



# 8

## Navigation

## 8 NAVIGATION

### 8.1 Objectives

296. The objectives for navigation are:

- Guarantee continuation of navigation on the Mekong mainstream consistent with Article 9 of the Mekong Agreement, through provision and management of ship locks at all mainstream dams.
- Ensure consistent design and operation of ship locks at all mainstream dams.
- Make sure that dam infrastructure does not impede the potential future development of mainstream navigation<sup>16</sup> in terms of cargo transport capacity, passengers transport capacity, and convoy transport development.
- Ensure safe and efficient lock operations.

### 8.2 Risks

297. Risks associated with navigation should be comprehensively assessed. The PNPCA documentation should indicate how the design has dealt with the potential risks associated with navigation, and in particular with the ship lock, as shown in [Table 8.1](#).

**Table 8.1. Potential risks associated with ship locks at mainstream dams**

| Risk                                                                                                           | Consequences/comments                                                                                                                                 |
|----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Lock approaches upstream and downstream</b>                                                                 |                                                                                                                                                       |
| Lack of a straight-line approach in upstream and downstream channels with poor visibility approaching the lock | Barges and convoys may hit the bull nose of the guidance wall or enter the penstocks or spillway of the dam if not properly aligned when approaching. |
| Deposition of sediment in upstream or downstream approach channels                                             | Vessels may run aground and block the entrance for other vessels.                                                                                     |

<sup>16</sup> Information may be sourced from relevant government or regional authorities (e.g. the MRC).

| Risk                                                                                                                  | Consequences/comments                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Strong side currents where the downstream approach channel merges with the main river course                          | Strong side currents can push barges and convoys off course and cause collision with oncoming ships or barges.                                                                                                                                                                                        |
| <b>Lock chamber and gate design</b>                                                                                   |                                                                                                                                                                                                                                                                                                       |
| Emptying and filling produces heavy turbulence and disturbs the position of ships and vessels, especially small boats | Barges and boats can be shaken by the turbulence or upward currents during filling, and damage can be caused to the hull structure.                                                                                                                                                                   |
| In case mitre gates are used, sunken debris can get stuck between gate and sill, or inside the gate chamber.          | Damage can be caused to the gate (torsion) or to the opening and closing hydraulics, potentially halting navigation for long periods.                                                                                                                                                                 |
| Vessels impacting against the chamber walls while entering the lock chamber                                           | The impact from big barges, vessels or convoys against the concrete walls from the lock chamber can deteriorate and crush the concrete.                                                                                                                                                               |
| Ships improperly entering the lock chamber and not properly berthed during lock operations                            | Vessels that are not properly berthed after entering the lock chamber can cause damage to other vessels or lock chamber devices during lock operations This is specifically the case when ships are berthed at line-hooks instead of floating bollard, potentially leading to capsizing of the vessel |
| Person overboard and/or ship in distress in the lock area                                                             | This may result in fatal accidents, drowning, and police investigation, etc.                                                                                                                                                                                                                          |
| Ships entering the lock chamber and not stopping before the gate.                                                     | Ships bumping against the mitre gate can damage the structure. Parts of the steel construction may have to be replaced, which can result in long outages.                                                                                                                                             |
| Smaller vessels unable to safely traverse ship lock                                                                   | Small vessels are more likely to be affected by turbulence in the lock during filling.                                                                                                                                                                                                                |

| Risk                                                                                                       | Consequences/comments                                                                                                                                                                                                                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Culvert design and operation</b>                                                                        |                                                                                                                                                                                                                                                                                                                                                               |
| Cavitation at tainter valves and inside culverts from locks over 25-m lift.                                | Cavitation is destructive to valves and culvert walls, mostly unseen and unnoticed. Repairs are likely to be complicated, expensive and time consuming.                                                                                                                                                                                                       |
| <b>Entire lock structure</b>                                                                               |                                                                                                                                                                                                                                                                                                                                                               |
| Earthquakes                                                                                                | Earthquakes can provoke unscheduled settlement and small movements in the lock chambers and lock heads, even disturbing the normal functioning of the mitre gates and the tainter valves in the culverts. Insufficient resistance to earthquakes can result in damage to the lock heads and gates such that normal operation is no longer possible.           |
| Differential settlement over the entire lock structure                                                     | The same consequences as above are possible. If differential settlement leads to malfunctioning of the mitre gates or tainter valves, this can lead to damage to the lock heads with potentially high consequences for navigation.                                                                                                                            |
| Seepage under the lock structure                                                                           | Seepage with consequential soil erosion can create cavities that sooner or later are able to collapse entire structures if not sufficient or inefficient waterproof screens have been established                                                                                                                                                             |
| <b>Impoundment</b>                                                                                         |                                                                                                                                                                                                                                                                                                                                                               |
| Excessive sediment deposits in the impoundment backwater                                                   | Ships and barges can run aground due to insufficient water depth, thereby blocking navigation for other traffic.                                                                                                                                                                                                                                              |
| Hidden submerged rock outcrops in the impoundment backwater                                                | Ships and barges can hit underwater obstacles such as rocks and reefs that are invisible due to inundation. Currents in the impoundment can be so weak that captains and skippers can no longer “read the water”. Hitting underwater obstacles (usually rock outcrops) can substantially damage the ship hull and lead to sinking or capsizing of the vessel. |
| <b>Water level changes</b>                                                                                 |                                                                                                                                                                                                                                                                                                                                                               |
| Any sudden release of water into the downstream river as a result of operations, such as sediment flushing | Berthed small boats downstream of the project can be dislodged and swept farther downstream during dam operations (e.g. spillway gate operations, turbine start/stop).                                                                                                                                                                                        |

| Risk                                              | Consequences/comments                                                                                        |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| Sudden changes in water levels in the impoundment | Improper anchored vessels and/or small boats can be dislodged and risk drifting into project infrastructure. |

### 8.3 Pre-project monitoring and analyses

298. Design of navigation facilities should take account of the design and operation of existing and planned upstream and downstream projects in a cascade.
299. The design should be informed by current and future proposals for free-flow channel improvements both upstream and downstream of the dam. A number of projects, studies, and proposals are under consideration, the most important being the Development Plan on International Navigation on the Lancang-Mekong River (2014–2025) by the Department of Transport of the Yunnan Province, August 2014.
300. The design should take into consideration two studies conducted by the MRCS regarding channel improvements in some dangerous areas for navigation (including reefs, rapids, and shoals):
  - “Condition Survey of Dangerous Areas for Navigation between Luang Prabang and Pakse in the Lao PDR and Thailand – October 2009”; and
  - “Condition Survey of Dangerous Areas for Navigation between Huay Xay and Luang Prabang in the Lao PDR and Thailand – April 2010”.
301. The developer should base the lock design on a detailed understanding of the geological, geomorphologic, hydrologic, and hydraulic conditions of the dam site, including seasonal variations. Application of the hydrological and hydraulic models described in Section 2.3 and the sediment modelling described in Section 3.3, can inform detailed planning for development and operation of the ship locks and its approaches.
302. Adequate channel clearance should be provided for vessels accessing the ship lock. The need for dredging or rock clearance to ensure safe access to the lock chamber should be documented. Adequate visibility of both upstream and downstream lock accesses should be provided.
303. The analyses of changes, risks, and mitigation options relating to navigation should clearly identify the residual impacts and document where these will occur in the river, in line with Clauses 7 and 25.

### 8.4 Design and operational guidance

304. An essential guide for many of the design aspects for the mainstream Mekong ship locks is

the 2009 Permanent International Association of Navigation Congresses (PIANC<sup>17</sup> report). Innovations in Navigation Lock Design; and an essential guide for Mekong navigation is the PIANC InCom WG report n° 141-2019, Design Guidelines for Inland Waterway Dimensions. It is the developer’s responsibility to obtain these guidance documents through the PIANC procedures. This Preliminary Design Guidance (PDG) directs the user to specific sections of these PIANC reference documents for important design requirements.

305. Mitigation options should be evaluated to determine which ones will best address identified risks. **Table 8.2** sets out mitigation options for the broad areas of risk, with more detailed guidance provided in the clauses following this table. Developers may propose alternative mitigation options based on the specific site location and associated risks with appropriate justification.

**Table 8.2. Mitigation options for navigation-related risks for mainstream dams**

| Risk                                                                  | Mitigation options                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Structural integrity of the ship lock infrastructure                  | <p>Ship locks should be earthquake-resistant (see Section 7 Dam Safety).</p> <p>The design should take into account the geological and geomorphology conditions of the site and the effects of potential differential settlement</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Issues arising in the approaches to the ship lock and the impoundment | <p>A straight-line approach channel with good approach visibility should be provided.</p> <p>Ensure that the guidance wall, ship lock openings, and ship lock chamber are designed to be in one straight line.</p> <p>Navigational hazard management measures should be implemented (e.g. initial surveys, clearance, markers for remaining hazards particularly in the impoundment backwater).</p> <p>Sediment management measures should be implemented (see Section 3).</p> <p>Debris management measures should be implemented (e.g. regular surveys, underwater jet system in front of the sills, manual mechanical clearance, adeep hole upstream created to capture potential hazards)</p> |

<sup>17</sup> PIANC, which was the Permanent International Association of Navigation Congresses, is now the World Association for Waterborne Transport Infrastructure ([www.pianc.org](http://www.pianc.org)). Documents are readily available at low cost.

| Risk                                                             | Mitigation options                                                                                                                                                                                                                                                                                                                                                                   |
|------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Excessive sediment deposits in the impoundment backwater         | Dredging of navigation channel in affected backwater reaches including tributary entry points should be carried out and navigation aids provided.                                                                                                                                                                                                                                    |
| Hidden submerged rock outcrops in the impoundment backwater      | Navigation aids should be provided for high and low water levels.                                                                                                                                                                                                                                                                                                                    |
| Issues arising within the lock chamber(s)                        | <p>Protective measures for ship impacts should be implemented (e.g. gate protection; steel sliders or armour devices embedded in concrete walls).</p> <p>Mooring facilities should be provided with floating bits, line hooks and fenders.</p> <p>Camera surveillance, loudspeaker for warnings, emergency stop facilities and traffic light signals should be provided.</p>         |
| Emptying and filling produces heavy turbulence affecting vessels | <p>The opening sequence of the filling valves for various types and sizes of boats/vessels/barges should be reprogrammed.</p> <p>The filling orifices should be reshaped or eventually, the entire filling system should be redesigned.</p> <p>Locking big barges together with small boats should be avoided, or the filling programme of the culvert valves should be adapted.</p> |
| Smaller vessels unable to safely enter and exit the ship lock    | Alternative methods (tractor/trailer) should be used to move smaller vessels past the structure.                                                                                                                                                                                                                                                                                     |

| Risk                                                                                                      | Mitigation options                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cavitation at tainter valves and inside culverts (in locks with over 25-m lift).                          | <p>Locks with a lift over 35 meters should not be constructed as a single ship lock. The design should opt for tandem locks.</p> <p>Special attention should be paid to avoid cavitation in locks with lifts of over 25m; may be designed with water saving basins to substantially reduce the pressure on the culvert valves (PIANC, 2009).<sup>18</sup></p> <p>Tainter valves with enlarged (deepened) chambers behind the valves should be considered.</p> <p>The culvert shape behind the filling and emptying valve should be optimized.</p> <p>Aeration of the tainter valve with an air intake system should be considered.</p> <p>The resistance of the culvert walls should be increased and improved against cavitation, e.g. by steel plates.</p> |
| Interruption of existing and ongoing navigation                                                           | <p>Alternative ways of transshipping goods, cargo and passengers should be provided during the construction of the ship lock.</p> <p>Information on construction progress should be provided to waterway users, in particular to boat associations from upstream and downstream ports, and commercial waterway transport operators.</p>                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Any sudden release of water into the downstream river as a result of operations such as sediment flushing | <p>Cascade Joint Operating Rules and Project-Specific Operating Rules should be applied to control how water levels will fluctuate.</p> <p>Early warning notifications should be provided.</p> <p>Prior safety inspections should be carried out ahead of major water level changes.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Fish passage during construction                                                                          | <p>The ship lock should be adapted as the sole fishway during construction in accordance with the guidelines under Clause 231.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

### Lock dimensions

306. Lock dimensions have been decided for all navigation locks to be constructed along mainstream dams, following the outcome of the Optimisation Study of the Mekong Mainstream Hydropower Projects commissioned by the Government of Lao PDR. Ship

<sup>18</sup> PIANC-InCom report from working group 29 (Report n° 106-2009): "Innovations in navigation lock design", Section 4.4.5 (p. 82).

lock chamber dimensions should be at least 120 m x 12 m x 4 m, which comfortably accommodates a convoy of two 500-t barges (Chinese design) with pusher vessel.

307. The Mekong/Lancang River upstream of the Khone Falls should be considered as a single navigation unit using the above ship and lock dimensions. Downstream of the Khone Falls (Cambodia – Viet Nam), different ship lock dimensions may be applied since this is another separate navigation unit with potential connection to the sea.

### ***Lockage time and availability***

308. Lockage time should be kept to the minimum whilst allowing for safe operations and safe movement of all vessels in the lock chamber(s) and should be guided by PIANC recommendations.<sup>19</sup>
309. The design criterion for hawser forces in all possible directions should be  $\leq 1\%$  x water displacement of the vessel (in tonnes) and should be guided by PIANC recommendations.<sup>20</sup>
310. The locks should be designed to operate at least 12 hours a day, every day of the year.
311. Each lock complex should be operational for at least 98% of its scheduled operating time during each year of its service life, excluding planned closures for scheduled maintenance and unscheduled repairs.
312. Outages related to incidental breakdowns should not exceed 2 percent of the operating time each year.
313. Service outages for scheduled maintenance should be on nine consecutive days (one working week and the two weekends) each year, during the same period for all dams on the Mekong mainstream waterway (upstream of Khone Falls) to avoid traffic disruption. This period should be established in the Cascade Joint Operating Rules. The official body in charge of navigation coordination along the Mekong River should be responsible for specifying the dates for servicing.

### ***Approach infrastructure***

314. Approach infrastructure should be designed in accordance with PIANC recommendations.<sup>21</sup> Three different berthing areas should be provided, each able to berth one full-sized design vessel/convoy, and include the following:
- a lay-by area where ships can be ready to immediately enter the ship lock as soon as the preceding vessel has left it or the green entry light is turned on;
  - a waiting area where ships can wait if there are several others ahead of them. The

---

<sup>19</sup> See PIANC (2009), Chapter 4.2.5 Duration of Lock Cycle and Vessel Passage (p. 56).

<sup>20</sup> See PIANC (2009), Chapter 5.2.3 Mooring Line/Hawser Forces during Filling and Emptying of Lock Chamber (p. 109).

<sup>21</sup> See PIANC (2009), Chapter 5.6 Lock Approach Structures (p. 148).

waiting area can be an extension of the lay-by area;

- the overnight area where ships and vessels can spend the night. The overnight area does not necessarily have to be connected to the lay-by or waiting areas, but all three areas should have access to land via a catwalk or via floating pontoons. The overnight area may be developed at a later date if demand is low at the time of project commissioning, and plans submitted at the PNPCA stage should indicate if this is the case and how it has been provided for; and
- one of the above three areas may provide facilities such as potable water, clean water, solid and liquid waste facilities, emergency aid, etc.

### ***Service life***

315. Each lock complex should be designed for a functional lifetime of 100 years.

316. Some components of the lock may have a service life shorter than 50 years. These components are listed below and should be designed to allow for easy replacement.

- Metal structures
- Hydraulic jacks
- Ball bearings, pulleys, joints, valves, etc.
- Cables
- Electrical equipment
- Communication and digital safety equipment, cameras, and TV sets.

317. Sufficient spare parts should be obtained during project implementation for the most vital mechanical parts of the ship lock. Guidance on life cycle management for locks is provided in the PIANC reference.<sup>22</sup>

### ***Future expansion***

318. The design of the locks system should allow for future construction of a second line of locks.

319. The owner/operator should be responsible for the construction of a second line of parallel locks when the number of lockages per year reaches at least 80 percent of the total maximum possible yearly lockages over a period of two successive years.

---

<sup>22</sup> See PIANC (2009), Chapter 4.3 Life Cycle Management for Locks (pp. 58–63).

### ***Further design and operational guidance***

320. Lock gates and their ancillary equipment should be protected against fire inside the chamber.
321. An overhead rolling crane, or other lifting equipment, running the full length of each chamber may be considered to:
- lift floating or sunken debris caught between the mitre door and the sill or lodged inside the door chamber;
  - assist small vessels in cases of emergencies inside the lock chamber;
  - position the stoplogs for each lock-head for maintenance purposes (e.g. mitre door pintle replacement) and repair/replacement of the tainter or sliding valves in the culverts; and
  - support emergency rescue operations for ships in distress inside the lock chamber.
322. If feasible, the ship lock may also be used as additional fish passage during migration periods (see Clause 231). This additional fish passage may be the only one during the construction of the powerhouse and the spillway, in which case it is an essential asset to be considered in the construction planning and should be operated as a fish passage during construction.
323. The project should make allowance for the installation of a monitoring system that allows future networking to other mainstream dams, to provide a real-time monitoring of vessel and barge movements on the Mekong. This may be the precursor of a fully-fledged River Information System, in which the real-time movement of vessels and barges is monitored and communicated to upstream or downstream locks and ports.

## **8.5 Project monitoring and adaptive management**

324. Plans for project monitoring of navigation locks should take into account the guidance in Clause 26. The PNPCA information should demonstrate that plans for navigation-related monitoring information to be collected during construction and operation will inform:
- Developers' needs regarding management of navigation lock operations; and
  - Indicators that may signal a need for adaptive management responses to navigation related management and mitigation measures.
325. The monitoring programme for navigation at the construction and operation stage should include a focus on operational efficiency, adherence to the minimum lock downtimes, effectiveness of communications and coordination, and maintenance and replacement of operating components.

326. Plans for the monitoring programme should include regular monitoring and inspections by the navigation lock operator of key navigation infrastructure, electro-mechanical equipment and keep records of navigation movements and any associated issues arising. Bathymetric surveys at both access channels and approaches should be conducted in coordination with related sediment monitoring set out in Section 3.5.