Session:

Hydropower safety
What is good practice?

David Wright
Norwegian Water Resources and Energy Directorate

For more information: www.hydropower.org/congress
Dam Safety

Two goals:

- Minimisation of all risks
- Managing the remaining parts of the risk in the best possible way
The 3 Pillars of Dam Safety

Safe Structure

Maintenance

Upgrading/ Rehabilitation

Monitoring

Danger Lines

Preparedness

Qualified Safety Personnel
(Manager, Chartered Dam Engineer, Inspection Personnel, Consulting Engineers, Contractor.)
The owner is “Responsible”

- The owner is responsible for fulfilment of the demands in the law, regulations and guidelines

- The owner has to prove by his internal control system that the requirements of the law and regulations are fulfilled
Regulations on classification of dams

Definition:

<table>
<thead>
<tr>
<th>Class</th>
<th>Hazard Category</th>
<th>Housing units affected</th>
<th>No. of dams (total 2350)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 4</td>
<td>Highest hazard dams</td>
<td>&gt; 150</td>
<td>60</td>
</tr>
<tr>
<td>Class 3</td>
<td>High hazard dams</td>
<td>21 - 150</td>
<td>315</td>
</tr>
<tr>
<td>Class 2</td>
<td>Significant hazard dams</td>
<td>1 – 20</td>
<td>675</td>
</tr>
<tr>
<td>Class 1</td>
<td>Low Hazard</td>
<td>0</td>
<td>1300</td>
</tr>
</tbody>
</table>

Classification also depends on other damages, like loss of storage reservoir, loss of electrical production, damage to infrastructure, property and the environment.
Regulations Governing Qualifications

Dam Owner’s Employees – Qualification Requirements

■ **Company Manager**
  - Complete a course with emphasis on legal requirements, emergency action planning and dam safety philosophy

■ **Chartered Dam Engineer** for dams in class 3 and 4
  - Approved by NVE
  - Civil engineer with a master’s degree
  - Passed exam from a 10 day course on university level

■ **Inspection Personnel**
  - Complete a 1 week course with emphasis on safety inspection of dams
Regulations Governing Qualifications

Consulting engineers responsible for planning and safety reassessments need a general approval from NVE

- Professional disciplines within five subject areas
  - Concrete dams
  - Embankment dams
  - Diversion works, pipes and adit gates
  - Flood hydrology
  - Hydraulics and flood diversion (from 2011)

The approval requirements are MSc degree in engineering and 10 to 60 months work experience (depending of the class of dams and subject area) from the respective approval area
Dam Safety Guidelines

- Safe Structures:
  - Classification
  - Flood calculations
  - Determination of loads
  - Concrete dams
  - Masonry dams
  - Embankment dams
  - Spillways
  - Gates, valves and penstock
  - Planning and construction
Planning and Design

- The plan must be prepared by an engineer approved by NVE

- The design shall include:
  - Determination of loads (design flood levels, ice pressure loads, earthquake loads, abnormal leakage, etc.)
  - Stability assessment of the structure
  - Design of spillways and diversion works
  - Foundation conditions and dam design
  - Monitoring during construction and operation
  - Drawings
  - Measures to reduce the impact on landscape
Design flood:
- Class 3 and 4 - 1000 year flood
  - Check for probable maximum flood (PMF)
- Class 2 - 1000-year flood
  - Check for PMF or 1,5 x 1000 year flood
- Class 1 - 500 year flood
  - Check for PMF or 1,5 x 500 year flood

Un-gated spillways are preferred

Gated Spillways, only when the consequences of possible malfunction are small (fear of blockage)

The spillway discharge must not be greater than the natural downstream flood discharge
Construction shall only be carried out in accordance with an approved plan.

The plan shall include:

- A Construction Program indicating all the important phases of the work
- Supervision of construction during execution of the works
- Site Organisation Plan

Progress reports and test results are sent to NVE at agreed intervals during the construction period.
Dam Safety Regulations

Initial Impounding, Testing and Operation

- Must include a program for first filling of reservoir
- Must include a program for testing of the spillway gates, valves and diversion works
  - Monitoring
  - Measurements
  - Testing
- Qualified personnel must be present and responsible for the testing program
Dam Safety Regulations
Monitoring Plan

- The dam owner has to prepare a monitoring plan
- The plan has to describe the inspection schedule, instrumentation, measurements and limiting values for corrective actions.
  - Depending on results of a safety evaluation, if necessary the plan for surveillance has to include video monitoring or other form of continual monitoring.
- The plan and the results have to be documented and included in reassessments
- The plan has to be made available to NVE
Dam Breach Flood Analyses

- Required for all dams in hazard class 4, 3 and 2
- Initial situations:
  - 1000 year flood
  - Mean annual flood
- Inundation map showing the area affected by the dam breach (*red area in map*)
- **Important tool for:**
  - contingency planning
  - classification of dams
Main Takeaway Messages

- **The owner is responsible** for fulfilment of the requirements of the law, regulations and guidelines

- Ultimately it is the **PROFESSIONALS** working in the industry who are the key to dam safety, and the regulations impose **Qualification Requirements on Owners, Consultants and Construction Firms**