Earthquakes and the Susitna-Watana Hydroelectric Project

by Bretwood Higman, Erin McKittrick, Andrew Mattox

LAST MODIFIED: 12TH AUGUST 2019

CREATED: JAN. 19, 2018

Ground Truth Trekking

Table of Contents

Overview

The proposed Susitna-Watana dam (/Issues/Renewable-Energy-in-Alaska/Susitna-Hydro-Dam.html) site lies in a seismically active area, 45 miles from the Denali Fault, which produced a magnitude 7.9 earthquake in 2002. Careful geological study will be necessary to fully understand seismic risk in the area.

There are many unknowns about nearby faults. Incomplete geologic understanding of seismic threats or inappropriate engineering of Susitna-Watana could lead to dam failures caused by earthquake shaking, movement along faults below a dam, or earthquake-generated reservoir tsunamis. Failure could lead to downstream flooding, affecting downstream communities and the environment. The loss of power and downstream sedimentation could add additional economic and environmental impacts.

WATANA CANYON — Susitna River: From Glaciers to the Sea. Leg 2: Damsite and Devil's — Get Photo (/photos/watana-canyon/)

Large concrete hydroelectric dams have an excellent record of seismic safety. No dam of this scale and type has catastrophically failed as a result of earthquake shaking. The engineering responses to common earthquake effects are well understood (http://www.iitk.ac.in/nicee/wcee/article/14_S13-049.PDF), and concrete hydroelectric dams are usually conservatively designed, making them able to withstand stresses greater than those which are geologically expected.

Catastrophic dam failures related to earthquakes historically been in small and/or earthen dams (http://pubs.usgs.gov/of/1985/0560/report.pdf).

That said, accurate estimation of earthquake hazard is essential for conservative engineering, since good engineering cannot offset inadequate design specifications. The history of large dam building is short, and the Susitna-Watana proposal poses some unique challenges. The majority of current dams of this type are built in areas that are less seismically active (http://www.nehrp.gov/pdf/ACEHRNov2010_USACE.pdf). Relatively few large dams have experienced powerful earthquakes. Our case-knowledge of the aging of massive concrete structures like the proposed Susitna-Watana dam is less than 100 years, and only since the 1970s (http://www.iitk.ac.in/nicee/wcee/article/14_S13-049.PDF) have dams been built based on a modern understanding of earthquake shaking. Finally, given the potential for Susitna-Watana to be a dominant source of electricity on Alaska's Railbelt, even partial failures related to seismicity could lead to substantial economic impacts, if redundant generation is also heavily impacted or is of substantially higher cost.

It is possible a fault could pass very near or even beneath the dam site. Many faults do not display earthquake activity, but determining a fault's true risk potential can be very difficult, particularly in seismically active areas.

General Seismic Hazards Associated with Large Hydroelectric Dams

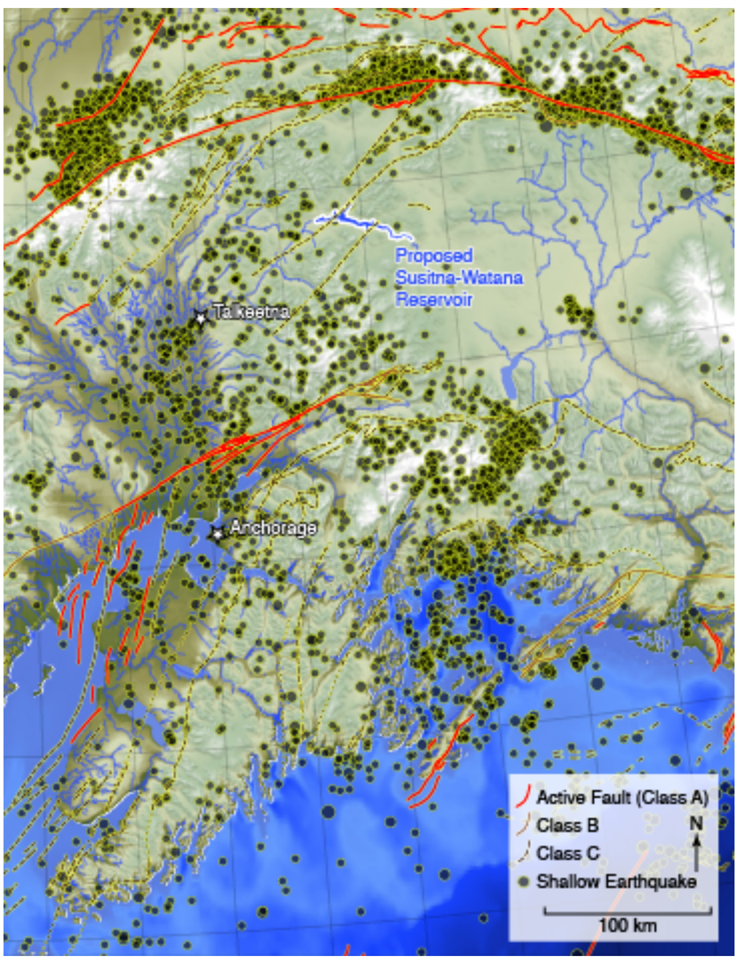
Strong earthquake shaking puts large forces on dams. If forces exceed what a dam is engineered for, dam failure may result, as happened at Japan's Fujinuma Dam (http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Tohoku_Japan_2011/QR5_Preliminary%20Observations%20of%20Fujinuma%20Dam%20Failure_(after the 2011 earthquake.

Direct shaking can have a complex impact (http://www.iitk.ac.in/nicee/wcee/article/WCEE2012_0383.pdf) on massive concrete structures , but engineering to withstand shaking is well-developed. More unusual problems can occur if movement on faults shifts a dam foundation, potentially opening cracks in the dam or weakening contact between the dam and surrounding bedrock. Failure for either reason could lead to downstream flooding. The loss of power and downstream sedimentation could add economic and environmental impacts.

Tsunamis can be generated by landslides or earthquakes in the reservoir. An extreme example occurred at Vaiont Dam (http://en.wikipedia.org/wiki/Vajont_Dam), in 1963, when a landslide-generated tsunami overtopped the dam and destroyed a town.

The filling of large reservoirs often triggers small earthquakes, due to water lubrication of faults and the weight of reservoir. Such earthquakes are typically of magnitude 6 or less (http://

www.sciencedirect.com/science/article/pii/S0074614202802431), and would probably have minimal impact in the Susitna-Watana area, which is already subject to larger earthquakes. However if the stored seismic energy is large enough, reservoir filling can trigger larger earthquakes, as likely happened (http://probeinternational.org/library/wp-content/uploads/2012/12/Fan-Xiao12-12.pdf) with a 2008 magnitude 8 earthquake in Zipingpu, China.



TECTONICS IN THE REGION AROUND SUSITNA (/figures/tectonics-earthquakes-faults-susitna/) — Faults and shallow earthquakes in the region surrounding this proposed Susitna-Watana hydroelectric reservoir.

Specific Seismic Hazards to Susitina-Watana

The Susitna-Watana hydroelectric project sits atop actively deforming crust which is subject to frequent earthquakes. Active faults have been identified north of the proposed reservoir and shallow seismic activity in the area suggests that more exist. Surface evidence suggests the proposed dam site itself may be underlain by a fault. A rupture beneath the dam could shift the dam foundation and lead to damage or possibly dam failure.

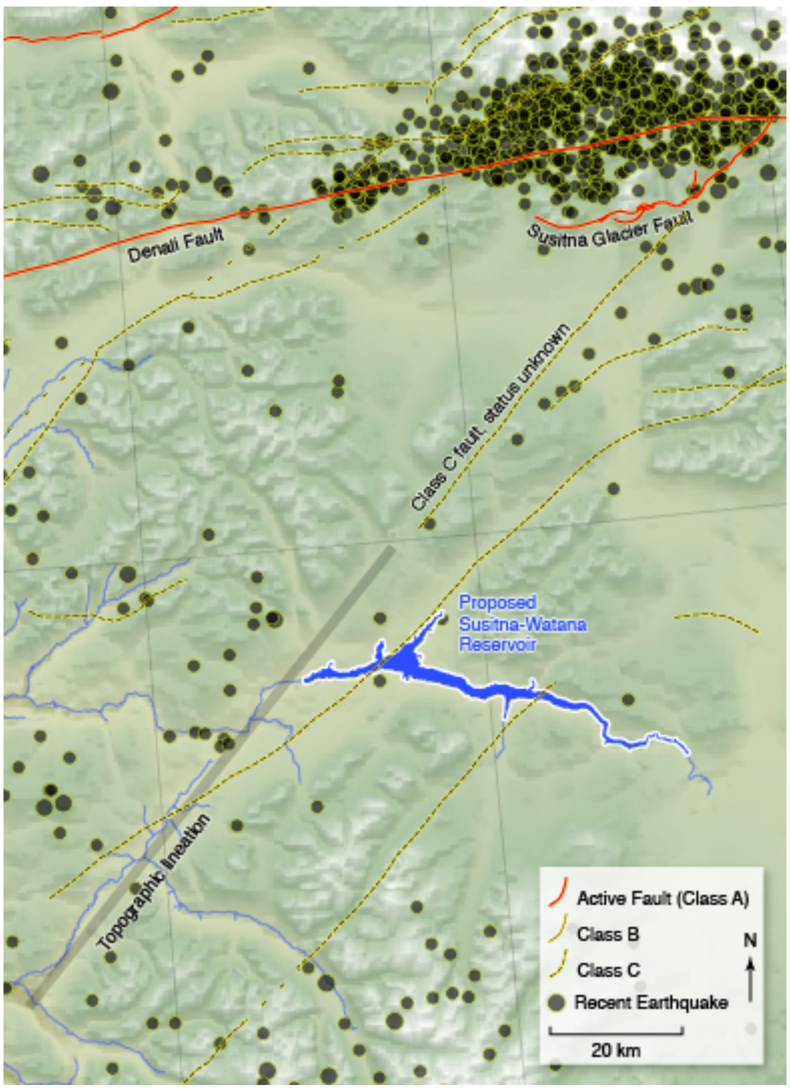
The proposed reservoir would cross another mapped fault of unknown status. An earthquake on this fault or another unknown fault might lift or tilt a portion of the reservoir, generating a tsunami. A landslide on steep slopes that would be partly or entirely inundated by the reservoir could also generate a tsunami.

Assessing and Minimizing Seismic Risk at Susitna-Watana

Geological Investigation

The region of the proposed dam site needs thorough investigation for seismic risk. Earthquake-generating faults can display little or no surface evidence of their potential, as demonstrated by recent earthquakes in Haiti (ftp://ftp.cc.purdue.edu/pub/eas/calais/NG_PAPER/haiti_eq_revised.pdf) and New Zealand (http://

srl.geoscienceworld.org/content/82/6/789.extract). Even where surface evidence may be present, it can easily be missed by geologic investigation, as happened with the Susitna Glacier fault prior to its rupture in 2002. A lack of obvious evidence of surface ruptures is insufficient to conclude that there are no active faults in areas where critical infrastructure is proposed.



TECTONICS NEAR THE PROPOSED SUSITNA-WATANA RESERVOIR (/figures/susitna-watana-hydropower-seismic-earthquake-hazards-map/) — Detailed tectonics near the proposed Susitna-Watana Reservoir, highlighting a lineation that could be associated with a hazardous fault.

Dam & System Design

If movement along a fault passing through the dam site is identified as a risk, dam design will need to account for deformation of its foundation. Regardless of local geology, any dam at Susitna-Watana must be designed to withstand strong shaking from the Denali Fault, and other potentially active faults in the vicinity. The dam, connected power grid, and associated facilities must also be designed to withstand associated or indirect effects of an earthquake, such as sudden loss of the dam's grid energy contribution if its turbines or transmission lines are damaged.

Lifecycle Planning

Susitna-Watana would likely be built with a functionally indefinite lifespan (http://civil.colorado.edu/~saouma/AAR/Library/Paris-2009/Charlwood/Predicting-long-term.pdf), meaning it will continue in some form of operation through the foreseeable future, until the reservoir fills with silt. Modern techniques for building long-life dams theoretically enable society to reap the maximum return on dam investments, but also necessitate a very long planning horizon. Relatively long-recurrence seismic events must be considered, such as 500- or 1000-year earthquakes.

As with perpetual waste storage (/Issues/OtherIssues/perpetual-waste-storage-perpetuity.html), hydroelectric dams are likely to last long enough that conventional financial planning and hazard analysis must be extrapolated beyond their empirical basis.

Further Reading

> Large Dams the First Structures Designed Systematically Against Earthquakes (http://www.iitk.ac.in/nicee/wcee/article/14_S13-049.PDF)

> Presentation slides for: USACE Earthquake Research & Implementation Activities (http://www.nehrp.gov/pdf/ACEHRNov2010_USACE.pdf)

> Current Seismic Safety Requirements for Large Dams and their Implication on Existing Dams (http://www.poyry.ch.mosaic.fi/sites/www.poyry.ch.mosaic.fi/files/current_seismic_safety_requirements_for_large_dams_0408.pdf)