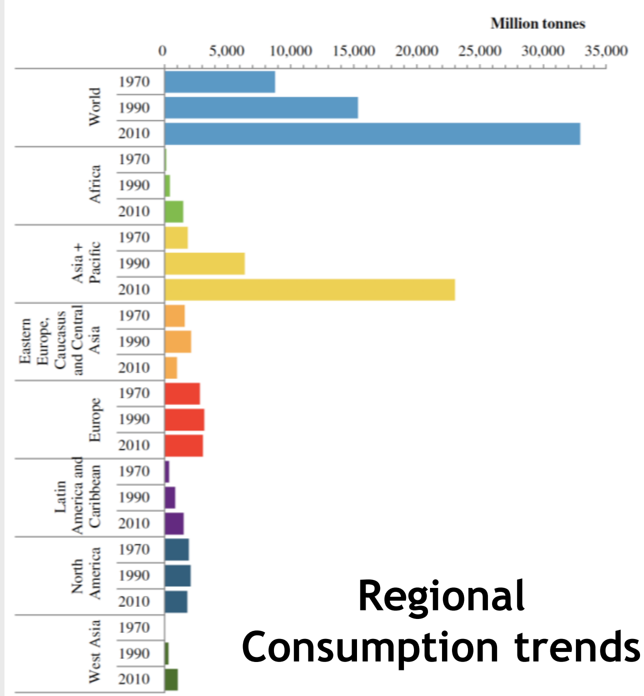
- Channel is stable if:
- Sed load & sed size is in balance with flow & river slope
- If sediment load decreases, bed will erode
- If sediment size decreases, bed will erode
- If flow increases bed will erode
- Hydropower changes flow & sediment load & sediment grain-size
- Sand mining reduces sediment load and changes sediment size

Sand mining: consumption trends

(Miatto, 2016)



- **Sand mining is a ubiquitous activity**
  - Global construction industry is based on cheap sand
  - Local activity – cost linked to transportation
  - Local governance frequently poor
  - Illegal extraction reported in over 70 countries
- **Estimated up to 50 billion tonnes of aggregate is extracted annually**
  - 30 billion tonnes used in construction
  - Road bases and land reclamation other major uses
    - 1 km requires 30,000 tonnes of aggregate



Regional Consumption trends

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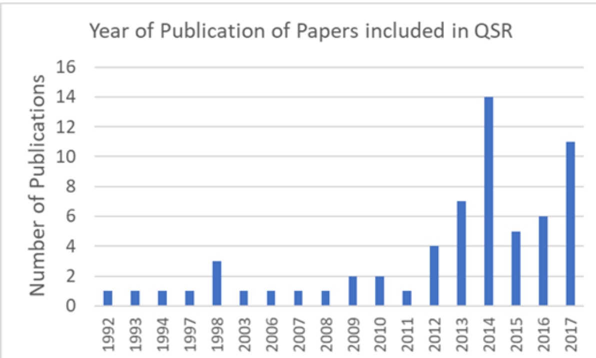
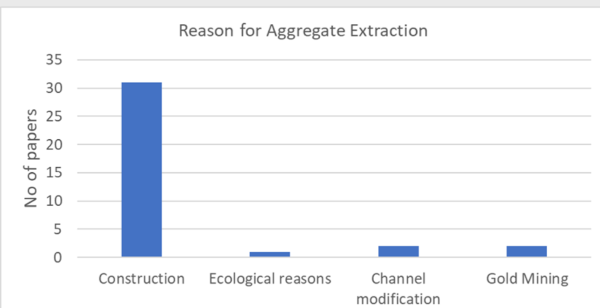
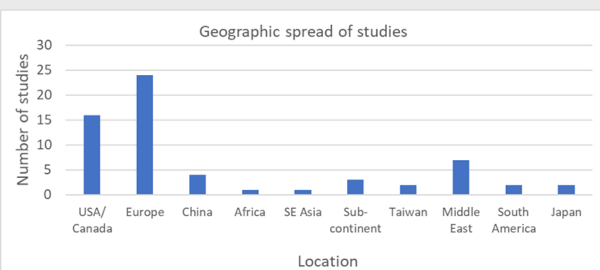
Structured literature review of sand mining impacts



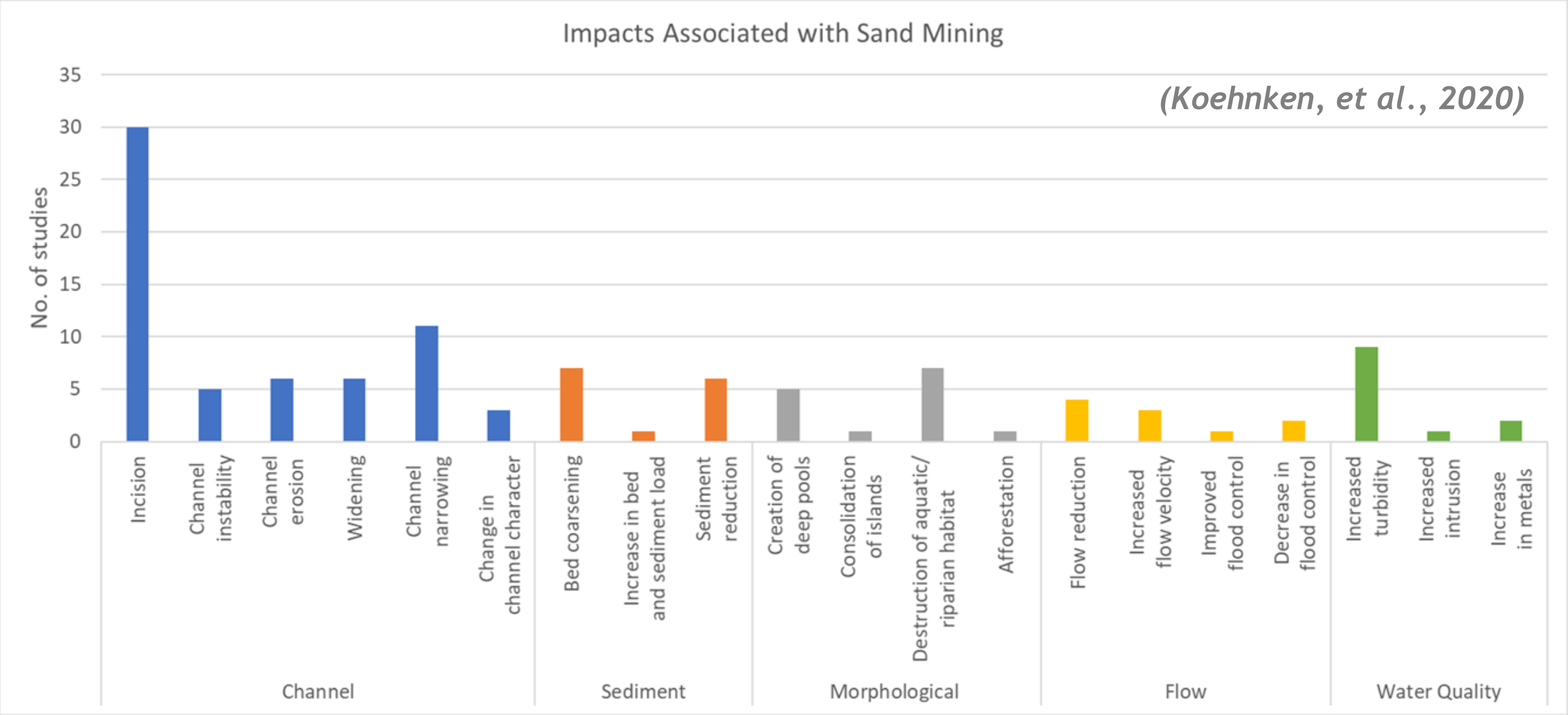




(Koehnken, et al., 2020)

- **Papers link sand mining with geomorphic change, but few establish direct link to ecosystem changes**
  - Spatially & temporally complex
- **An increasing number of investigations about sand mining are being published**
- **The vast majority of the sand is being extracted for construction**
- **Most investigations are from North America and Europe**
  - May reflect exclusion of papers not in English

Summary of Physical Impacts



- Physical changes to environment widely documented, affecting channel morphology, sediment budgets, instream habitat, the flow regime and water quality
- Channel incision is the most widely reported impact

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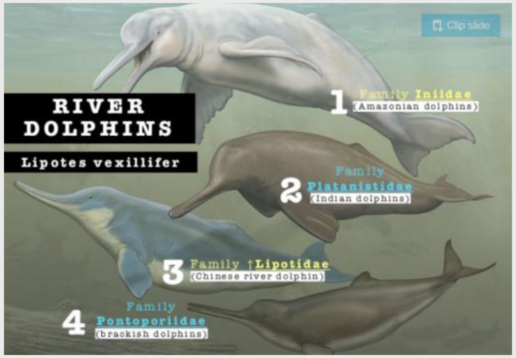
Ecosystem impacts by sand mining

- **Demonstrated impacts include:**
  - Fish kills
  - Reduction in diversity and abundance of fish in mined areas
  - Change from lentic to lotic populations due to removal of riffle sequences
  - Increase in invasive species in disturbed areas
  - High mortality during embryonic stage due to suction dredging
  - Temporary and reversible change to abundance and diversity of invertebrates in **small scale** mining
  - Change in food web dynamics in mined areas
  - Impacts on larval drift due to increased turbidity
  - Changes to riparian vegetation

- **Inferred impacts include:**
  - Loss of gravel substrate impacting fish spawning
  - Channel alterations affecting migratory patterns
  - Decline in native fisheries
  - Water quality changes affecting biota
  - Decline in deltaic ecosystems and coastal fisheries

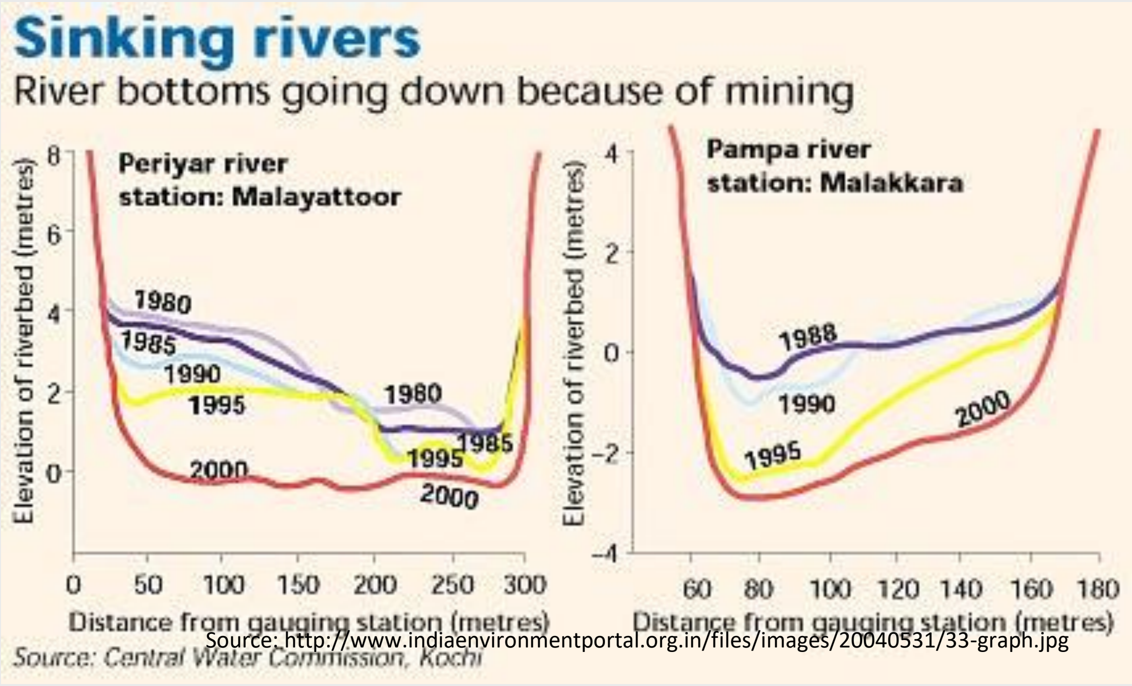
Habitat loss & destruction is #1 stressor on IUCN Redlist



(Pham, 2017)

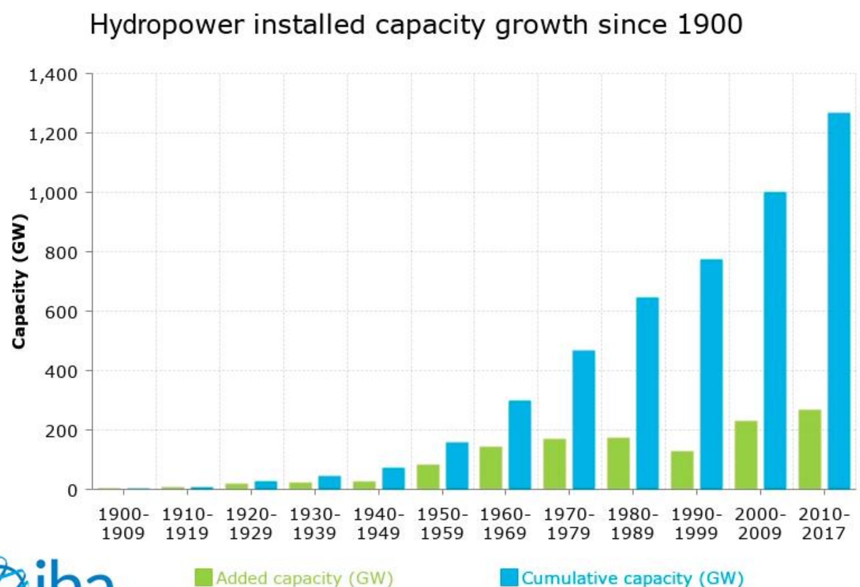
Examples of changing river profiles from mining

- **Examples from India due to sand mining**
- **As channels deepen, banks become unstable**
  - Bank erosion
  - Risk to infrastructure
  - Loss of channel & riparian habitats

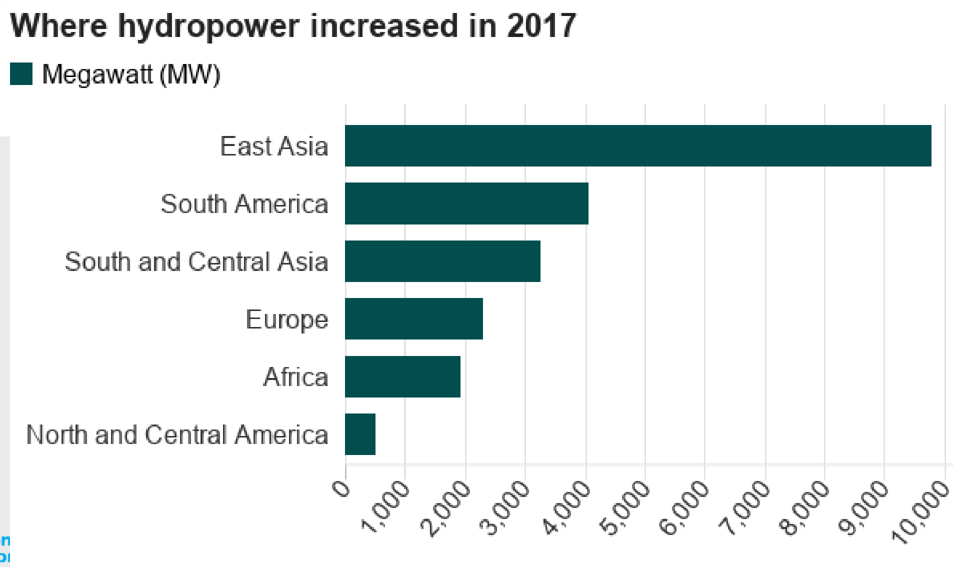


Source: http://www.indiaenvironmentportal.org.in/files/images/20040531/33-graph.jpg

Hydropower developments increasing



- Hydropower installed capacity also increasing rapidly
- Same regions developing HPPs where demand for sand is increasing
- Dam construction large consumer of sand
  - 13Mm^3 sand and gravel in Three Gorges



Source: International Hydropower Association

- **HPPs capture sediments**
- **Change grain-size distribution downstream**
- **Alter downstream flow patterns**
  - **Affects channel morphology**

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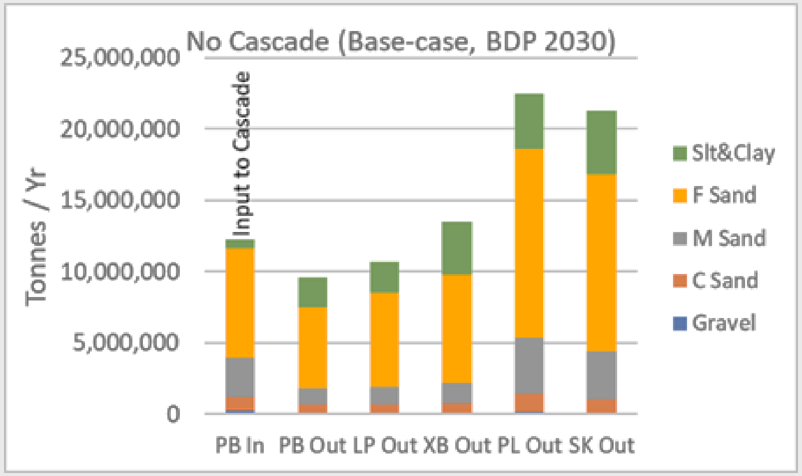
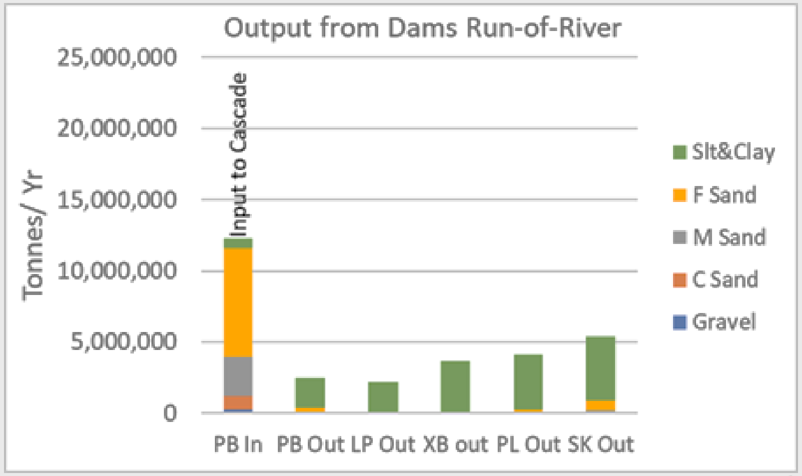
Example of sediment changes from HPP cascade





MRC, 2020

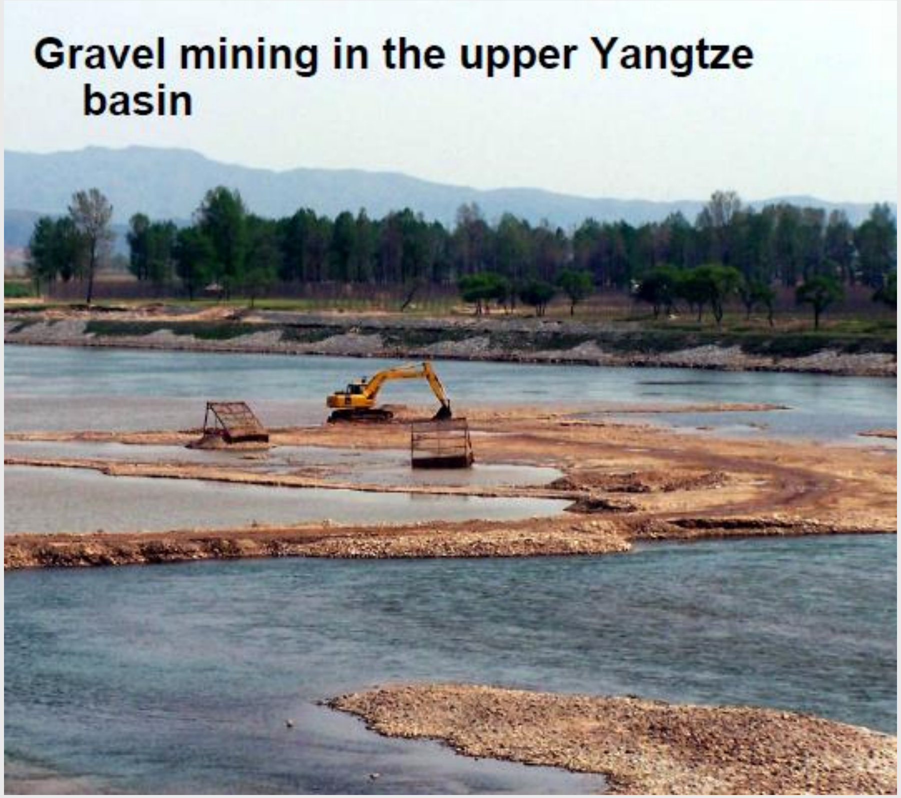
- **Hydropower cascade is reducing sediment load & changing grain-size distribution of the sediment load**
- **Results in channel erosion downstream**
- **Big impact to ecology even if channel is bedrock controlled**

HPP & mining mitigation measures – Manage where sediment deposits

- **Check dams or sedimentation ponds to promote sediment deposition at head of impoundment**
  - Sediment available for mining
  - Reduction in sedimentation in active volume of impoundment
- **Does not address downstream impacts from hydropower**
  - Prevents additional impacts from sand mining

HPP & mining mitigation approaches – Extract deposited material from HPPs

- **Sediment mining during draw down of impoundment**
  - Reduce pressure in upstream and downstream river channel by mining sand captured by impoundments
  - Requires lake level management
    - Draw down during dry season
  - Can be used in combination with check dams or sediment settling basins
- **Dredging can also be used**



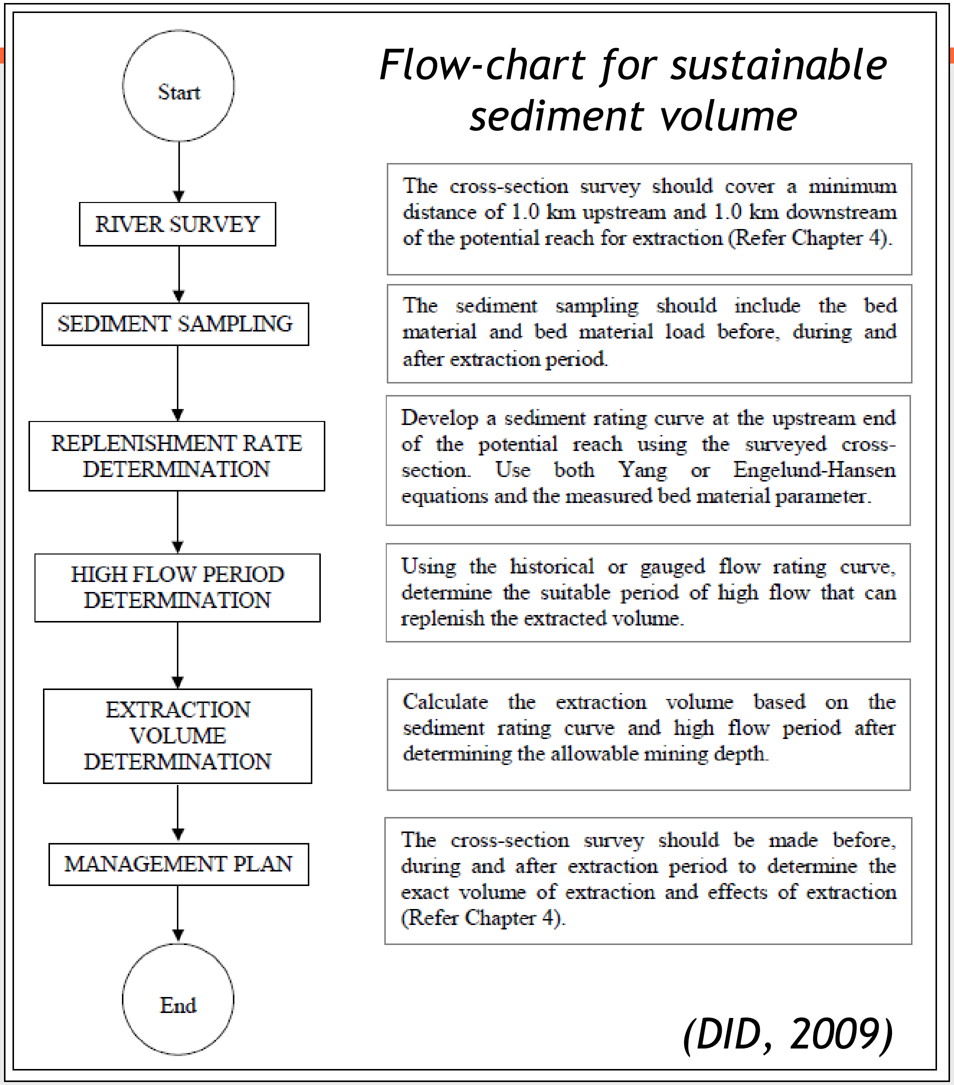
Sediment flushing from HPPs

- **Maintains sediment supply to downstream channel**
- **Ecological risks if sediment concentration too high**
  - Timing and frequency are important
- **Managed using**
  - Rate of water level raw down
  - Duration of flushing
  - Release of ‘clean’ water
  - Set maximum sediment concentration limit for downstream
  - Monitoring & modelling
- **Mitigation needs to be considered during dam design**

Sediment flushing in Shihmen Reservoir, Taiwan

Sustainable sand mining?

- **Some evidence mining can be sustainable if volume extracted is small compared to sediment load**
  - Within range of natural variability
- **River will ‘adjust’ to any change, aim is to maintain change within acceptable limits**
  - Need to consider entire river
- **To establish sustainable volume requires extensive research and on going monitoring / modelling expertise**
  - No examples in literature of long-term sustainable extraction
  - More research required



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Synthesis / Final comments

- **Sand / sediment is a fundamental & critical component of river systems**
- **Dam development and sand mining impact sediment budgets**
- **Both sand mining and HPP development are increasing – most rapidly in developing economies**
- **Any river development needs to be based on sound understanding of river**
  - Rivers are a continuum
    - Sediment budget - upstream, at development & downstream
    - Ecosystem characteristics and values throughout river system
- **Sediment mitigation / management needs to be included at earliest design stage of HPPs**
  - Strategic development of HPPs can minimise sediment disruption
  - Flexibility of infrastructure to respond to changing conditions & issues
  - Operating procedures to mimic natural flow and sediment patterns
- **Sand mining requires ongoing monitoring and evaluation**
  - Identification of off stream sources should be priority

Thank you