ATTACHMENT 7: DISCUSSION OF MCE AND OBE

Briefing Document
14-13-BD

Discussion of MCE and OBE

1. General

FERC guidelines only establish the requirements for a seismic hazard analysis for a project, but do not give guidance as to the selected ground motions. Until recently, FERC guidelines are based on a deterministic approach in which the maximum magnitude is estimated for each known seismic source. The shortest distance from the dam site to the seismic source is found and the ground motion is computed (typically at the 84th percentile level for high activity sources). This approach has a long history of use. It should be noted that the traditional selection of the 84th percentile implicitly acknowledges that worst case ground motions could be much higher. And by extension, the decision has already been taken that it is not "reasonable" to use a worst case ground motion. Discussions with the Board have included suggestions that – for dams with high hazard classification, the 69th percentile is sometimes recommended for very rare events.

Despite the focus on deterministic events, the draft FERC guidelines describe requirements for both deterministic and probabilistic development of ground motions at sites. Under both approaches, use of the most recent and multiple attenuation, or Ground Motion Prediction Equations (GMPEs), is recommended.

2. Design Criteria

Translation of the results of the hazard analysis into useful design criteria will involve the selection of actual events. In the absence of a classic "risk based approach", various authorities – including the US Army Corps of Engineers, Alaska Dam Safety Program, Federal Emergency Management Authority (FEMA), and International Commission on Large Dams (ICOLD) have published guidelines on the selection of design criteria as described below and all focusing on a design seismic event which produces no interruption in service , and a large event which can cause damage, but not lead to uncontrolled release of water.

3. Corps of Engineers

The current United States Army Corps of Engineers (USACE) guideline for earthquake design is ER 1110-2-1806.

The USACE guidance and direction for the seismic design provides for derivation of the criteria using both deterministic and probabilistic analysis.

USACE defines the following criteria:

1. ***Maximum credible earthquake*** **(MCE).** This earthquake is defined as the greatest earthquake that can reasonably be expected to be generated by a specific source on the basis of seismological and geological evidence. Since a project site may be affected by earthquakes generated by various sources, each with its own fault mechanism, maximum earthquake magnitude, and distance from the site, multiple MCE's may be defined for the site, each with characteristic ground motion parameters and spectral shape. The MCE is determined by a DSHA.

2. ***Maximum design earthquake*** **(MDE).** The MDE is the maximum level of ground motion for which a structure is designed or evaluated. The associated performance requirement is that the project performs without significant failure, such as uncontrolled release of a reservoir, although severe damage or economic loss may be tolerated. For critical features, the MDE is the same as the MCE. For all other features, the MDE shall be selected as a lesser earthquake than the MCE which provides economical designs meeting appropriate safety standards. The MDE can be characterized as a deterministic or probabilistic event.

3. ***Operating basis earthquake*** **(OBE).** The OBE is an earthquake that can reasonably be expected to occur within the service life of the project, that is, with a 50-percent probability of exceedance during the service life. (This corresponds to a return period of 144 years for a project with a service life of 100 years.) The associated performance requirement is that the project functions with little or no damage, and without interruption of function. The purpose of the OBE is to protect against economic losses from damage or loss of service, and therefore alternative choices of return period for the OBE may be based on economic considerations. The OBE is determined by a PSHA

USACE is at present preparing an Engineering Manual EM 1110-2-6000 entitled "Selection of Design Earthquakes and Associated Ground Motions," but it has not yet been published.

4. Alaska Dam Safety Program

Under Alaskan guidelines and jurisdiction, the Susitna-Watana dam would be a Class 1, High Hazard dam, and the design criteria would be dependent on that classification.

Alaska represents the OBE as the event producing ground motions considered to have a reasonable probability of occurring during the functional lifetime of the project. All critical elements of the project must remain functional during the event, and any resulting damage must

be capable of repair "in a limited time." The OBE can be defined based on probabilistic evaluations, with the level of seismic hazard (probability that the amplitude of ground motion will be exceeded during a particular length of time) being determined relative to the hazard potential classification and location of the dam.

Alaska also defines the MDE as the event producing ground motions from the most severe earthquake considered at the site, relative to the acceptable consequences of damage in terms of life and property. All critical elements of the dam and appurtenant structures for which the collapse or failure could result or precipitate an uncontrolled release of the reservoir must be designed to resist the MDE. In addition, the dam and appurtenances must be designed to resist the effects of the MDE on the reservoir and reservoir rim. The MDE may be defined based on either deterministic or probabilistic evaluations, or both.

For a Class I hazard dam, probabilistic return periods (inverse of the seismic hazard) considered appropriate for defining the OBE and MDE are:

OBE	150 to >250 yrs.
MDE	2,500 yrs. to MCE

Within the context of these ranges, the OBE should be selected in direct correlation with the frequency of regional earthquakes, the estimated useful life span of the facility, and the difficultly of quickly accessing the Susitna-Watana site for repairs. The return period selected for the MDE should be selected based on in direct correlation with the magnitude of the MCE for the known or suspected regional sources

5. FEMA Definitions

Published FEMA guidelines are generally in accordance with FERC guidelines, but do include terminology definitions similar to USACE, as follows:

1. ***Maximum Credible Earthquake (MCE).*** The MCE is the largest earthquake magnitude that could occur along a recognized fault or within a particular seismotectonic province or source area under the current tectonic framework. The loading resulting from the MCE can and often is exceeded for Probabilistic Methods for high return period faults close in, such as the San Andreas Fault in California.

2. ***Maximum Design Earthquake (MDE) or Safety Evaluation Earthquake (SEE).*** This is the earthquake that produces the maximum level of ground motion for which a structure is to be designed or evaluated. The MDE or SEE may be set

equal to the MCE or to a design earthquake less than the MCE, depending on the circumstances. Factors to consider in establishing the size of MDE or SEE are the hazard potential classification of the dam (FEMA 1998), criticality of the project function (water supply, recreation, flood control, etc.), and the turnaround time to restore the facility to operability. Guidance on selecting the MDE and SEE is contained in paragraph C.3. In general, the associated performance requirement for the MDE or SEE is that the project performs without catastrophic failure, such as uncontrolled release of a reservoir, although significant damage or economic loss may be tolerated. If the dam contains a critical water supply reservoir, the expected damage should be limited to allow the project to be restored to operation in an acceptable time frame.

3. ***Operating Basis Earthquake (OBE).*** The OBE is an earthquake that produces ground motions at the site that can reasonably be expected to occur within the service life of the project. The associated performance requirement is that the project functions with little or no damage, and without interruption of function. The purpose of the OBE is to protect against economic losses from damage or loss of service. Therefore, the return period for the OBE may be based on economic considerations.

Note FEMA defines the SEE as the same as the MDE

6. International Commission on Large Dams (ICOLD) Guidelines

The International Commission on Large Dams (ICOLD) is a non-governmental international organization which provides a forum for the exchange of knowledge and experience in dam engineering. ICOLD publishes bulletins on a regular basis that include recommended standards and guidelines, the most recent bulletin focused on the seismic aspects of dam design was Bulletin 72, Guidelines for Selecting Seismic Parameters for Large Dams (2010).

This bulletin presents two earthquake events to evaluate the seismic hazard. The first is the SEE, which is defined as a level of shaking that allows for some damage to the dam so long as there is no uncontrolled release of water from the reservoir. ICOLD further recommends that the SEE be taken as the maximum of the probabilistically and deterministically-evaluated ground motions, with a very long return period for the selection of the probabilistic analysis (10,000 years). However, ICOLD does leave their recommendations open ended (essentially embracing a risk-based approach) by stating that:

> *"Where there is not a great risk to human life the SEE may be chosen to have a lower return period depending on the consequences of dam failure."*

The second earthquake event used to evaluate the seismic hazard is the OBE, which represents the level of ground motion for which only minor damage is acceptable. ICOLD recommends that a minimum return period of 145 years (50% probability of being exceeded in 100 years), but again allows for some interpretation in this selection. In theory, OBE can be determined from an economic risk analysis but this is not always practical or feasible.

7. Other Authorities

Other Authorities, such as the Bureau of Reclamation, no longer use the deterministic approach and so their criteria do not easily fall into the concepts described above.

8. Approach for Susitna-Watana

So far the discussion on the criteria for Susitna has focused on the seismic event selected for the Maximum Credible event. Approaches were made to FERC to adopt a risk based approach, but they were unwilling to consider that. In the event the interim results of the seismic hazard analysis and MWH analysis of rare subduction zone events was presented to the Board of consultants and FERC during the 4th BoC meeting in April 2014.

The Board of consultants, after listening to MWH analysis of subduction zone events, commented that:

> *"The BOC is generally satisfied with the deterministic estimates of M_{max} (i.e., 7.5, 7.8, and 8.0) and the associated level of ground motions (i.e., 84th % for 7.5 and 69th % for M7.8 and M8.0) for the intraslab events. However, the BOC considers that the magnitude of 7.5 is a more defensible MCE for the dimensions and historical activity of the McKinley Block beneath the site; and recommends that a M_{max} of 7.5 at the closest hypocentral distance and 84th percentile deterministic ground motion (PGA of 0.76g) be adopted for the feasibility/design"*

MWH intends to adopt these recommendations for the MCE for the feasibility design. Therefor the dam structure is being analysed to this criteria but the model will be allowed to crack and displace as long as there is no uncontrollable release of water. In addition to the use of the MCE as the MDE(SEE) for the structural analysis of the dam, the same event will be used in any analysis of particular key facilities such as the spillway gates and operating mechanism, and the low level outlets and mechanisms so that in the event of damage, the reservoir can be evacuated. If no structural analysis is performed, the detailed design criteria will reflect this requirement for future detailed design.

More challenging is the selection of the OBE. According to the published guidelines discussed above, the normal choice of OBE would be the earthquake that can reasonably be expected to occur within the service life of the project, that is, with a 50-percent probability of exceedence during the service life. (This corresponds to a return period of 144 years for a project with a service life of 100 years.). For Susitna- Watana such an event would equate to a PGA of the order of 0.16g, which might be unacceptably low to the general public who are not conversant with civil and structural design. The following are the PGAs for selected return periods:

Return period, years	PGA
100	0.13g
150	0.16 g
500	0.27 g
1000	0.37 g

MWH recommends that the OBE be selected as the 500 year event, equating to a PGS of 0.27g. The dam structure will be evaluated under this event and from a structural perspective all facilities will be able to continue to operate without interruption of significant repair.

9. Conclusion

The selected MCE for the dynamic analysis of the dam, and for use as the detailed design criteria for the spillway gates, piers, and low level outlets should be such as to produce a PGA of 0.76 g.

The selected OBE for the project structural analysis, and for which no damage shall be accepted should be the 500 year event, sufficient to produce a PGA of 0.27 g.