

| GLOBAL FAILURE MODES                                 | ELEMEN AND/OR ELEMENT FUNCTION  | MOST BASIC FUNCTIONAL FAILURE CHARACTERISTICS   | External Hazards  |  |   |  | Internal Hazards (Design, Construction, Maintenance, Operation)   |  |  |  |  |   |
|--|---|---|---|--|---|--|---|--|--|--|--|---|
|  |   |   | Meteorological  | Seismic  | Reservoir Environment   | Human Attack   | Water barrier   | Hydraulic struct.  | Mech/elec  | Infrastructure & Plans   |  |   |
| DAM COLLAPSE BY OVERTOPPING (erosion or overturning) | Water elevation too high  | Inadequate installed discharge capacity   | Meteorological inflow > buffer + outflow capacity   | Could a meteorological event cause the inflow to be greater than the outflow capacity and lead to dam overtopping / failure due to insufficient installed discharge capacity?                      | Could a seismic event cause a meteorological event and cause the dam to be overtopped/fail from a reduced discharge capacity (inlets, outlets)?   | Could the reservoir environment (landslide, debris) cause a meteorological event leading to the dam to be overtopped/fail because of insufficient installed discharge capacity?            | Could terrorist action cause a meteorological event that leads to the dam being overtopped/fail due to insufficient installed discharge capacity?                       | Could design or construction of the water barrier cause a meteorological event leading to dam overtopping / failure due to insufficient installed discharge capacity?                  | Could the design or construction of the hydraulic structure cause a meteorological inflow greater than the buffer + outflow capacity and cause the dam to be overtopped/fail?                                | Could the design or construction of the mech/elec systems cause a meteorological inflow greater than the buffer + outflow capacity and lead to the dam being overtopped/fail due to insufficient installed discharge capacity? | Could inadequate infrastructure and plans cause a meteorological inflow greater than the buffer + outflow capacity and lead to the dam being overtopped/fail due to insufficient installed discharge capacity? |   |
|  |   | Inadequate available discharge capacity   | Inadequate reservoir operation (rules not followed)   | Could the dam be overtopped/fail during a meteorological event if the operating rules are not followed?  | Could a seismic event create a condition that prevents the operating rules from being followed, leading to the dam being overtopped/fail?   | Could the reservoir environment cause the operating rules to not be followed leading to the dam being overtopped/fail?   | Could terrorist action cause the operating rules to not be followed leading to the dam being overtopped/fail?   | Could design or construction of the water barrier cause the operating rules to not be followed and cause the dam to be overtopped/fail?  | Could the design or construction of the hydraulic structure cause the operating rules to not be followed and lead to dam collapse by overtopping?  | Could the design or construction of the mech/elec systems cause the operating rules to not be followed leading to dam overtopping/failure?   | Could inadequate infrastructure and plans cause inadequate reservoir operation leading to dam collapse by overtopping?   |   |
|  |   | Inadequate available discharge capacity   | Random functional failure on demand   | Could the dam be overtopped/fail during a meteorological event if there is a random functional failure of spilling capability?   | Could a seismic event cause a random functional failure of spilling capability leading to the dam be overtopped/failed?   | Could the reservoir environment cause random functional failure on demand of discharge capability and lead to the dam being overtopped/fail?   | Could terrorist action cause random functional failure of spilling capability causing the dam to be overtopped/fail?  | Could design or construction of the water barrier cause a random functional failure of spilling capability and cause the dam to be overtopped/fail?                                    | Could the design or construction of the hydraulic structure cause random functional failure of spilling capability and lead to the dam being overtopped/fail due to inadequate available discharge capacity? | Could the design or construction of the mech/elec systems cause a random functional failure on demand leading to dam collapse by overtopping?  | Could inadequate infrastructure and plans cause random functional failure on demand leading to dam collapse by overtopping?  |   |
|  |   | Inadequate available discharge capacity   | Discharge capability not maintained or retained   | Could the dam be overtopped/fail during a meteorological event if the discharge capacity is not maintained?  | Could a seismic event cause the discharge capacity to be damaged causing the dam to be overtopped/fail?   | Could the reservoir environment cause loss of the discharge capability leading to the dam being overtopped/fail?   | Could terrorist action cause loss of discharge capability and cause the dam to be overtopped/fail?  | Could design or construction of the water barrier cause the discharge capability to be not maintained/retained and cause the dam to be overtopped/fail?                                | Could the design or construction of the hydraulic structure cause loss of the discharge capability and lead to the dam being overtopped/fail due to inadequate available discharge capacity?                 | Could the design or construction of the mech/elec systems cause the discharge capability to be not maintained / retained leading to dam collapse by overtopping?   | Could inadequate infrastructure and plans cause discharge capacity to not be maintained or retained leading to dam collapse by overtopping?  |   |
|  |   | Inadequate freeboard  | Excessive elevation due to landslide or U/S dam   | Could the dam be overtopped/fail during a meteorological event due to a reservoir landslide or upstream dam failure?   | Could a seismic event cause the dam to be overtopped/fail by a reservoir landslide or upstream dam failure?   | Could the reservoir environment cause excessive elevation of the reservoir leading to the dam being overtopped/fail?   | Could terrorist action cause a landslide or upstream dam failure leading to the dam being overtopped/fail?  | Could design or construction of the water barrier cause a reservoir landslide or upstream dam failure and cause the dam to be overtopped/fail?   | Could the design or construction of the hydraulic structure cause excessive elevation due to a landslide or upstream dam failure leading to the dam being overtopped/fail due to inadequate freeboard?       | Could the design or construction of the mech/elec systems cause excessive elevation due to a landslide or upstream dam failure leading to dam collapse by overtopping?   | Could inadequate infrastructure and/or plans cause the dam to fail due to a reservoir landslide or upstream dam failure?   |   |
|  | Inadequate freeboard  | Wind-wave dissipation inadequate  | Is freeboard and wind wave dissipation adequate to prevent overtopping/failure during a meteorological event?                                       | Could a seismic event cause the dam to be overtopped/fail due to inadequate freeboard and wind wave dissipation?   | Is freeboard and wind wave dissipation adequate to prevent overtopping/failure from failure of features in the reservoir environment?   | Could terrorist action cause inadequate freeboard and wind wave dissipation leading to dam overtopping/failure?  | Could design or construction of the water barrier cause inadequate freeboard and wind wave dissipation and cause overtopping/failure?                                   | Could the design or construction of the hydraulic structure cause inadequate wind wave dissipation leading to dam collapse by overtopping?   | Could the design or construction of the mech/elec systems cause inadequate wind wave dissipation leading to dam collapse by overtopping?   | Could inadequate infrastructure and plans cause inadequate wind-wave dissipation leading to dam collapse by overtopping?   |  |   |
|  | Management System Failure   | Safeguards fail to provide timely detection and correction  | Operation, maintenance and surveillance fail to detect/prevent hydraulic adequacy   | Could a meteorological event prevent the Dam Safety Engineers activities (based on OMS requirements, see column L) from detecting/prevent hydraulic inadequacy leading to dam overtopping/failure? | Could a seismic event prevent the Dam Safety Engineers activities (based on OMS requirements, see column L) from detecting/preventing hydraulic inadequacy leading to overtopping/failure of the dam? | Could the reservoir environment prevent Dam Safety activities (based on OMS requirements, see column L) from detecting/preventing hydraulic inadequacy leading to dam overtopping/failure? | Could terrorist action cause the OMS activities to not detect/prevent hydraulic inadequacy leading to dam overtopping/failure?  | Could inadequate operation, maintenance and surveillance fail to detect / prevent hydraulic adequacy and lead to failure of the water barrier?   | Could inadequate operation, maintenance and surveillance fail to detect / prevent hydraulic adequacy and lead to failure of the hydraulic structure?   | Could inadequate operation, maintenance and surveillance fail to detect / prevent failure of the mech/elec system leading to dam collapse by overtopping?  | Could inadequate operation, maintenance and surveillance of the infrastructure and plans cause the OMS activities to not detect /prevent hydraulic inadequacy before leading to overtopping/failure of dam?    |   |
|  |   | Safeguards fail to provide timely detection and correction  | Operation, maintenance and surveillance fail to detect poor dam performance   | Could the meteorological event prevent the OMS rules from being implemented by the DS Engineer leading to dam collapse by loss of strength?  | Could a seismic event cause the OMS rules to not be followed leading to collapse by loss of strength during a seismic event?  | Could the reservoir environment cause the OMS rules to not be followed leading to dam collapse by loss of strength?  | Could terrorist action cause OMS activities to not be followed leading to dam collapse by loss of strength?   | Could inadequate operation, maintenance and surveillance fail to prevent poor dam performance and lead to dam collapse by loss of strength?  | Could inadequate operation, maintenance and surveillance of the hydraulic structure fail to prevent poor dam performance and lead to dam collapse by loss of strength?                                       | Could inadequate operation, maintenance and surveillance of the mech/elec systems fail to prevent poor dam performance and lead to dam collapse by loss of strength?   | Could inadequate surveillance and management of the infrastructure and plans cause the OMS activities to not detect /prevent dam collapse by loss of strength?   |   |
|  | DAM COLLAPSE BY LOSS OF STRENGTH (External or internal structural failure and weakening)  | Crest elevation too low   | Stability under applied loads   | Mass movement (external stability- displacement, tilting, seismic resistance)  | Could loss of strength and static instability occur during a meteorological event and cause dam collapse?   | Could a seismic event cause mass external instability and cause dam collapse?  | Could the reservoir environment cause external instability of the dam leading to dam collapse?  | Could terrorist action cause external instability of the dam and cause dam collapse?   | Could design or construction of the water barrier cause external instability and lead to dam collapse?   | Could the design or construction of the hydraulic structure cause external instability leading to dam collapse by loss of strength?  | Could the design or construction of the mech/elec systems cause external instability leading dam collapse by loss of strength?   | Could inadequate infrastructure and plans cause external instability leading to dam collapse by loss of strength?                                 |
|  |   |   | Stability under applied loads   | Loss of support (foundation or abutment failure)   | Could reduction/lack of support in foundation or abutments during a meteorological event cause dam collapse?  | Could a seismic event cause reduction/lack of support in foundation or abutments leading to dam collapse?  | Could the reservoir environment (debris, ice, landslides) cause foundation or abutment failure leading to dam collapse?   | Could terrorist action cause reduction/lack of support in foundation or abutments and cause dam collapse?  | Could design or construction of the water barrier cause reduction/lack of support in foundation or abutments and cause dam collapse?   | Could the design or construction of the hydraulic structure cause reduction/lack of support in foundation or abutments and lead to dam collapse by loss of strength?   | Could the design or construction of the mech/elec systems cause a reduction/lack of support in foundation or abutments leading to dam collapse by loss of strength?  | Could inadequate infrastructure and plans cause reduction/lack of support in foundation or abutments leading to dam collapse by loss of strength? |
| Watertightness                                       |   | Seepage around interfaces (abutments, foundation, water stops)  | Could seepage around interfaces/abutments/foundation during meteorological event reduce water tightness sufficient to cause dam collapse?           | Could a seismic event cause seepage around interfaces / abutments / foundation reduce water tightness sufficient to cause dam collapse?  | Could the reservoir environment (debris, ice, landslides) cause seepage around interfaces/abutments/foundation and reduce water tightness sufficient to cause dam collapse?                           | Could terrorist action cause seepage around interfaces / abutments / foundation and reduce water tightness sufficient to cause dam collapse?   | Could design or construction of the water barrier cause seepage around interfaces / abutments / foundation and reduce water tightness sufficient to cause dam collapse? | Could the design or construction of the hydraulic structure cause seepage around interfaces/ abutments/ foundation leading to dam collapse by loss of strength?                        | Could the design or construction of the mech/elec systems cause seepage around interfaces/ abutments/ foundation leading to dam collapse by loss of strength?  | Could inadequate infrastructure and plans cause seepage around interfaces/ abutments/ foundation and reduce water tightness sufficient to cause dam collapse by loss of strength?  |  |   |
| Watertightness                                       |   | Through dam seepage control failure (filters, drains, pumps)  | Could through -dam seepage (filters/drains/pumps, internal instability) during a meteorological event reduce watertightness and cause dam collapse? | Could a seismic event cause through dam seepage (filters/drains/pumps) to fail and reduce watertightness and cause dam collapse?   | Could the reservoir environment (landslides, ice, debris) cause through dam seepage control be lost (filters/drains/pumps) and reduce watertightness and cause dam collapse?                          | Could terrorist action cause failure of through dam seepage (filters / drains / pumps) control and reduce watertightness and cause dam collapse?   | Could design or construction of the water barrier cause through dam seepage (filters / drains / pumps) and reduce watertightness and cause dam collapse?                | Could the design or construction of the hydraulic structure cause through dam seepage control failure (filters/ drains/ pumps) and lead to dam collapse by loss of strength?           | Could the design or construction of the mech/elec systems cause through dam seepage (filters/ drains/ pumps) and reduce watertightness and cause dam collapse?   | Could inadequate infrastructure and plans cause through dam seepage (filters/ drains/ pumps) and cause dam collapse by loss of strength?   |  |   |
| Durability/cracking                                  |   | Structural weakening (internal erosion, AAR, crushing, gradual strength loss)   | Could structural weakening (internal erosion, crushing, cracking, strength loss) caused by a meteorological event cause dam collapse?               | Could a seismic event cause internal structural weakening (internal erosion, crushing, cracking, strength loss) and cause dam collapse?  | Could the reservoir environment (landslides, ice, debris) cause internal structural weakening (internal erosion, crushing, cracking, strength loss) and lead to dam collapse?                         | Could terrorist action cause internal structural weakening (internal erosion, crushing, cracking, strength loss) and cause dam collapse?   | Could design or construction of the water barrier cause internal structural weakening (internal erosion, crushing, cracking, strength loss) and cause dam collapse?     | Could the design or construction of the hydraulic structure cause internal structural weakening (internal erosion, crushing, cracking, strength loss) leading to dam collapse?         | Could the design or construction of the mech/elec systems cause internal structural weakening (internal erosion, crushing, cracking, strength loss) leading to dam collapse by loss of strength?             | Could inadequate infrastructure and plans cause internal structural weakening (internal erosion, crushing, cracking, strength loss) and cause dam collapse by loss of strength?  |  |   |
| Durability/cracking                                  | Instantaneous change of state (static liquefaction, hydraulic fracture, seismic cracking) | Could instantaneous change of state occur (Liquefaction, hydraulic fracture) caused by a meteorological event cause dam collapse? | Could a seismic event cause instantaneous change of state to occur (Liquefaction, hydraulic fracture) leading to dam collapse?                      | Could the reservoir environment (landslides, ice, debris) cause instantaneous change of state to occur (liquefaction, hydraulic fracture) and cause dam collapse?                                  | Could terrorist action cause instantaneous change of state to occur (Liquefaction, hydraulic fracture) and cause dam collapse?  | Could design or construction of the water barrier cause instantaneous change of state occur (Liquefaction, hydraulic fracture) and cause dam collapse?                                     | Could the design or construction of the hydraulic structure cause instantaneous change of state to occur (Liquefaction, hydraulic fracture) leading to dam collapse?    | Could the design or construction of the mech/elec systems cause instantaneous change of state to occur (Liquefaction, hydraulic fracture) leading to dam collapse by loss of strength? | Could inadequate infrastructure and plans cause instantaneous change of state occur (Liquefaction, hydraulic fracture) and cause dam collapse by loss of strength?   |  |  |   |