Earth Consultants International

Project No. 3104
April 15, 2011

To: **Lozeau | Drury LLP**
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Oakland, California 94607

Attention: **Michael R. Lozeau**

Subject: **Geologic Review of Potential Faulting and Tsunami Inundation Hazards for the Homewood Resort Project**

Introduction:

This letter was prepared at your request to review and comment upon the faulting and tsunami sections of the Homewood Resort EIR and supporting geotechnical reports by Holdridge and Kull. I was not able to review the earlier geohazards report prepared by Kleinfelder, and referenced in the Holdridge and Kull (2010a) report. The two Holdridge and Kull geotechnical reports that I did review (2010 a&b) do contain a general geological discussion, and are signed by two licensed geologists, but they do not contain even a geologic map for the proposed projects, let alone cross-sections, a quantitative geologic analysis of the sites, or even current geologic references. The majority of my information therefore came from independent sources, readily available papers in published journals, and easily located through internet search engines. I am disappointed with the rigor apparently applied to researching and discussing the faulting, seismic, and tsunami hazards sections of either the geotech reports or the EIR. In my opinion, this falls well below the level of practice I expect, especially for a significant project.

Lake Tahoe and the Tahoe Basin have been created by episodic, differential displacements across a suite of generally north-south trending faults (Figure 1). Although the faults were always suspected of being geologically young, it is really only in the past decade that research has begun to both confirm, and generate quantitative results on just how active they are. In essence, the paradigm of seismic hazards and vulnerability of the Tahoe Basin is in flux, and that hazard is definitely increasing. It is therefore unfortunate that the Homewood Resort's EIR relies on generally older references to the seismic hazards, sources which have mostly been superseded by more recent, and more technically advanced, studies. That the two geotechnical engineering reports do not provide this information either probably made the EIR preparer's task more difficult.

The geotech reports and the EIR are completely silent on the potential hazard generated by an earthquake-induced or a landslide-induced lake tsunami or seiche. This is an issue, that while unlikely, has definitely occurred multiple times in the geologic past, obviously has the potential to occur in the future, and has received significant media attention, both locally and nationally. Since this is a resort project, the majority of the users would likely be from out of the area. The 2004 Indonesian tsunami clearly demonstrated that coastal tourists are a highly vulnerable population because they are unaware of the hazard, have no recognition of the warnings, and have no idea how to respond if they did. For the EIR to fail to even mention the word tsunami, let alone discuss its potential to be an impact to the project, is stunning.

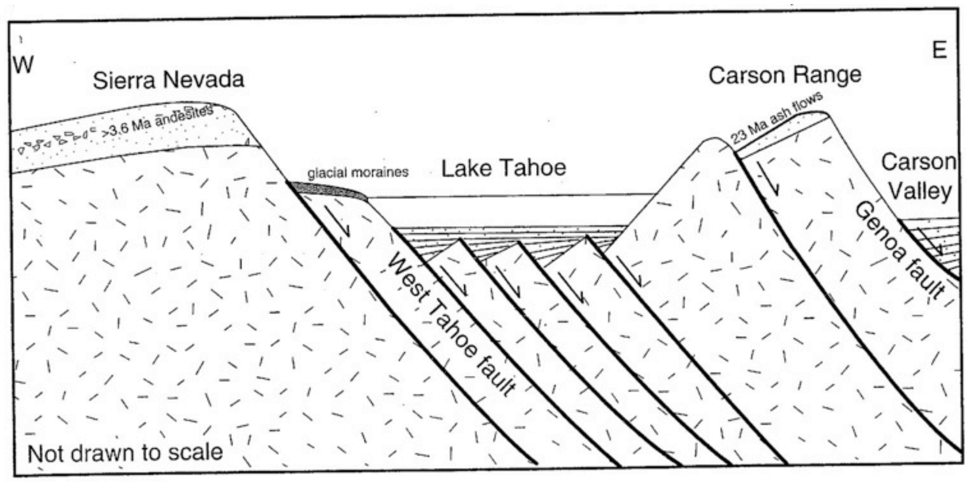


Figure 1: Structural geometry interpreted from recent seismic reflection and bathymetric data showing the basin to be a half-graben (Schweickert et al., 2004). Note the presence of a major boundary fault to the west of the West Tahoe fault, and west of the Lake Tahoe lake shore. Absent fault-specific geologic investigations, no one could preclude that any or all of these faults are active Holocene structures.

Faulting:

On Page 14-8, the EIR makes a point that the Unnamed Fault #1 (Figures 2 & 3) is shown as a Quaternary-age fault on the more recent Geologic Map of the Lake Tahoe Basin (Saucedo, 2005), but they make more of a point that the fault is not shown on the older geologic map of the Chico Quad (Saucedo and Wagner, 1992). The obvious interpretation is that Unnamed Fault 1 was discovered during the significant focus on Lake Tahoe seismic studies in the past decade. Indeed, the newer map is authored by the same geologist. Who better to revise their own work? This does not make it a new fault, it has been there all along, but it had not been mapped during the prior work. This is a frequent (though unfortunate) event in geology, because while the science builds on the past work, it progresses from new exposures, new understanding of processes, and new expertise being applied. In this case, I would note that it was from studies focused on the seismic hazards of Lake Tahoe that identified this fault, that mapped this fault, and that consider it to be at least a Quaternary-age fault, which makes it "potentially active" under California A-P regulations.

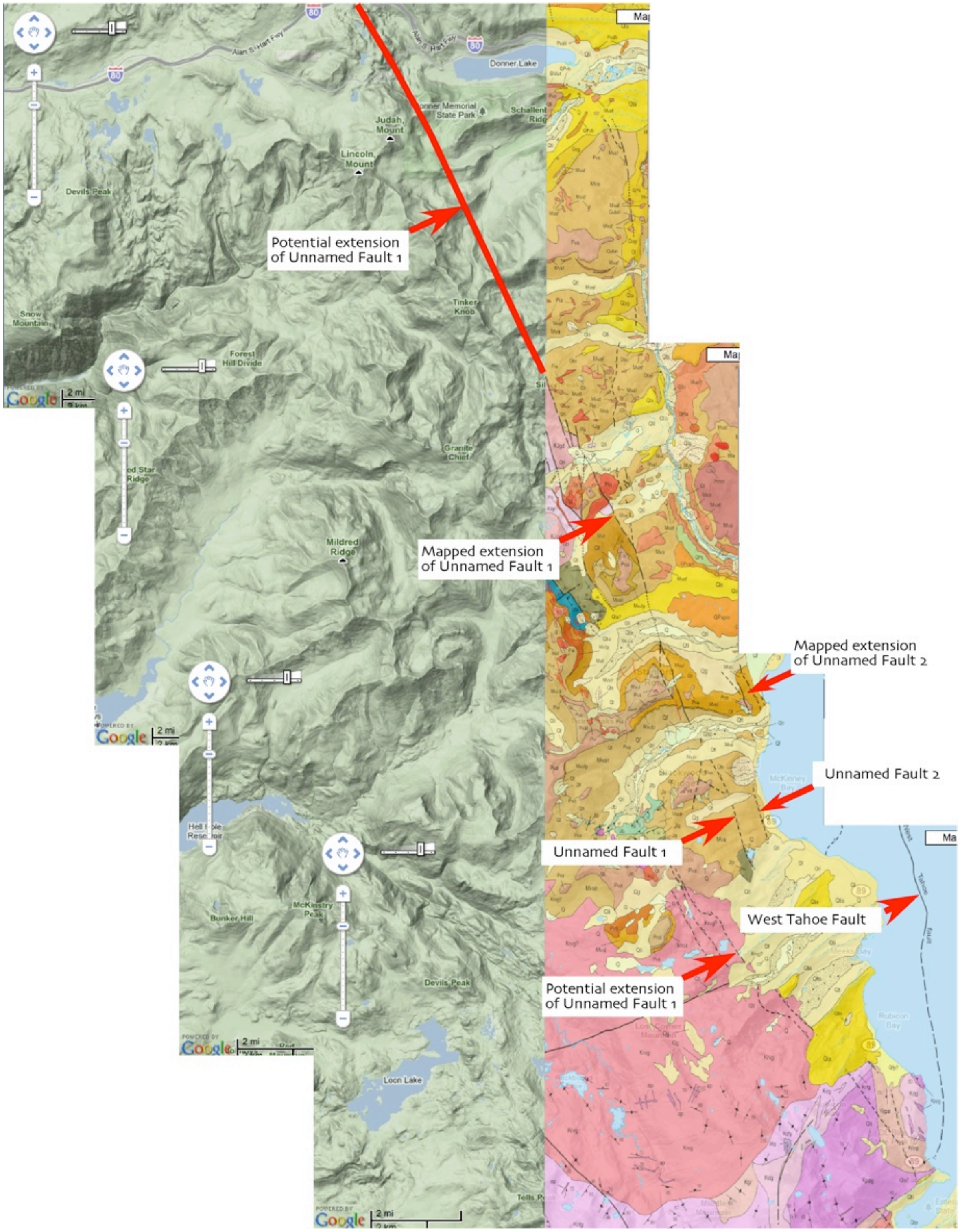
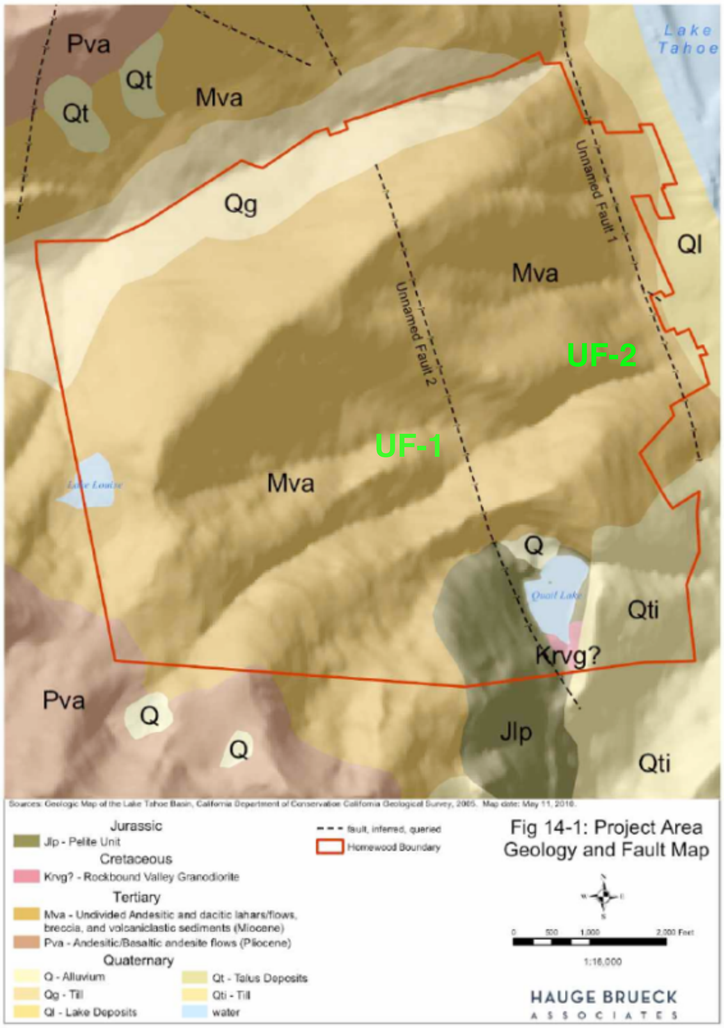


Figure 2: Annotated geologic map of the western side of Lake Tahoe, labeled to show the primary fault systems, and a potential northward extension of the Unnamed Fault 1. Modified from Saucedo, 2005, and available at http://www.quake.ca.gov/gmaps/RGM/tahoe/tahoe.html

The EIR also states that the fault is short and discontinuous, making the hazard low for it to be big enough to be hazardous. This is neither accurate nor true. The Unnamed Fault 1 has been mapped at least another 5.5 miles north of the project site (to the limits of the Tahoe Basin mapping), and the geomorphology of the fault can be interpreted for at least 4.5 more miles past the map limits (Figure 2). Furthermore, the southern termination of the Unnamed Fault 1 can (and should) be interpreted as stepping to the west onto another unnamed fault system that continues an additional 5 miles southeast before joining with the West Tahoe Fault in Emerald Bay (Figure 2).

In my opinion, Unnamed Fault 1 is <u>the</u> west bounding fault system for the Tahoe Basin graben (Figure 1 and 4). It has a total length of at least 15 miles, it controls the location of Quail Lake (Figure 3), it ties directly into the known active fault through the lake (West Tahoe fault), it is identified as potentially active, and it has major hazard implications for the project that have never been quantitatively addressed.

Figure 14-1. Project Area Geology and Fault Map



Sources: Geologic Map of the Lake Tahoe Basin, California Department of Conservation California Geological Survey, 2005. Map date: May 11, 2016.

Figure 3: Modified geologic map of the site as taken from the EIR report. The map shows the two faults across the site, but it has the fault name labels reversed from the text of the report. Based on the text of the EIR report, Unnamed Fault 1 lies on the west, and Unnamed Fault 2 is to the east. This is the convention used in this letter and relabeled in green on the figure. UF-1 forms the western boundary of Quail Lake, leaving open the question of whether Holocene movement on the fault is responsible for the creation of the lake. UF-2 lies parallel to the shoreline of the lake along a break in slope that leaves open the question as to whether that geomorphic feature is a fault scarp.

Unnamed Fault 2 (Figures 2 and 3) is in a similar category. The fault is considered to be Quaternary in age, making it potentially active according to the A-P Act and as stated in the EIR. it appears to form the margin for the lake level of Lake Tahoe (Figure 2), indicating that it may be an active structural feature controlling the shoreline location (Figure 3). The EIR even states that the fault is located along a break in slope. This geomorphic feature is presumably formed of the surficial (and therefore young) deposits that underlie this eastern part of the project (Figure 3). Is this "break in slope" a fault scarp, which, when combined with the young deposits, would certainly make this a Holocene-age feature? No matter what it is, it is inconceivable that the presence of a potentially active fault, lying parallel and proximal to a known active fault, and coincident with a scarp-like geomorphic feature, would not trigger a competent and professional geologic investigation.

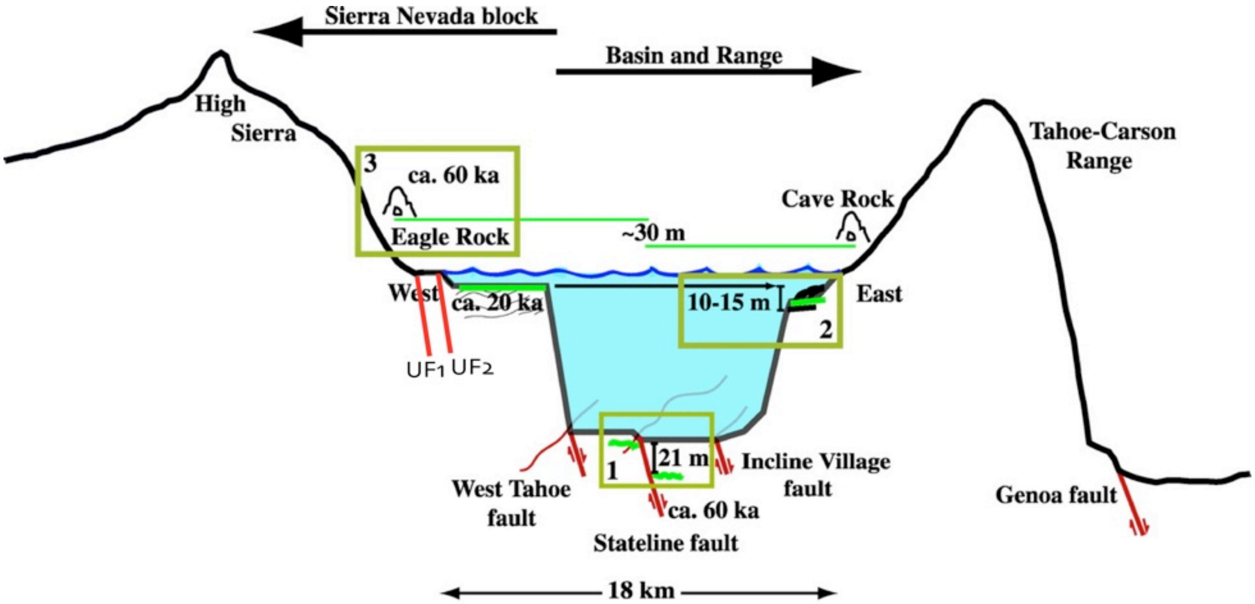


Figure 4: Schematic cross section across the Tahoe basin showing relations of the 10 m offset of ~20 ka submerged shorelines and 21-25 m offset of the 60 ka McKinney Bay landslide (Kent et al., 2005). The original figure has been modified to show the approximate locations of the Unnamed Faults 1 and 2 that trend across the site on the western side of Lake Tahoe.

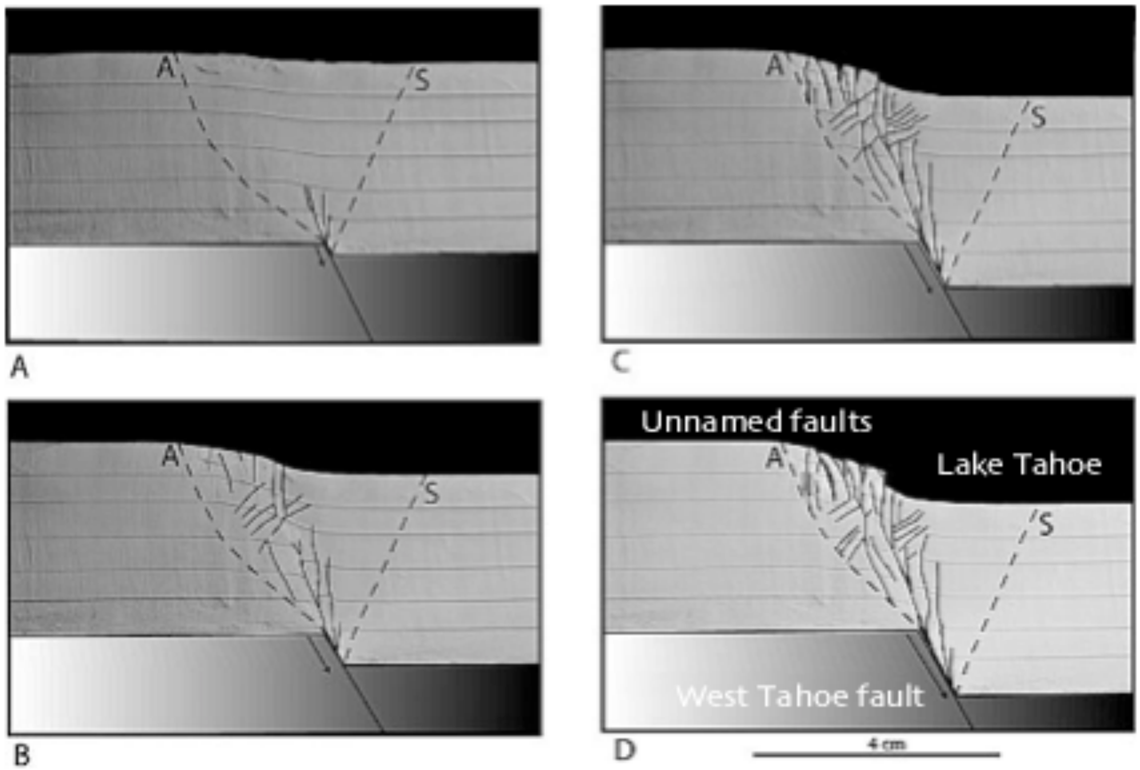


Figure 5: Experimental results of oblique (strike slip and extensional) faulting through a layered clay model. The results clearly demonstrate the messy nature of immature faulting, wherein dozens of secondary fault structures are created, any of which may be reactivated in a major event on the main fault. As slip accumulates and the fault system "matures", a dominate fault emerges and the slip on the secondary faults diminishes. In the figure above, consider the real world case where the main fault is the West Tahoe fault, and the secondary faults to the left are the zone of faults that comprise the Unnamed Faults 1 and 2, as hypothetically labeled in D. Figure modified only by insertion of analogy labels from Miller and Mitra, 2011.

That these two faults have not been incorporated into an A-P Zone may be due to several factors: 1) the CGS is not currently working on A-P zones in the Tahoe area since these faults were discovered, or 2) no one has yet trenched the faults to quantify their recency of activity. The three principal fault strands now recognized from the high-resolution bathymetry in the Tahoe basin include the West Tahoe-Dollar Point, Stateline-North Tahoe, and Incline Village faults, but only the Incline Village fault has been trenched to reveal its paleoseismic history (Figure 6). The last event on the Incline Village fault has been dated to about 500 years ago. Whether this segment of the Tahoe Basin fault zone ruptured separately, or was linked in a cascading rupture spanning multiple fault segments, is unknown.

The only way to definitively confirm or refute a fault rupture hazard on these two potentially active faults is to conduct exploratory geologic trenching similar to that done for the Incline Village fault (Figure 6). The boreholes and test pits conducted for geotechnical engineering and hydrogeological analysis are totally inadequate for active fault determination. The standard of practice for fault investigations requires that the fault actually be exposed in direct contact with sediments which are of a suitable age to show the timing of the last fault rupture. Selection of the trenching sites for such studies require a consideration of the fault's kinematics (anticipated sense of movement), the geologic conditions along the fault, the age of the sediments, and the hydrogeology. Since the state's A-P Act has defined an active fault as one which has displaced sediments of Holocene age (about the last 11,000 years), it is therefore necessary to expose the fault trace as overlain by sediments at least that old in order to conclude that the fault is not active. If the sediments are younger than 11,000 years, and are impacted (offset) by the fault, then the fault is considered active and structural setbacks from occupied buildings are required, and additional design impacts (especially infrastructure) should also be evaluated. If the faults are determined to be active, then additional trenching will be necessary to accurately track the fault locations across the site and to define an appropriate width for the setback zones; which may vary with fault zone complexity changes across the site.

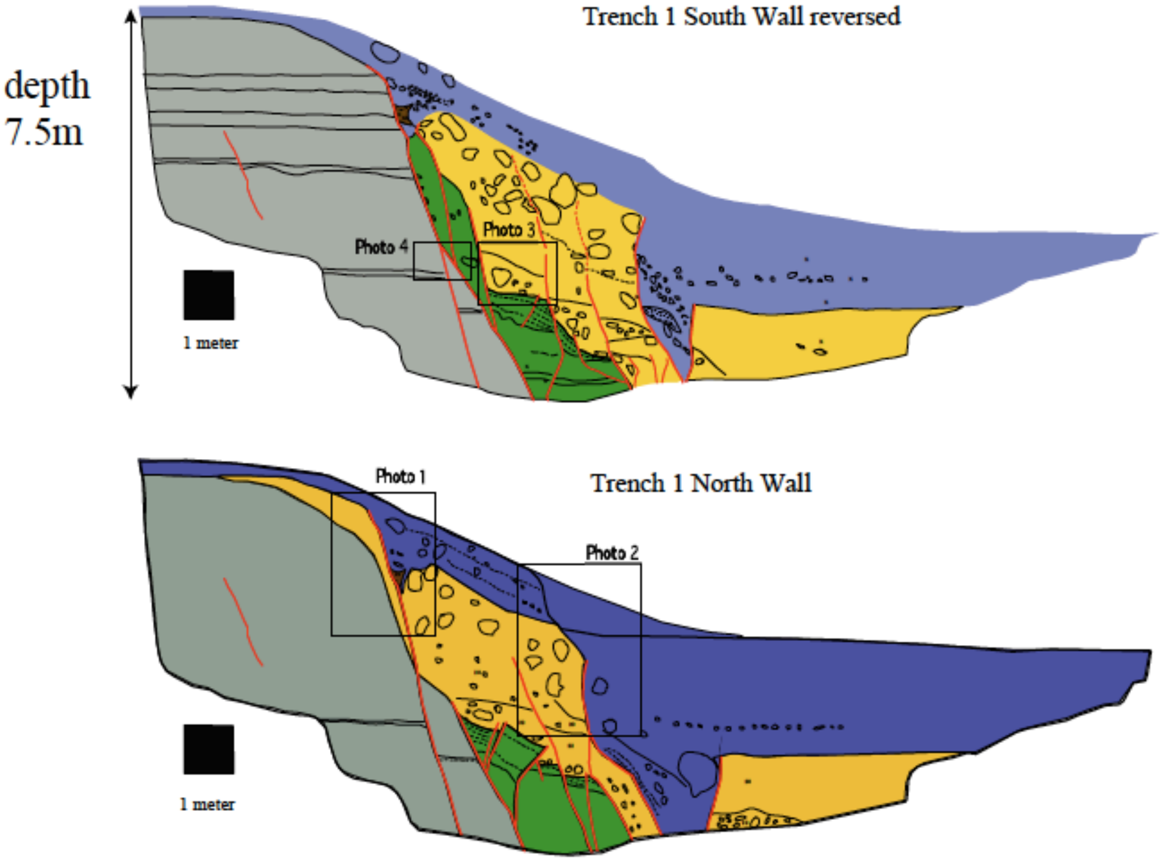


Figure 6: Geologic logs of the paleoseismic trenches excavated across the Incline Village fault, showing the scarp derived colluvial deposits on the hanging wall block. Blue: most recent event deposits, Yellow: penultimate event deposits, Green: triultimate deposits. Figure from Seitz and Kent, 2005.

However, instead of trenching to determine if the faults are active or not, the criteria as to whether there is a fault hazard across the site appears to have been decided solely upon whether the California Geological Survey had previously A-P zoned the faults or not. Perhaps the CGS made an incorrect assessment based on limited exposures, or (more likely) has not even reviewed them yet? There is no evidence that any independent geological analysis occurred either in the preparation of the geotechnical report, or in the analysis for the EIR, as to whether these faults posed a hazard. The faults are identified as "potentially active" because they apparently affect Quaternary-age units, and this alone should have triggered a geologist to question (and to investigate) whether they had evidence of Holocene-age displacement or not. Whether required by the A-P Act or not, a prudent professional geologist would certainly recommend that their client investigate a potentially active fault hazard in sufficient detail as to determine whether it poses a surface rupture hazard to the project. If such an action is not included in the geotechnical site reports, it calls into question the ability of the EIR to evaluate the project's feasibility, because the impact of an active fault (or two) bisecting the project certainly must be included as a factor into a project's design and feasibility analysis.

The most recent assessment of the basin-wide seismic strain results in a cumulative extension rate of 0.52-0.99 mm/yr (Dingler et al., 2009). While this may sound trivial, it means that in 1000 years, approximately 1 meter of strain is accumulated. One meter of strain released in an earthquake would generate an earthquake magnitude of about 6.5-6.7. That means that across all of the faults in the Tahoe Basin (Figures 1 and 4), there should be the expectation of a large magnitude earthquake, on average, every millennia. It is possible that the earthquake recurrence is longer than 1000 years, but if so, the earthquakes would be larger (2000 years = 2 meters = M~7). It appears that a large earthquake ruptured the Incline Village fault segment about 500 years ago (Figure 6), and that the West Tahoe fault ruptured about 4,000 years ago (Brothers et al., 2009), but what is the timing of the last earthquake on the other faults? And, in particular, what is the relationship to the potentially active Unnamed Faults that trend through the Homewood project site to the known active fault West Tahoe fault? Unless a competent geologic and paleoseismologic investigation is completed for these "unnamed faults" across this project, we will likely never know until the next earthquake.

Tsunami:

The tsunami hazard for the properties surrounding Lake Tahoe has received considerable media attention in the last few years, based on a series of studies of the geological record of past tsunami events within the Tahoe Basin (Gardner et al., 2000; Ichinose et al., 2000; Moore et al., 2006; and Schweickert et al., 2004).

Ichinose et al. (2000) modeled the lake basin deformation from Mw 7.0-7.2 earthquakes on the Tahoe basin faults and estimated that tsunami wave amplitudes could be between 3 and 10 m, depending on the shoreline geometry around the lake. At the Homewood project site, they model a 3.5 to 6.0 meter wave height runup (Figure 7). While still somewhat controversial, Gardner et al (2000) proposed that a large earthquake on the Tahoe basin faults triggered the McKinney Bay mega-slide [Schweickert et al. (2004) estimated a Holocene age for the event], and modeled that the landslide could have produced a tsunami wave more than 100 m in height.

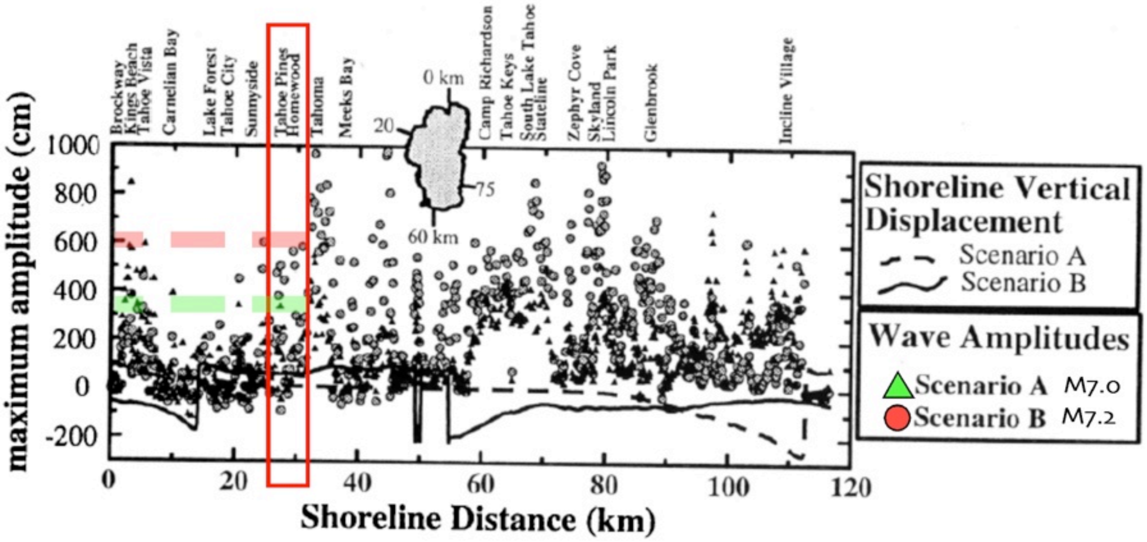


Figure 7: Modeled tsunami runup heights around Lake Tahoe, based on two plausible earthquake magnitudes for Tahoe Basin faults. The Homewood project site location is shown in the red box. Based on magnitude 7.0 and 7.2 earthquakes, the predicted runup heights of a tsunami wave are 3.5 and 6.0 meters, respectively, at the project site. Figure modified from Ichinose, et al., 2000.

While it is acknowledged that the McKinney Bay mega-landslide and tsunami event (Gardner et al., 2000) is highly implausible, and the earthquake-induced lake-bottom tsunami of Ichinose (et al., 2000) is also unlikely, their omission from discussion in the EIR is unacceptable. The 3.5-6.0 meter tsunami event is the expected result of a rupture of the basin's faults across the lake bottom, and the possibility of this event must be disclosed and potential mitigation measures discussed. In California, the definition of an active fault is one which has had surface rupture within the Holocene (about the last 11,000 years) time period. The faults of the Tahoe Basin certainly qualify under this definition, the seismic hazard for the Tahoe Basin could expect a large earthquake on a millennial scale, and a plausible scenario is for the lake-bottom faults to rupture together in a chain reaction (a "cascade" event), leading to generation of the tsunami.

Summary:

Although this was only a brief review, I hope that some of the material herein is useful to you in your analysis of the project's geologic and seismic hazard setting. I was quite frankly stunned to find that the two faults were considered as "potentially active", that the geotechnical reports were signed by two licensed professional geologists, and that neither they, nor the EIR team, ever considered it necessary to prove that the two faults across the site posed no hazard. Indeed, when I consider that these two faults have geomorphic expression, that they splay from the proven to be active West Tahoe fault only 5 miles to the south, and that they seem to be part of a significant, sub-parrallel fault zone that forms the western margin of the Tahoe Basin, I would strongly urge that they be considered as "active" faults unless proven otherwise. If active, they pose a significant design constraint that is never considered in the EIR's feasibility or hazard analysis. As for the tsunami hazard, it is simply inconceivable that neither the geotechnical nor the EIR reports even mention it as a possibility. I thought that the entire world became sensitive to tsunami hazards after the 2004 Indonesian earthquake, and indeed the Tahoe Basin spawned several tsunami hazard studies in the last decade, all of which demonstrated that it is a geologic event that has occurred before around the lake. But, there is no mention of it at all in the hazards analysis of the EIR. Perhaps the 2011 Japanese earthquake and tsunami will trigger someone to require that the EIR at least examine the tsunami hazard potential for this project.

I appreciate the opportunity to do this review for you. If you have any questions or desire just to talk about something in this letter, please do not hesitate to call me at [714-412-2653] or email at [gath@earthconsultants.com] me.

Respectfully submitted,

EARTH CONSULTANTS INTERNATIONAL, INC.

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