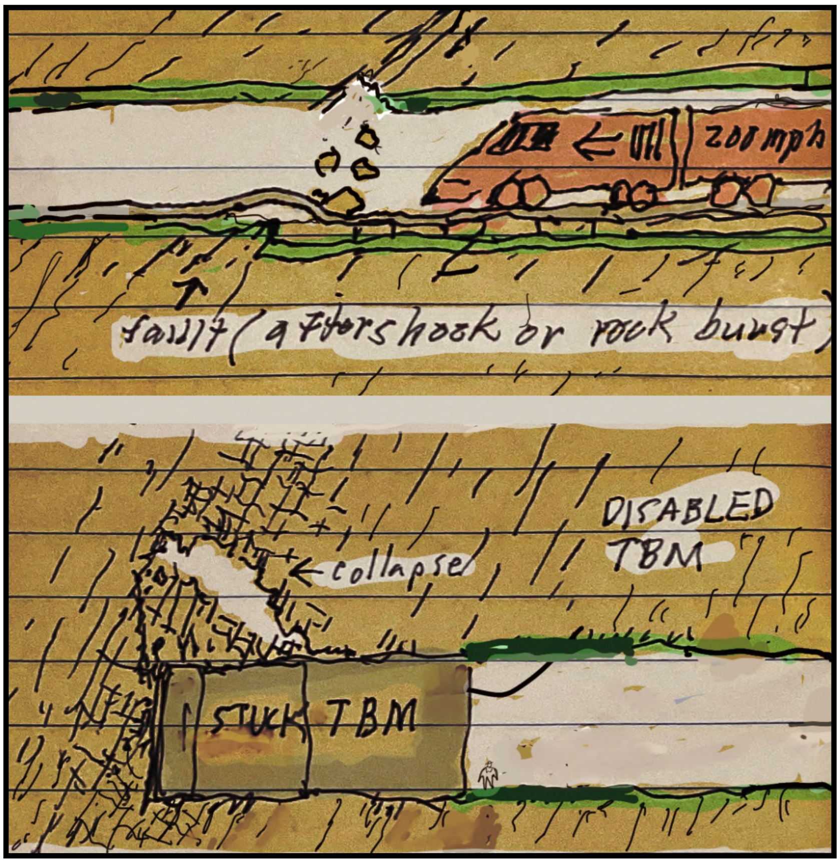
Comments on
California High-Speed Rail System
Proposed Palmdale-Burbank Section
Draft Environmental Impact Report



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December 1, 2022

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Appreciation

The authors appreciate the support and complete independence provided by SAFE, an organization of citizens who live close to the proposed alignments of the high-speed train. SAFE volunteers and several other experts and colleagues on reviewing drafts of our report had a number of questions which provided a starting point for our own questions presented topically herein. We think these questions need to be answered by CHSRA in a future amended, final EIR.

The focus of our concern, mainly safety of passengers and the future viability of the CHSR project, is based on our experience with many critical infrastructure projects in California over the past half century, some successful and some not.

Sources

The background research for this review was conducted in September and October 2022, relying the most part on CHSRA documents including the DEIR itself and some reports on geotechnical issues that were referenced in the DEIR and available on CHSRA website archives.

The DEIR itself is rather difficult to find on the web, notwithstanding the many CHSRA notices of public availability in many libraries and several languages. We used https://hsr.ca.gov/programs/environmental-planning/project-section-environmental-documents-tier-2/palmdale-to-burbank-environmental-documents/ as our main link to the DEIR. In addition to CHSRA documents, we also consulted several detailed technical memoranda written for the CHSR project by consultants Parsons Brinkerhoff in the years before 2016. These memoranda are not offered for public review by CHSR, and we have only been able to review a fraction of them that have apparently been retrieved by others through demands pursuant to the Freedom of Information Act. As far as we know, they are not officially relevant to the DEIR even though they discuss various seismic problems —often in a more detailed and scientifically coherent way than does the DEIR.

It is possible that some of the impacts that we have discussed here have been covered in some background document, linked or referred to by the DEIR, that we have not seen.

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Purpose and Scope of This Review

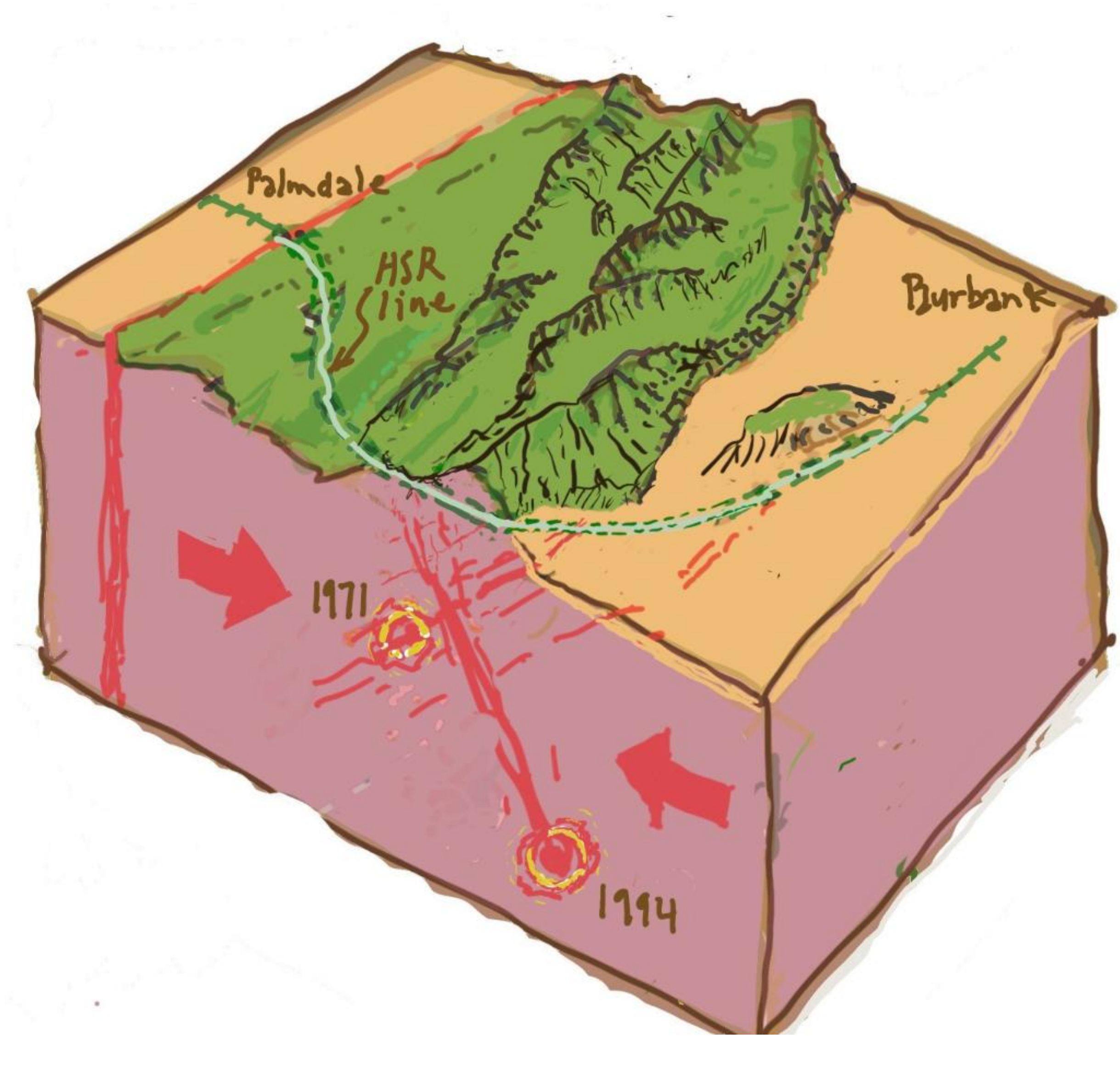
This report examines the adequacy of understanding and documentation (DEIR) of the environmental impact of construction of a 38-mile section of the California High-Speed Rail project (CHSR) by the California High Speed Rail Authority (CHSRA) which is meant to connect northern and southern California. Some parts of the project in California's Central Valley are approved and under construction at present (November 2022). The feasibility of building the reach from Palmdale to Burbank, tunneling at depths of up to 2000 feet beneath the San Gabriel Mountains, is one of the most problematic of the entire system because of the extreme physical geography of the San Gabriel Mountains which it traverses. The DEIR for this reach is currently under consideration with regulatory decisions on the DEIR due for late 2022. This report sets forth results of our review of the geotechnical elements of the DEIR and raises questions about this specific Palmdale-Burbank section which we ask the reviewers to consider.[1]

We find that the quality and consistency of the parts of the DEIR and supporting documents dealing with geotechnical hazards varies. Some of the fieldwork, notably the recent 2016 rock test borings, meets high standards. But we find the overall discussion and recommended remediation measures for geotechnical problems to be extremely weak, at least for this Palmdale to Burbank section. Serious known issues are ignored or minimized—or at best presented incoherently. For example, seismic damage to track is sidelined with only passing references to a couple of famous faults, and fault nomenclature is oversimplified in a way that minimizes attention to this topic which has emerged as critical for many existing international high-speed rail systems. Tunnel portal problems including gas, slope instability, and track buckling or breakage are not discussed. Some potential groundwater issues — the impact of deep tunnel dewatering on surface hydrology and ecology—are discussed but not for shallow tunnels beneath the San Fernando Valley. Ground subsidence and associated stretching and cracking of track caused by wells in the Pearland-Palmdale-San Andreas areas is not analyzed or flagged for mitigation. The deadly 1971 gas explosion in a MWD tunnel project very close to the CHSR line, a case with 17 fatalities that served as a safety warning to tunnel contractors on the LA Metro project and led to large claims, as yet unresolved, for undisclosed site conditions in the Wilshire Boulevard area, is not even mentioned in the DEIR.

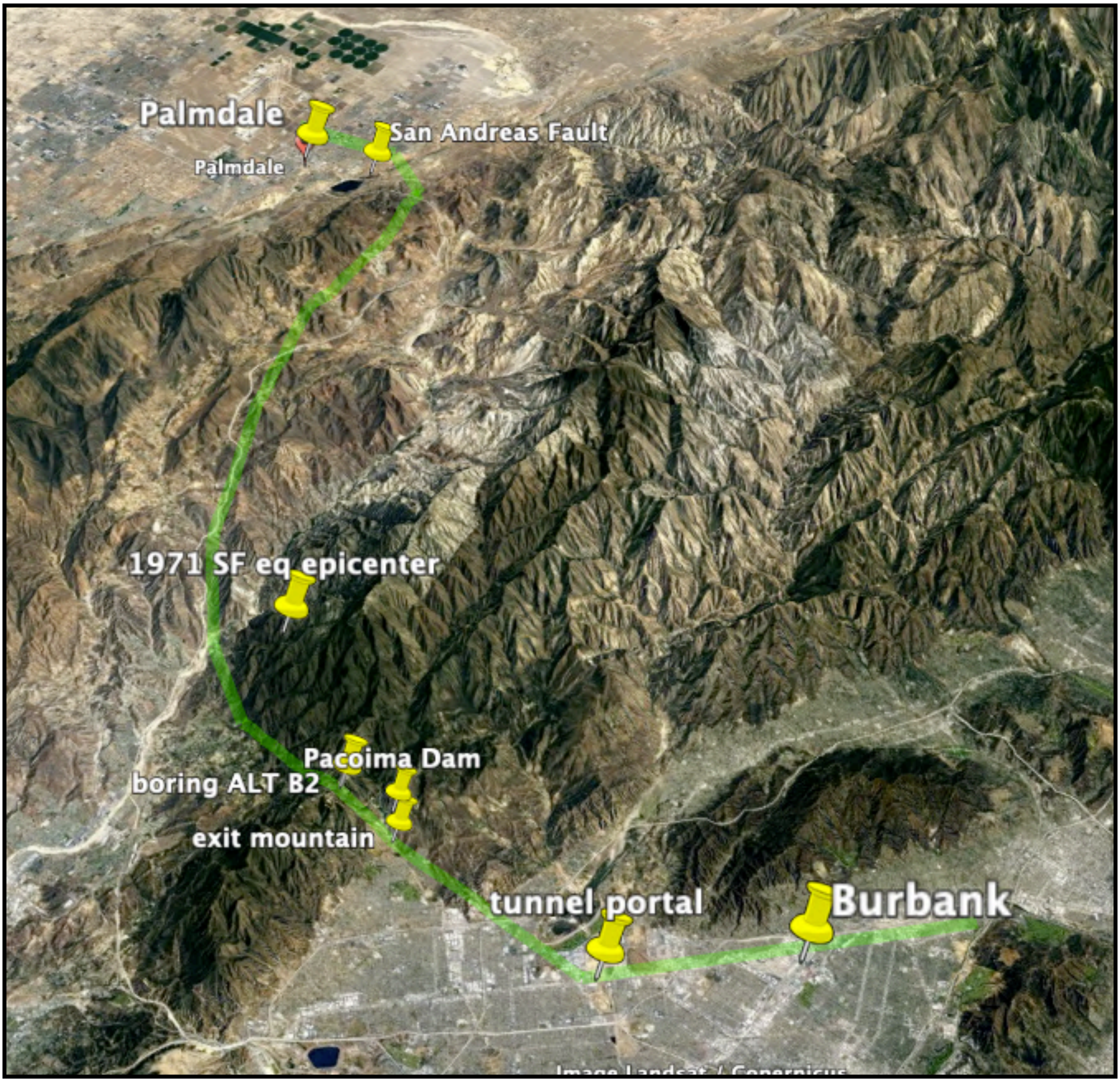
If the DEIR is included as a document to be considered as baseline in future contracts, we believe that it will mislead contractors in such a way as to encourage minimum investment in safety and later possible grief for all.

[1] DEIR comments to be submitted for review on December 1, 2022

Block Sketch of Palmdale-Burbank Section



Sketched block diagram shows (light green) high-speed rail line with red faults beneath the "blind thrust" zone of the San Gabriel Mountains. Red arrows indicate general compressive (principal) stress. The left shallower hypocenter is San Fernando; the right deeper epicenter is Northridge.



Google Earth Overview of Palmdale-Burbank High-Speed Rail Project

The California High-Speed Rail system is a complex and multi-billion dollar project with financial feasibility a matter of long and continuing debate. We have not attempted to comment on the hundreds of pages of studies of local project features and environmental impacts that have been produced by the CHSRA, but we do note that the focus of the current DEIR seems to wander extensively into areas — fossils, tsunamis, the abrasive quality of rocks — that do not strike the writers as being of central significance to the project, while omitting even mention of several impacts that may be decisive to both project safety and economic feasibility. The environmental documents are rather heavily weighed toward bureaucratic concerns that seem more appropriate to construction of California shopping centers and housing subdivisions than to innovative and untested multi-billion projects of unprecedented difficulty and great geographic extent. We aim here to stimulate fuller and more balanced concerns in our area of experience, and focus on major likely geotechnical impacts— at least one of which, geologic fault ruptures and deformations, of various types and magnitudes, disturbing track alignment, may be impossible to mitigate, and as such may provide reason to not build this section or any of its alternatives for the Palmdale-Burbank link as presently proposed in the DEIR.

The authors of this report, a mining/engineering geologist and civil engineer, have been working together on geotechnical problems in large engineering projects ranging from nuclear power plants to water projects in California for more than fifty years. Our earliest joint work clarified the sources of fault ground rupture in the Baldwin Hills which led to a dam failure at that former reservoir site.[2] Several of these projects involved tunnels, but we also note that California's experience and capabilities in major tunnel projects is relatively limited on the international stage.

The writers have local experience with California tunneling problems: our earliest training in the 1950s included study of the Caldecott tunnel in Oakland which, in its first phase in the 1930s, suffered a massive construction failure in which the tunnel was suddenly filled with tunnel muck which subsequently cemented. Serious ground dislocation in a high mountain area shut down PG&E's Helms pumped storage project, where we served as investigation consultants to PG&E after that 1982 failure. More recently, San Mateo's new Lantos tunnel which bypasses the difficult Devils Slide coastal area in San Francisco, originally conceived of by D. Hamilton of this report in the early 1990s, went on to be successfully completed (though with massive construction cost overruns and disputes between the contractor, Peter Kiewit, and Caltrans because of claimed unexpected geologic conditions). Most recently in 2021, the writers served as consultants on claims arising from hundreds of costly TBM shutdowns due to the presence of methane in the LA Metro tunneling project at Wilshire Boulevard and also completed a study supporting a negative review of the Caltrans SR-710 highway extension via tunneling from Pasadena to Central Los Angeles. (See the back of this report for Hamilton and Meehan Qualifications.)

The DEIR is completely inadequate in failing to address the first paragraph issue raised in last month's NYT article (by Ralph Vartabedian, former LA Times national correspondent), namely:

> *Building the nation's first bullet train, which would connect Los Angeles and San Francisco, was always going to be a formidable technical challenge, pushing through the steep mountain and treacherous seismic faults of Southern California with a series of long tunnels and towering viaducts.*[3]

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[2] Meehan, RL; Hamilton, DH (April 23, 1971): "Ground Rupture in the Baldwin Hills," Science. 172, no. 3981, 333-344.

[3] Vartabedian, Ralph. *How California's Bullet Train Went Off the Rails.* October 9, 2022. *The New York Times.*

We can trace this persistent concern with "treacherous" faults in the LA Times back to 2012, when the same reporter interviewed some distinguished engineers on the same problem and was told that the significant risk of a catastrophe arising therefrom, specifically a seismic train wreck 2000 feet below ground caused by track or tunnel failure immediately following an earthquake, could not be completely avoided or prevented even with the best new technologies:

> *Stephen Mahin, Director of the Pacific Earthquake Engineering Research Center at UC Berkeley said the bullet train's operating plan suggests a "strong probability" that the train could be going over a fault if it ruptures. But good engineering can reduce the risk.*[4] [5]

So even a decade ago, one principal barrier to the whole CHSR project was seen as the potential for geologic fault ruptures with fatal impacts that may be difficult or impossible to fully mitigate, notwithstanding engineer Mahin's optimism. Notably on the CHSR, this condition will be found along several reaches of track in Northern California (Mt. Diablo area) and also along the Bakersfield-Palmdale reach (White Wolf Fault), but most significantly within the Palmdale-Burbank section which tunnels through the "blind fault" terrain (zones where observable surface faulting is not found) of the San Gabriel range which is our current focus. This latter forty-mile stretch includes the San Andreas Fault and, beneath the south side of the San Gabriels, the scene of both the extreme San Fernando (1971) and Northridge (1994) earthquakes arising in the intensely and compressively fractured miles of the San Gabriel range which has upthrusted the mountains north of the Pacoima reservoir between Palmdale-Burbank.

Meanwhile over the years. the CHSRA has attempted to plug serious but separate overarching financial risks for the whole $100 billion CHSR project (e.g., passenger demand, funding uncertainties, etc.), including likely future major contractor claims for extra costs associated with unforeseen underground conditions[6], by moving to design-build contracts where all such risks are meant to be borne by the contractors of each segment. So we now have the CHSR project broken into privatized segments with proposed separate design-build contracts. Perhaps it seemed politically logical to simply bundle longterm operating seismic risk along with these other multibillion dollar financial risks and say it will be the contractor's responsibility to produce a turnkey product at a stable price, guaranteed quake-proof. In any event, the result seems to be that CHSRA apparently proposes to abandon its role as an active manager enforcing specific standards for project construction and operation.

This attempt to pass off core safety issues under the banner of privatization would in our view be unworkable and irresponsible, and may conflict with the general trend in California law — perhaps similar to arguing that the spillway failure at Oroville Dam is not a state responsibility, but rather the fault of the original construction contractor. However, the question of future liability is a complex topic

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[4] Note here that Mahin is referring to a case where the body of the train itself may be over the fault rupture. We are focusing more on the case of the trains' stopping distance extending over the fault rupture.

[5] Vartabedian, Ralph. *The Mountains and Earthquakes that Stand in the Way of California's High-Speed Dreams.* November 13, 2012. *The Los Angeles Times.*

[6]Precautionary examples from authors' case files: Devils Slide tunnel, LA Red Line project, with large cost overruns for "unforeseen geologic conditions."

involving not only California tort liability but also condemnation law.[7] [8] We hope that it is being openly raised elsewhere as an important factor in route selection.

Future CHSRA liability is a complex legal and policy question that we cannot address. Better that we focus on that technical "standard" the CHSRA is likely, as shown in the DEIR and other documents, to require of the contractor to assure seismic safety and the possible workarounds that might be proposed. For that, we have to go outside of the scope of the current DEIR which mainly avoids the subject in favor of imagining, unrealistically in our experience, that future contract operators will take on responsibilities for catastrophes. But we do have a record of what the state as owner *would have* proposed for a seismic safety standard going back a decade or so before this current design-build solution was proposed. We have from that earlier time the capable Parsons-Brinkerhoff[9] CHSR detailed studies of those problems, so-called PB Technical Memoranda, circa 2009-2016; these appear in the case of fault deformation to be modeled after many advanced seismic risk analyses of the late 20th century, including the Diablo Canyon Nuclear Power Plant.

This issue falls squarely within our expertise. We can argue for the inadequacy of the proposed fault rupture solution—namely any acceptance of even a small risk of underground fault rupture of the tunnel and track, because that particular condition at the San Gabriel CHSR reach thrust zone is actually different and even more difficult than the simpler faulting condition at Diablo Canyon Nuclear Power Plant[10], even if Diablo Canyon were accepted as an exemplar of seismic safety evaluation (which it is not). Over the past decade there has been a major change in the way that CHSR is managing the issue of seismic hazard, leaving this and other serious risks out of the DEIR almost completely. So the DEIR has evolved to be a disorganized compendium of trivia (paleontology, tsunamis, "abrasion"). We can also comment from experience on the scope and difficulty of possible engineering remedies for fault damage to track, including creating a much enlarged outer tunnel bore (say, 12m) that would protect an isolated inner 8m tube. This would not be a "fault chamber," but a requirement for much of the tunnel reach beneath the San Gabriel range, increasing the cost for this reach by a factor of probably three to six times where such special preventive measures must be built into the project.

Question: *Is CHSRA anticipating legal responsibility for injuries and death for tunnel failures throughout the 50 year life of the project for any reason, including earthquakes? Has legal advice on this been sought from the State Attorney General Office or other legal experts?*

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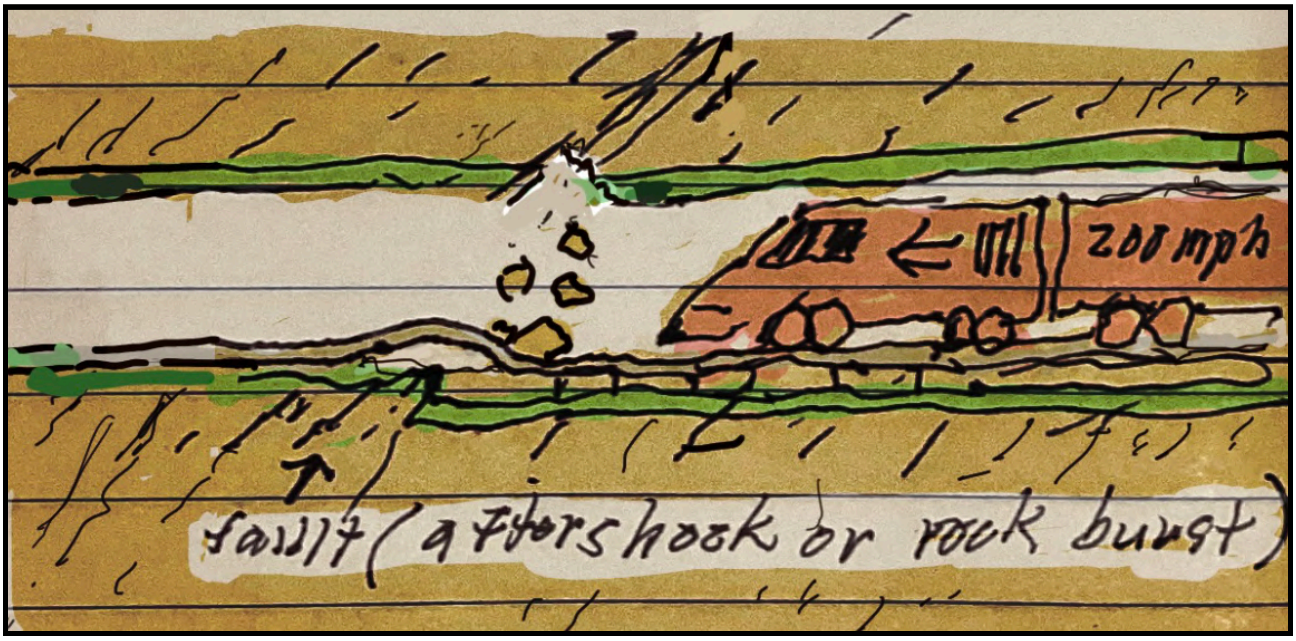
[7]Example: Peter PATERNO et al., Plaintiffs and Appellants, v. STATE of California et al. 2003 extends State liability for infrastructure projects owned by the state. Previously the state had claimed that local levee districts bore the responsibility for flood safety. California's Supreme Court did not agree.

[8]The history of rail safety in America is amply covered in Ian Savage's *The Economics of Railroad Safety* Department of Economics and the Transportation Center Northwestern University, Kluwer Academic Publishers Boston/Dordrecht/London.

[9] Project consultants for CHSR program management at the time.

[10] Hamilton, D.H., 2014, December. Seismic Hazard to the Diablo Canyon Nuclear Power Plant, Coastal Central California; a Realistic Assessment Needed. In *AGU Fall Meeting Abstracts* (Vol. 2014, pp. NH23A-3845).

Geological Disturbances to Track Geometry



In an early part of the DEIR for Palmdale-Burbank, CHSRA recognizes the United States' lack of experience in high-speed rail but offers its fundamental argument for an assuredly safe CHSR train system:

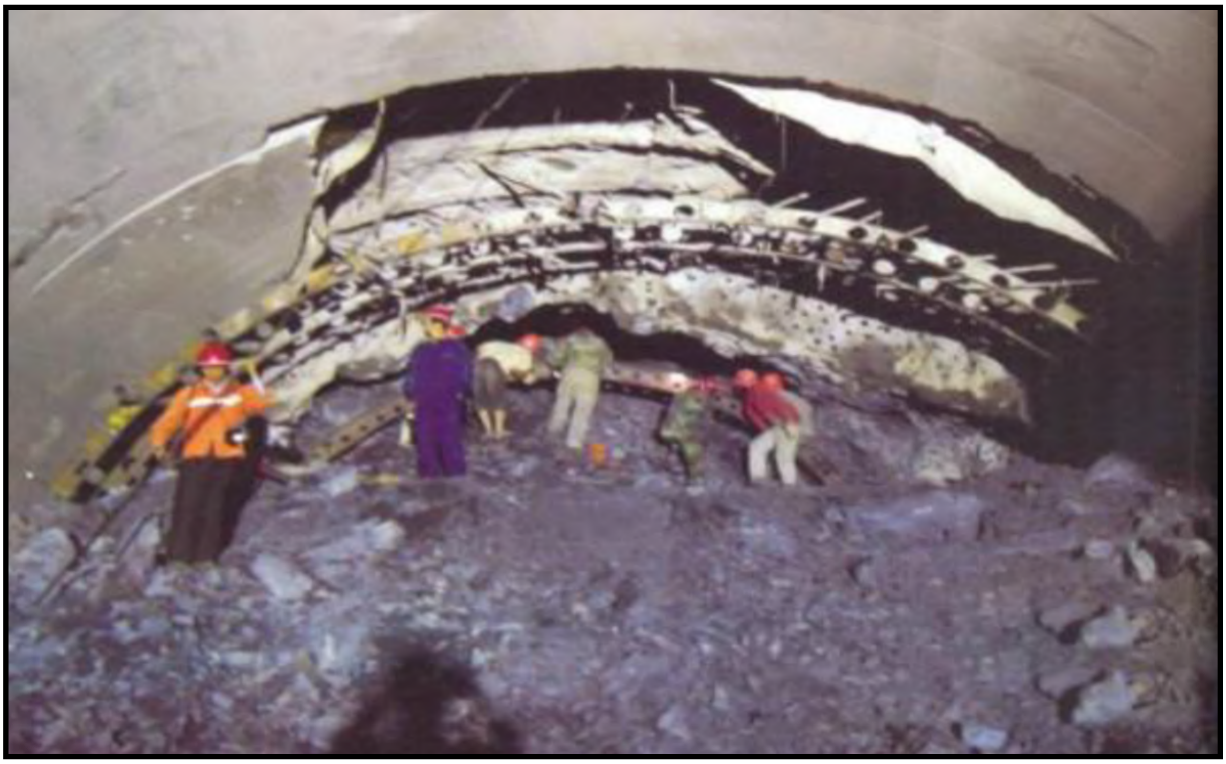
> *(DEIR quotes in red color)*
>
> *The overall safety and reliability of the California HSR System would be achieved by the application of proven technical standards commensurate with the desired level of performance. Based on the long-term operating success of European and Asian HSR systems, the California HSR System design considers and adapts to the existing European and Asian process and standards with regard to speed and technical issues with high-speed vehicles. —Chapter 3.11 DEIR for Palmdale-Burbank section*

Something to Consider

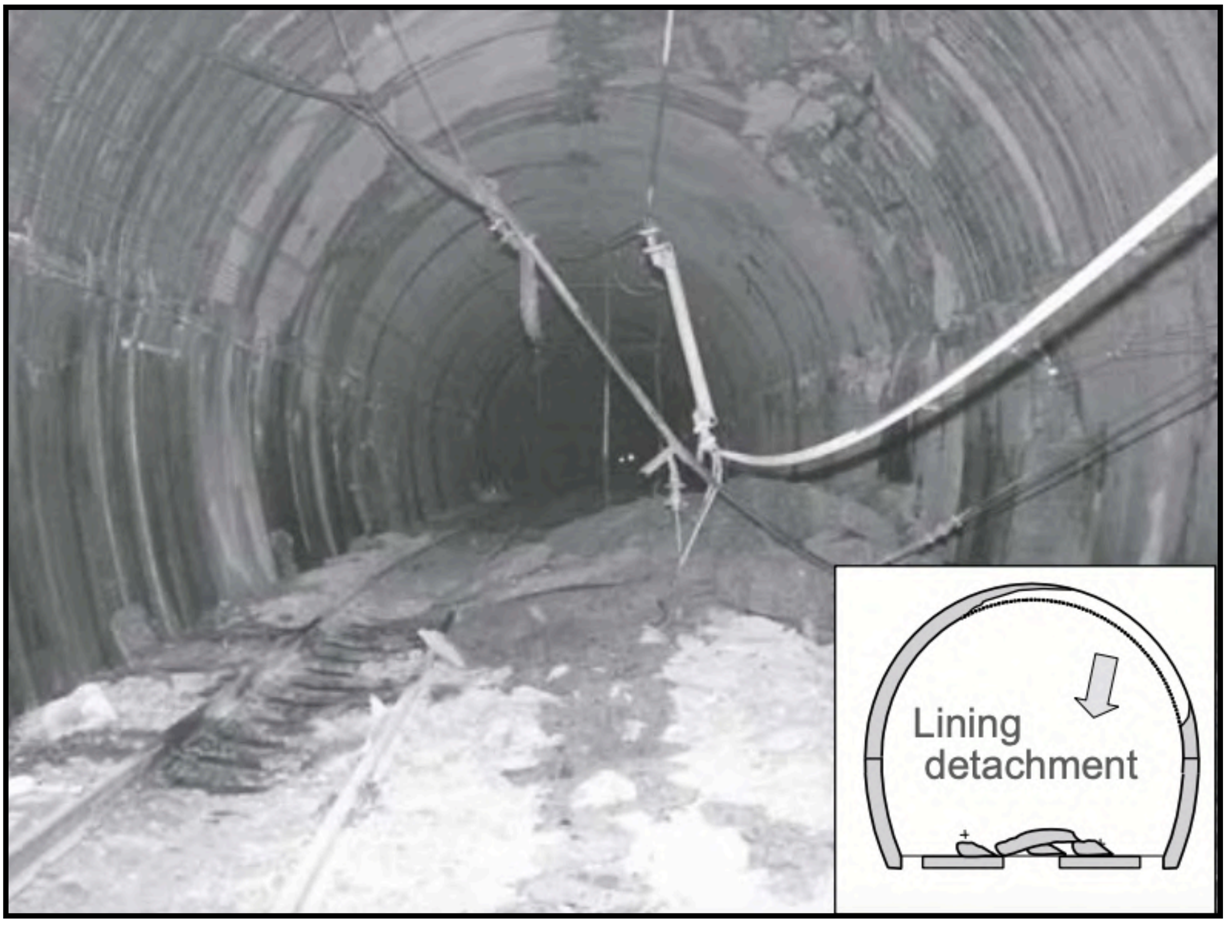
A train traveling 200 mph carrying 400 passengers receives an earthquake warning from an automatic warning system a few seconds ago and at once begins to brake. Now fifteen seconds later and half a mile further on, it is still traveling over 100 mph where it encounters one of the four following conditions somewhere in the tunnel between Palmdale and Burbank.

Seismic ground faulting buckled tracks at several locations including inside tunnels in the 1952 earthquake south of Bakersfield.

2016 San Benedetto tunnel following the Norcia earthquake in Italy.



Wenchuan earthquake 2008 tunnel collapse at fault crossing.



Japanese seismic failure at the Wanatsu tunnel in 2004, in which "compressive failure at the crown with a longitudinal length of about 40 m, and large blocks fell off the lining."

Confusing, Misleading or Incorrect Statements in the DEIR

DEIR (quotes in red color)

Project trackway, stations, ancillary facilities could be subject to **surface fault rupture**. Damage or collapse could potentially result in damage to nearby structures, injury, or loss of life. Implementation of GEO-IAMF#8 requiring the suspension of operations during earthquakes would reduce the potential for injuries or loss of life during operations from surface fault rupture. GEO-IAMF#6 would ensure that the project design incorporates early warning systems that track strong ground motion associated with ground rupture. This will help identify situations where fault creep or rupture have the potential to damage facilities and **engage train control in a manner that would reduce the potential for accidents.** GEO-IAMF#10 would **ensure that structures are designed to industry standards, limiting vulnerability to surface fault rupture.**

3.9.4.5 Method for Determining Significance under CEQA: The Authority is using the following thresholds to determine if a significant impact on geology, soils, seismicity, and paleontological resources would occur as a result of each of the six Build Alternatives. A significant impact is one that would:

• Directly or indirectly cause substantial adverse effects, including the risk of loss, injury, or death involving: – Rupture of a **known earthquake fault,** as delineated on **the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault (refer to Division of Mines and Geology Special Publication 42 [CGS 1997]**

Meehan/Hamilton comments

The focus here is on tunnel safety. The relevant issue for tunnels is not surface faulting, but rather faulting rupture at depth which is not seen at the ground surface. The DEIR fails to recognize this latter most important hazard.

Should read "engage train control in a manner that would reduce the potential for some, but not all, accidents," as the train control system would be ineffective for locations that are closer than the train stopping distance of about 2 miles.

There are no standards limiting vulnerability to surface rupture—or any other rupture—for 200 mph (or any other) high-speed trains.

Unknown faults are the greater hazard. They are hard to detect and difficult to mitigate.

These maps, referred here redundantly, are not suited for projects with critical or difficult geotechnical vulnerabilities.

Question: *With respect to the warning system GEO-IAMF#6, who will be in charge of making the calculations and determination as to whether the safest decision is for the train to decelerate/stop as soon as possible or to continue at speed in an attempt to clear the tunnel? Or will the stop routine be initiated automatically at some level of shaking?*

Question: *As there are no standards limiting vulnerability to surface rupture (or any other rupture) for 200-mph (or any other) high-speed trains, how are the mitigation measures set forth in GEO-IAMF#10 even applicable to CHSRA's high-speed train proposal?*

Question: *CHSRA has limited its methodology to study known and active earthquake faults. As unknown or inactive faults create irregular loading of constructed tunnel elements with the passage of seismic waves, a significant hazard to the high-speed train traversing through the San Gabriel Mountains, how does it propose to study and address the potential impacts of unknown and inactive faults in this area?*

Question: *In the critical section Section 3.9, "Geology, Soils, Seismicity, and Paleontological Resources," the maps are based on National Geographic shaded relief maps of unknown accuracy and do not include any coordinates that would allow viewers to geolocate the map. Map coordinates are a basic requirement in technical documents. Why is CHSRA utilizing maps which are not suited for projects with critical or difficult geotechnical vulnerabilities?*

Question: *Does the DEIR recognize faulting rupture at depth, which is the most significant hazard facing the train vis a vis tunnel safety? Will the final DEIR address this hazard, or will this be a matter left to the contractors to address?*

Question: *Does the DEIR account for the hazard of "inactive" faults, known and unknown, which create irregular loading and failure of constructed tunnel elements with the passage of seismic waves?*

The Case of the San Andreas Fault

The CHSR proposed alignments all cross the San Andreas Fault about 3 miles south of Palmdale. There is no doubt about the activity of the San Andreas fault, and the annual likelihood of a major earthquake producing many feet of ground displacement that would instantly and completely destroy the rail (which is at grade here) is said to be about 1% per year. For a fast-moving train within about 3 miles of the ground disruption, which will occur at the same time as the earthquake, a perfectly efficient earthquake warning system would begin to decelerate the train at a rate of about 2 mph per second. However, the train could still be moving at high speed when it hit the disrupted track, with disaster then a certainty. Since the trains will be quite frequently passing with a distance between them of perhaps 20 miles, the chances of a train being within a 2-mile braking distance of about 2 miles are about 10 to 20%. Recent Japanese experience has shown that a train traveling at about 100 mph and derailing may (with good luck) be "contained" in an above-ground site, bringing the train to a halt without fatal consequences. Therefore, planning for derailment by "containment" of the derailed train is necessary.

On the assumption there is no tunneling at the San Andreas Fault crossing at grade, this is a hazard that may be mitigated by good engineering. But what of a similar scenario in the tunnels hundreds of feet below ground? Or a shallow tunnel in the alluvial areas of the San Fernando Valley which has already demonstrated multiple splay faults?

This problem is bypassed in the DEIR by resorting to comforting assurances. Note the following bold claim in regard to earthquake warning systems presented in a CSHR brochure meant to convince the public of safety.

> *The Authority is adopting an Early Earthquake Detection System (EEDS) that will be designed to detect the initial wave produced by a seismic event, and immediately stop all trains in operation at the time of the earthquake. This process will allow for the inspection of tracks, bridges, and signals before resuming service.*[11]

While it is true that EEDS will significantly reduce the probability of derailment and likely disaster in a tunnel and elsewhere, there remains still a significant probability that cannot be ameliorated by warning systems. This would apply to any fault disruption including dislocation of surrounding rock at so-called "inactive" faults or zones of sharply contrasting rock properties (see Chinese experience following). We believe this condition exists at many locations, suspected and as yet unknown, along the alignment. We believe this poses an unacceptable risk for this section of the CHSR.

Question: *If the Early Earthquake Detection System (EEDS) is instructed to immediately stop all trains at the time of an earthquake, what will happen to the trains that are somewhere in the middle of the longest 22-mile tunnel?*

Question: *What is the warning lead time predicted to be achieved by the EEDS (yet to be developed)? Assuming a five-second lead time and a two-minute time for the train to stop, how can catastrophic derailment be prevented when the train is still moving at high speed and encounters a track disruption? CHSRA's assertions regarding the EEDS seem to be applicable only to trains running at grade. What are the potential outcomes for application of the EEDS in a tunnel, when faced with not only the possibility of derailment, but also the probability of tunnel collapse or floor and track uplift during a major seismic event?*

Question: *What is the plan for evacuating passengers and crew in the event of a tunnel failure or derailment for any reason, including earthquakes? Does it account for seismic damage to emergency facilities such as cross passages, escape and ventilation shafts, and tunnels? To potential blockage of any of the 10 portals?*

Question: *The longest planned continuous tunnel under the San Gabriel Mountains is a length of 22 miles. Traveling at maximum speed of 200 mph, riders will spend over 6 minutes in a tunnel underground; traveling at a more conservative speed of 100 mph, riders will spend over 13 minutes in a tunnel underground. In the event of a tunnel collapse caused by an earthquake, CHSRA's plan appears to be for riders to cross through cross passages to a twin tunnel, where they will either be rescued by another train or walk to safety. In the event of an earthquake of significant enough size to cause a tunnel collapse of Tunnel A, isn't there a likelihood that adjoining Tunnel B will also be damaged, making it difficult or impossible to effectuate a rescue utilizing Tunnel B?*

[11] *Early Earthquake Warning*, CHSRA brochure, https://hsr.ca.gov/about/safety/early-earthquake-warning/

Question: *For the 22-mile tunnel, the longest distance that a passenger could conceivably have to walk to safety outside the tunnel in the event of an earthquake would be 11 miles. What do applicable transportation safety guidelines say is the longest distance that a passenger should have to walk to reach a safety area/passenger assembly zone adjacent to the portal?*

Question: *In the event of a power outage caused by earthquake or other disaster, how will CHSRA ensure that communication lines remain open and working for the purpose of communicating with passengers and crew?*

Question: *Given that the warning systems will be ineffective for locations that are closer than the train's stopping distance of approximately 2 miles, how does CHSRA propose to address the scenario of a still fast moving train colliding with debris or derailed by track damage within that 2-mile braking zone?*

Japanese Experience

Japan got off to an early start with high-speed rail and the successful construction and operation of its famous Shinkansen line. Shinkansen operated for 50 years with no passenger fatalities, and that record has been held up as a shining example of excellence throughout the world and is the starting point for many claims of the excellent safety record of high-speed trains.

Meanwhile in Japan, exultation over its lack of fatalities in operation of ever faster high-speed trains has given way to a much more precautionary tone in connection with earthquakes, as shown as early as 2004 in this article from the Quarterly Report of the Railway Technical Research Institute:

> *Since mountain tunnels are generally surrounded by stable ground, their displacement during seismic activity tends to be minimized, making such structures less susceptible to seismic damage. Despite this, many railway mountain tunnels have sustained damage, from the 1923 Kanto Earthquake to the 2004 Niigataken-Chuetsu Earthquake. This paper provides an outline of the historical damage to mountain tunnels in Japan and outlines the results of case studies on damage sustained in mountain tunnels. Also outlined here is a classification of the damage patterns and the conditions of damage based on the results of the case studies, and we refer to the estimated causes of damage to tunnels in the 2004 Niigataken-Chuetsu-Earthquake.*[12]

The derailing of a Japanese bullet train due to seismic shaking (not fault offset) in 2022 provides an ongoing reminder of the seismic rail hazard in that country. Reportedly this train, the Tohoku Shinkansen bullet train, received an automatic shut down warning from a shock that preceded the main shock, so the train had come to a halt by the time of the main shock which followed. Early warning systems also allowed stopping of Japanese high-speed trains in the large 2011 earthquake. From these cases, it is evident that development of fast automatic warning systems based on the fortuitous separation of compression and slower seismic shear wave velocities can be an effective mitigation measure and a significant improvement, especially in the cases where earthquakes are both very large and distant. The warning time shrinks to zero when the earthquake is close to the rail line. But as we shall see later, and as it is acknowledged by experts, warning systems can reduce but do not adequately eliminate the risk of disaster.

Recent Chinese Experience

Starting about 20 years ago, China engaged in a remarkable program to build a high-speed rail network covering the entire country. At the time, tunnels and other deep structures were heralded as mostly likely immune to seismic problems. China now has some 50,000 km of high-speed rail and, until recently, had no serious accidents in spite of the country also being an area of high seismic vulnerability. The 2008 collision of a high speed train traveling at about 110 mph with a stopped train on a viaduct was a serious disaster. Attempts by the government to avoid publicity on the matter—to the extent of actually burying the smashed cars—led to a widespread revolt against government censorship by local commentators and even the government press. High officials were threatened with jail sentences. That in itself may have been the reason for China's recent liberal policy with respect to experts and academics commenting on

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[12] Yashiro, K., Kojima, Y., Shimuzu, M., 2007. Historical earthquake damage to tunnels in Japan and case studies of railway tunnels in the 2004 Niigataken-Chuetsu earth-quake. Quart. Rep. Railway Tech. Res.Inst. 48 (3), 136–141. Zhang, X., J https://www.jstage.jst.go.jp/article/rtriqr/48/3/48_3_136/_pdf

safety concerns about high-speed rail. At the same time, the very high exposure rate of the western part of this vast rail network to China's most seismically-active areas suggests high possibilities for future seismically-induced accidents including fault damage to track, as Chinese engineers and geologists have explicitly pointed out in many recent publications.

One recent Chinese review considers both the pace of progress and attempts to grapple with the question of mitigation of fault-induced track damage:

> *Driven by the growing demand for infrastructure in mountainous areas, the constructions of tunnels in highway and railway network is accelerated. More challenges and complex geological conditions are met with in tunnel projects, especially with large scale, than in the past. Numerous cases of damages of mountain tunnels have been reported in earthquakes, such as 1999 Chi-Chi, 2004 Mid-Niigata Prefecture, 2008 Wenchuan and 2016 Kumamoto earthquakes etc.[1–6]. Seismic damages of these cases have led scholars and engineers into topics researching seismic response of tunnels and underground facilities. Many earthquake damage investigations on mountain tunnels reveal that fault or fracture zone crossing is one of the most critical factors leading to tunnel damages.* [13]

Following a catalog of examples (which also includes 9 historical cases of seismic tunnel damage in Japan with its longer history of HSR), the paper also notes that:

> *All these records indicate that the tunnel section crossing fault is the most vulnerable part when subjected to an earthquake. But in use standards and codes guiding tunnel construction have mostly qualitative description upon this problem, which shows that existing research has not providing enough guidance for engineering practice.*

Further, in regard to the formerly presumed seismic safety of tunnels:

> *Nevertheless, this traditional viewpoint has been challenged by several strong earthquakes happened worldwide in recent years. For example, in the 1995 Kobe earthquake over 30 mountain tunnels were reported to have experienced minor damage and about 10 of them required countermeasures to make them safe (Asakuraand Sato 1996). The 1999 Chi-Chi earthquake and the 2005 Niigataken-Chuetsu earthquake also caused different damages to mountain tunnels, and several tunnels were severely damaged, even collapsed at the linings when crossing fractured zones and active faults (Li 2008; Wang et al. 2001). In the 2008 Wenchuan earthquake, more than 30 mountain tunnels suffered damages in different levels, and a number of tunnel sections crossing faulted zones even collapsed during the earthquake (Gao et al. 2009). It can thus be seen that the safety of mountain tunnels in seismically active areas is still an important issue to tunnel engineers.*

The Wenchuan tunnel damage is particularly relevant here because those tunnels are in terrain of exceptional high seismicity with high lateral stresses like the San Gabriel Range. China is now aware that their extensive network of high-speed trains in these western mountainous areas faces serious earthquake risks. A magnitude-6.6 earthquake occurring early this year in the Qinghai province in Western China

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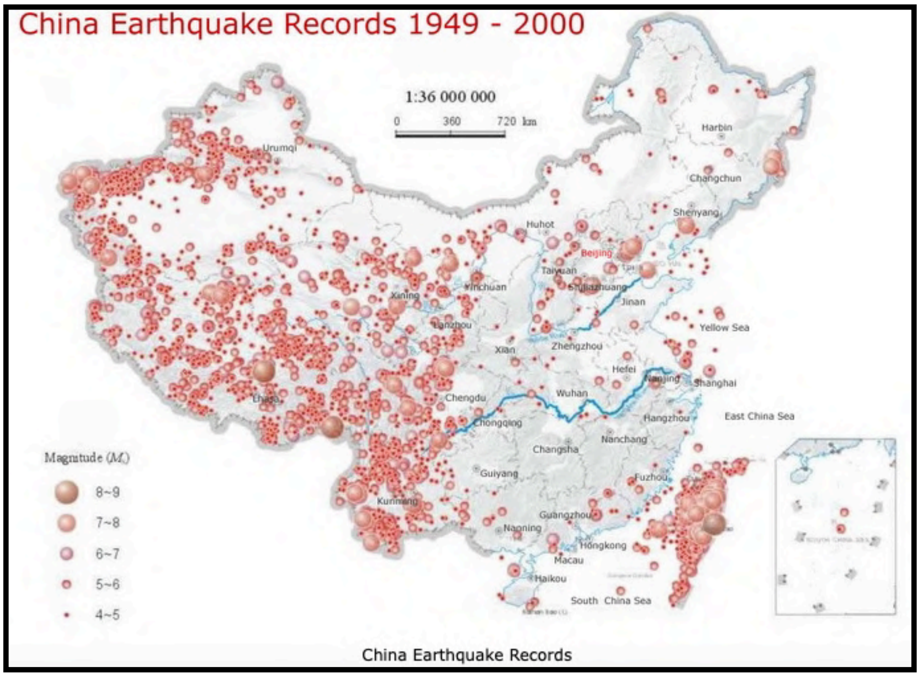
[13] Zhang L 2020 F1, Li R H2, Liu H1, Fang Z B1, Wang H B1, Yuan Y2, Yu H T2 A Review on Seismic Response and Aseismic Measures of Fault-crossing Tunnels https://iopscience.iop.org/article/10.1088/1755-1315/570/5/052046/pdf. Also Yu, H.T., Chen, J.T., Yuan, Y. and Zhao, X., 2016. Seismic damage of mountain tunnels during the 5.12 Wenchuan earthquake. *Journal of Mountain Science*, *13*(11), pp.1958-1972.

(January 7, 2022) caused temporary halts of several high-speed rail lines.[14]

Fortunately, most of China's rails are in the fertile Southeast part of the country, the major westerly HSR is located artfully on less seismically-active ground. China would like to open up its mountainous western regions, but justifiably fears the damage and national scandal of another high-speed train wreck.



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[14]"A powerful magnitude-6.6 earthquake occurred in the Qinghai province in Western China on January 7, 2022 (Figure 1). The quake struck at 1:45 a.m. local time in a remote region of Menyuan county. It was the largest earthquake in China since the magnitude-7.3 Maduo earthquake in the same province in May 2021. The Menyuan earthquake was widely felt in surrounding regions and caused temporary halts of several high-speed rail lines."

According to the Chinese, damage can occur at fault crossings whether the fault is "active" or "inactive". In the first case, the fault itself is seismogenic, prone to dislocation and radiating familiar seismic waves that shake the ground and are the ordinary concern of engineers. In the second, the "inactive" feature may be a zone of shattered rock, originally probably a seismogenic fault, which amplifies or concentrates stress concentrations from several sources: passing seismic waves which are superimposed on the regional stress pattern, the excavation of the tunnel itself, which may induce rock bursting and other deformations, water pressure changes, or even ground stresses created by passing trains. But track damage may occur at and around these features:

> *"Inactive fault does not cause dislocation in an earthquake, so the influence of fault on the tunnel is similar to fracture zone in an earthquake. Due to the existence of such a fault, tunnel structure on both sides of fault may suffer from shear action of fault as a result of the inconsistent movement of surrounding rock on both sides of the fault."*[15]

Utilization of the terms *active* and *inactive* is a useful pragmatic distinction, but one which must be used with some caution. First of all, *active* and *inactive* may have particular and highly specific definitions (e.g., Quaternary v. Holocene, corresponding aftershocks, etc.) depending upon some agency or a country which believes that its lexical authority extends into the realm of geophysics. Secondly, the distinction between seismogenic active faults and inactive faults which move in response to passing seismic waves becomes blurred when within the "source area." Was the San Fernando earthquake one earthquake or two "simultaneous" earthquakes on separate faults?[16] Does the large earthquake at Northridge immediately following the"main shock"[17] also mean there was no single earthquake? What kind of faults are rock bursts triggered by seismic or non-seismic excess stresses? What about dangerous rock bursts which involve shear fracture of previously unbroken rock? Are dislocations accompanying aftershocks of Magnitude 5 or more faults? The common terminology fails. This is at the heart of CHSRA's use of erratic terms -- "known faults" or "named faults"— a belief that there exists somewhere an "official" or "legal" list of faults which fits the concern of this project, that being sudden track damage or track misalignment even of a very small amount.

Japanese engineers set a limit of 5 mm per 10 m for vertical misalignment of high-speed rail. Chinese engineers have aggressively studied this problem and have developed some preventive measures which they believe will protect tunnels at known fault crossings for displacements up to 20 cm (8 in). These include extra rock reinforcement and double lining with expanded tunnel size. Zones requiring such treatment are presumed to be determined during construction.[18] By contrast, CHSRA's DEIR visualizes special treatment in only two or three famous faults, and even there offers no assurance that this

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[15] Zhang 2020, op cit

[16]Dreger, D., 1997. The large aftershocks of the Northridge earthquake and their relationship to mainshock slip and fault-zone complexity. *Bulletin of the Seismological Society of America*, *87*(5), pp.1259-1266.

Galli, P., Galderisi, A., Martino, M., Mugnozza, G.S. and Bozzano, F., 2020. The coseismic faulting of the San Benedetto tunnel (2016, Mw 6.6 central Italy earthquake). In *Tunnels and Underground Cities: Engineering and Innovation meet Archaeology, Architecture and Art* (pp. 805-811). CRC Press.

Tsutsumi, H. and Yeats, R.S., 1999. Tectonic setting of the 1971 Sylmar and 1994 Northridge earthquakes in the San Fernando Valley, California. Bulletin of the Seismological Society of America, 89(5), pp.1232-12.

[17] Heaton, T.H., 1982. The 1971 San Fernando earthquake: A double event?. *Bulletin of the Seismological Society of America*, *72*(6A), pp.2037-2062.

[18] Huang Run-qiu1*, LI Yan-rong2, QU Ke3, WANG Ke3 *Engineering Geological Assessment for Route Selection of Railway Line in Geologically Active Area: A Case Study in China* https://d-nb.info/1238583024/34

treatment will prevent catastrophic derailing.

Even as CHSR is claiming Asian success as a model goal for the California system, the Chinese began having second thoughts a decade ago. Concerns were described by a *Financial Times* report on China's growing reservations about safety for high-speed rail:[19]

> *China is lowering the operating speeds on its new bullet train lines because of safety and affordability concerns over the biggest high-speed rail network in the world. The top speed for trains running on the country's main high-speed lines will be reduced from 350km/h to 300km/h [217mph to 186 mph], said Sheng Faulta, China's new railway minister. "This will offer more safety," Mr Sheng was quoted as saying in the official Communist party mouthpiece, People's Daily.*

Question: *The DEIR says that the CHSRA is going to follow the tunneling methodology of Asian and European models. What model is CHRSA using? Does that model include all recent high-speed rail accidents and up-to-date assessment of safe speed limits for high-speed rail projects in experienced Asian and European countries? How does that model hold up to scrutiny, given the accidents that are discussed in this Meehan-Hamilton Review Report?*

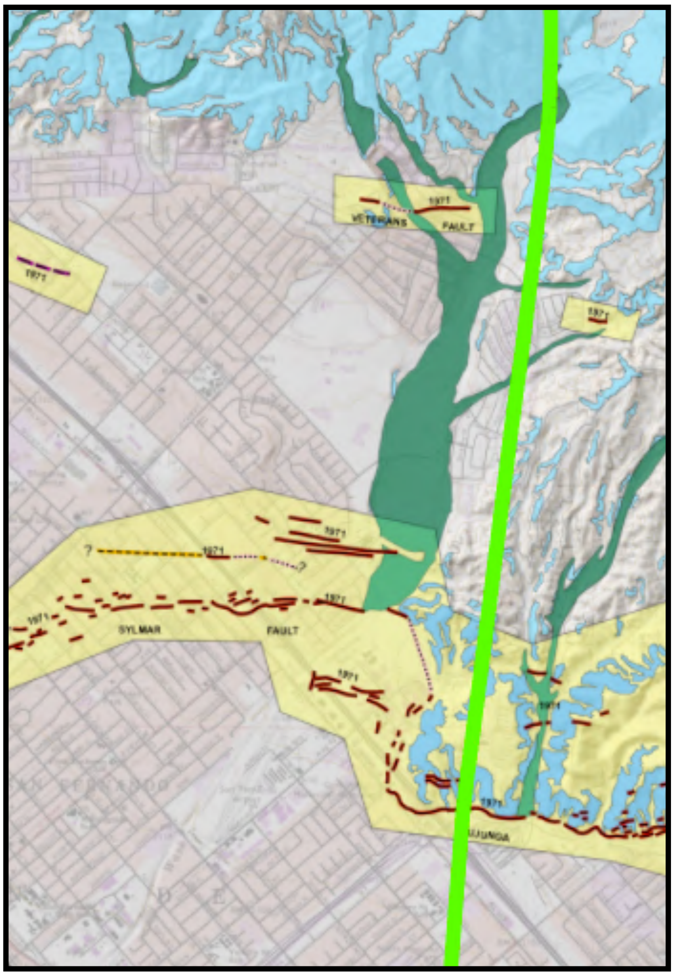
Question: *The maps clearly demonstrate that China, despite an ambitious interest in and significant experience with high-speed train construction, has intentionally avoided the areas with the most seismic activity. Given that the CHSRA has no experience in building a high-speed train, let alone building a high-speed train through one of the most geotechnically challenging regions in the country, why should the public have confidence in CHSRA's ability to successfully build what the Chinese have intentionally avoided? Would it not be the more prudent choice to build the high-speed rail network closer to grade in an environment less threatening from a seismic standpoint (e.g. crossing the mountains to the north near Bakersfield, not Palmdale) in order to eliminate the significant risk of tunnel accidents?*

Question: *Does the CHSRA aim to meet the standard in Japan for maximum vertical track alignment of no more than 5mm per 10 meters?*

[19] Financial Times JULY 25 2011

Fault Rupture Sources Ignored in the DEIR

San Fernando Valley Faults



The DEIR's insistence on limiting fault rupture to features from specific State sources such as Alquist Priolo maps, which are intended for use on small local construction projects such as housing tracts and shopping centers, is a serious error and would mislead any bidding contractor attempting to address project safety. Fault ruptures are by nature dissimilar to geophysical seismic wave attenuation processes such as those that lie at the heart of most probabilistic earthquake models which have been developed since the late 1960s. These models, which may be seen as increasingly naïve for estimation of rupture potential, given recent experience with earthquakes, are suitable for distant earthquakes where the earthquake can be characterized by a simplified conceptual model, usually featuring a fault line containing an epicenter which is imagined to be the source of the vibratory disturbance. However, recent earthquakes have shown that *local* fault rupture is erratic and dependent on many variables and, as often as not, invisible and detached by many miles from earthquake epicenters. For example, the fault ground ruptures shown on this Alquist Priolo map (with one proposed tunnel alignment shown in green) are 9 miles away from the epicenter of the 1971 earthquake that is often taken to be the fault that produced them, which is located in the San Gabriel Mountains off the map to the north. The line does not avoid the indicated Veterans Fault which is known to extend below ground far both east and west from the indicated surface break.

From the time of the earliest investigations of the San Fernando earthquake as by Yerkes and Wentworth,[20] geologists have been warning that the San Fernando Valley is underlain by many faults, invisible at the ground surface, of greater or lesser magnitude, including faults with greater potential displacements than the 1971 earthquake. In fact, those authors cautioned that a reasonable design earthquake should be more than Magnitude 7 for this area. But even if the map showing here were a complete catalogue of all of the faults that would show movement at the tunnel depth, one would be left with the question of how so many potential and fatal track disturbances (more than an inch or two) could be reasonably mitigated.

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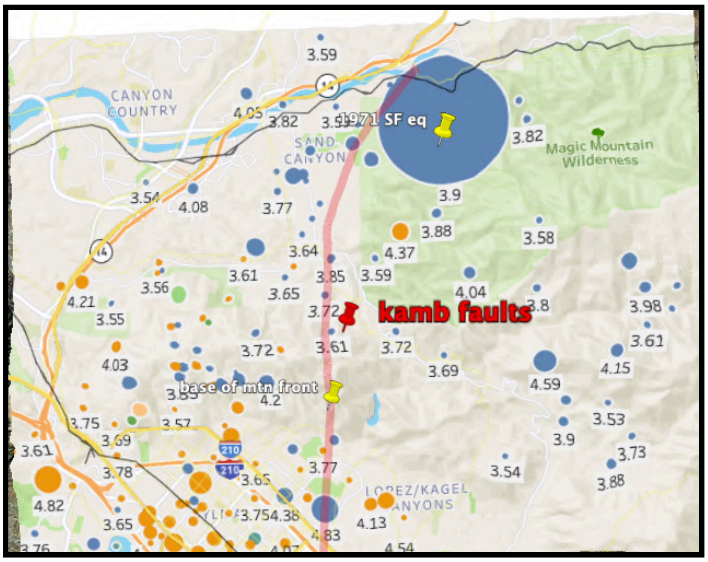
[20] Wentworth, Carl M. and Yerkes, R. F. and Allen, Clarence R. (1971) *Geologic Setting and Activity of Faults in the San Fernando Area, California.* In: The San Fernando, California, Earthquake of February 9, 1971: A Preliminary Report Published Jointly by the U.S. Geological Survey and the National Oceanic and Atmospheric Administration. Geological Survey Professional Paper. No.733. United States Geological Survey , Washington, DC, pp. 6-16. https://resolver.caltech.edu/CaltechAUTHORS:20190906-153619517

For a more recent treatment see Levy, Y. and Rockwell, T.K., 2019. Geological structure of the Sylmar basin: Implications for slip distribution along the Santa Susana fault system in the San Fernando Valley, California, USA. *Structural architecture of the Western and Central Transverse Ranges, California, USA*, *1001*, p.79.

San Gabriel Mountains Faults

Barclay Kamb and associates from Cal Tech reported visiting the site shortly after the 1971 earthquake and recognizing that the entire range was created by faults, known or suspected, near the ridge north of the Pacoima Reservoir. They did in fact find active ground offsets exposed in road cuts in this area and noted that some of them (shown as “Kamb faults” here) were located close to the proposed rail line. Being close to the mountain road, these features were relatively easy to identify. Elsewhere in the steep roadless terrain of this area, it would be very difficult to see evidence of either current or past faulting because, among other reasons, surface evidence would be quickly covered by slope erosion and other geomorphic processes.[21]



Map of San Gabriel Mountains area showing San Fernando (blue) and Northridge (orange) aftershocks and fault features discussed by Kamb.

> *North of Pacoima reservoir, at lat 118°23.6' W.,long 34°21.2' N. cracks were observed along several preexisting faults of unknown age and displacement. On the average, these faults strike N. 60° W. and dip 40° SW. Two examples showed dip-slip displacement of 1-2 cm, down to the southwest. This displacement could represent the movement of either tectonic or large landslide blocks downward toward the San Fernando basin.*

According to Kamb, the only truly seismogenic fault observed at the ground surface is the Veterans Fault, which is seen on the Alquist map just to the left of the proposed track alignment where it produced about 4 inches of ground offset. We may reasonably expect that this feature continues underground both east and west, so it would cross almost any rail alignment in this area. One might argue that the Veterans Fault is second only to the San Andreas Fault as a "known fault" certain to produce track damage, but it is not even mentioned in the DEIR.

On the other hand, to the north of the Mint Canyon quad, the Alquist Priolo map shows no faults, suggesting to at least the CHSRA that this mountainous terrain north of Pacoima is free of faulting of any relevance to the project. Notably the San Gabriel Fault is not shown in the Alquist Priolo database covering the HSR alignment (Mint Canyon quad), though its westerly extension is shown as being active in the adjoining Newhall Alquist Priolo map.

Although most of the abrupt measured vertical ground movement from the 1971 earthquake is located in the San Fernando Valley at Foothill Blvd, several inches of vertical strain are indicated as occurring in the San Gabriel Mountains just to the north, where faulting has been claimed by seismologists as involving multiple faults or splay faults unobserved at the ground surface in this rugged terrain. Alewine

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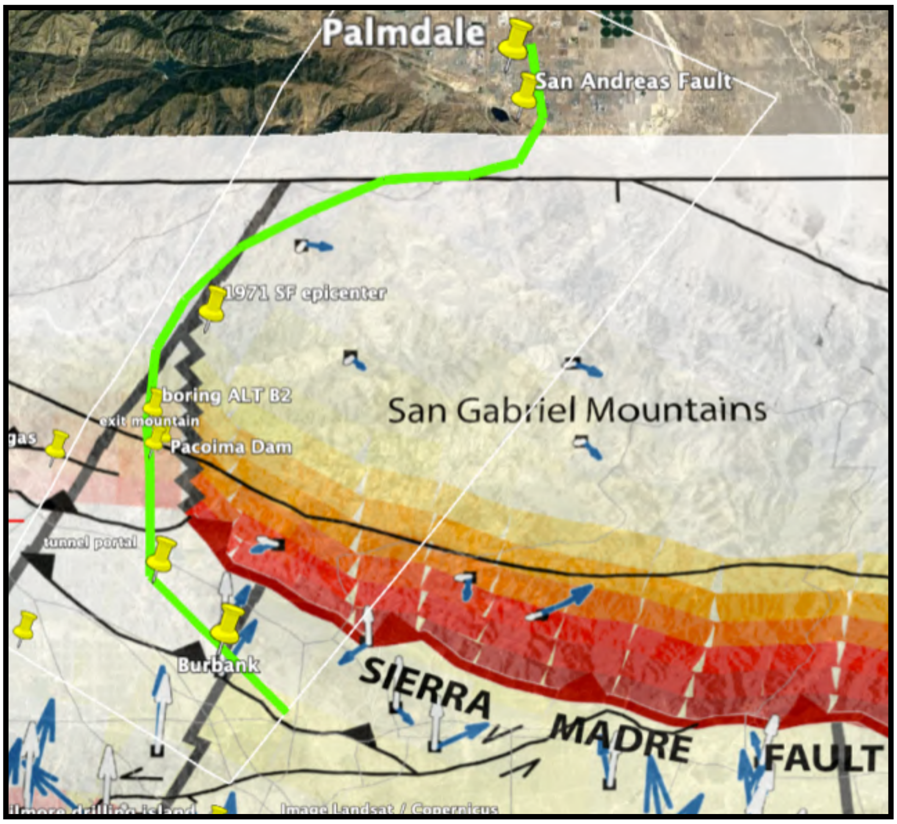
[21]Kamb, B., Silver, L.T., Abrams, M.J., Carter, B.A., Jordan, T.H. and Minster, J.B., 1971. Pattern of faulting and nature of fault movement in the San Fernando earthquake. *US Geol. Survey, Profess. Paper*, *733*, pp.41-54. Kamb recon 34.353,-118.393

https://authors.library.caltech.edu/115954/1/Pattern%20of%20faulting%20and%20nature%20of%20fault%20movement.pdf estimates vertical shear strain between fault outcrops in the San Fernando Valley and the 1971 epicenter of several inches which may have been produced by splay faults with unknown, if any, surface displacement.[22]

The geology section of the DEIR considers only three faults which it considers to be significant potential for track displacement: the San Andreas, San Gabriel, and various surface faults in the San Fernando Valley. However, the hydrology section of the DEIR report (Section 3.8) indicates there are other known and unknown faults on the alignment that could affect groundwater flow. Our view is that these unknown faults, to be discovered in a more extensive geotechnical investigation order during construction, will also need to be considered in regard to the question of track alignment and derailing.

Section 3.8 DEIR:

> *However, it is likely that not all faults in the ANF have been mapped because of limited surface evidence and the inherent limitations of surface geologic investigations. Additional geological investigation would occur before final design and construction.*



Current strain accumulation rate, southwest side of San Gabriel Mountains. The proposed Palmdale to Burbank alignment (green line) passes about 2 miles west of the red 5mm per year convergence in this area, which is the highest rate in Los Angeles. This "hot" area has not experienced a significant earthquake for a long time, so an earthquake of Magnitude 5 to 7 may be "overdue." Strain base map from Rollins (2018).[23]

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[22] Alewine III, R.W., 1974. *Application of linear inversion theory toward the estimation of seismic source parameters* (Doctoral dissertation, California Institute of Technology) .https://thesis.library.caltech.edu/3912/3/alewine_rw_1974.pdf

[23] Rollins, C., Avouac, J.P., Landry, W., Argus, D.F. and Barbot, S., 2018. "Interseismic Strain Accumulation on Faults Beneath Los Angeles, California." *Journal of Geophysical Research: Solid Earth*, *123*(8), pp.7126-7150.

Question: *Why does the DEIR not address the Veterans Fault, which is taken by some geologists as the one major seismogenic fault breaking ground in the San Fernando earthquake?*

Question: *What further investigations, including but not limited to borings, will CHSRA complete before requesting bids for design and build?*

Seismic Vibratory Effects on High-Speed Rail

The reader might think after this extensive discussion of fault rupture that the subject of seismic hazard has been exhausted, but so far we have only been discussing seismic damage caused by permanent ground deformation which damages tunnel linings, walls, crowns, or track alignment in a way that causes derailment.

However, probably the greatest seismic hazard to CHSR is the effect of very strong ground motion on the stability of a fast-moving train regardless of track disturbances. This strong motion may and will occur almost instantly anywhere along the alignment traversing local earthquakes, usually of Magnitude 5 or more. Whereas in Japan the seismicity is such (i.e., producing large, distant events) that EEDS warnings may offer a minute of more of time allowing for braking, the seismicity of the San Gabriel Mountains area would not allow for more than a few seconds, and maybe only a second or two, of warning of incoming strong ground motion.

But we have yet to address the question of the direct effect of earthquake shaking on the stability of a speeding train itself.

Ground motions in the San Fernando and Northridge earthquakes were shockingly high to most engineers, reaching levels of more than 1.5 g—much higher than the traditional range of accelerations assumed in engineering work. Now it is generally agreed that those accelerations, where deep below the ground surface, are less, perhaps 50% or so, of the surface accelerations such as the 1.8g measured at Pacoima Dam. However, even a reduced acceleration of say .8 g or more is far above what has traditionally been considered a safe level, about .2 g, for ordinary trains which are susceptible to derailment and overturning because of their high center of gravity and their proneness to vibratory rocking.

We must further consider that trains and other wheeled vehicles traveling at high speed tend in any event toward instability, known as “hunting” in railroad engineering lingo, with very slight rhythmic track disturbance, [24] initiating at the track level and propagating upward into the train components which may begin to resonate with the ground vibration. Instability will develop at an increasing amplitude until the train is thrown off the track. Hunting instability may be spontaneous at high speeds, but as any driver of an old car with wobbly steering notes, any disturbance of the moving vehicle (e.g., speed bumps, etc.) initiates instability at a lower speed.

This hazard for this reach of the HSR to earthquake vibrations is extremely high in our opinion, but we have not been able to get full documentation of the CHSRA engineering rationale for safe design, as various technical memorandum (including those by Parsons Brinkerhoff of a decade past) are not available in CHSRA online databases. Also an adequate review of this question would be a major task requiring specialized structural engineering expertise which is outside of our capacity, therefore we leave it as a hazard which is very high but not explored in this review.

[24] Japanese engineers believe that a longitudinal track misalignment of more than 5 mm (1/4 inch) in 30 feet of running track is a danger warning point.

Rock Bursts

Rock burst in a Chinese tunnel

Rock bursts are a serious hazard in both deep tunneling and mining projects. The risk of rock bursts is heightened and extends to shallow depths when the terrain is subject to high lateral stresses, as is the case in the San Gabriel Mountains. Rock bursts result from overstressed rock that explodes into the tunnel. They are capable of destroying tunnel lining, throwing rock onto the track, and rupturing the floor of the tunnel. They may occur at the time of construction or later when they may be triggered by earthquakes or even non-seismic changes in stress conditions in and around the tunnel. Are these to be counted as a kind of fault? In any event, rock bursts are a hazard that does not appear to be addressed in the DEIR, though it has been a major concern and some other projects—including the famous and comparable Gotthard Tunnel recently completed in Switzerland. In that case, we know that the owner of the project was required to retain responsibility for adverse events arising from rock bursts during future operations.[25]

Although rock bursts are often associated with tunnels and mines deeper than 2000 feet, they also occur at shallow depths of less than 2000 feet where basement rocks are brittle and horizontal stresses in the

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[25] Rehbock-Sander, M. and Jesel, T., 2018. Fault induced rock bursts and micro-tremors–Experiences from the Gotthard Base Tunnel. *Tunnelling and Underground Space Technology*, *81*, pp.358-366.

Zhang, C., Feng, X.T., Zhou, H., Qiu, S. and Wu, W., 2012. Case histories of four extremely intense rockbursts in deep tunnels. *Rock mechanics and rock engineering*, *45*(3), pp.275-288.

Nussbaumer, M.M., 2000. *A comprehensive review on rock burst* (Doctoral dissertation, Massachusetts Institute of Technology). https://core.ac.uk/download/pdf/17029577.pdf rock mass are very high, as in the San Gabriel Mountains. Unfortunately the geotechnical testing done in 2016, which would have allowed for an estimate of this high hazard to both construction and future safe operations, had technical problems (acknowledged in the DEIR supporting documents) and did not produce enough data to allow for a good estimate of the severity of the rock burst problem.

Question: *Does the DEIR address the hazard of rock bursts, which could be fatal either during construction or later in operation? What level of tectonic stress conditions (especially horizontal principal stress) would lead to rock burst danger at tunnel and cross passage depth? What stress does CHSRA assume in avoiding mention of this hazard?*

Near Surface Ground Disturbances Possibly Leading to Track Damage

The DEIR does not, as far as we can see, even mention the potential for seismic disturbances in the alluvial soils of the San Fernando Valley, wherein the tunnel will be about 100 feet below ground surface. In our experience, liquefaction, lateral spreading, or ground lurching hazards (often manifesting as broken or buckled curbs and sidewalks, broken pipelines, and damage to houses) occurred during the Northridge earthquake over large areas of the valley floor. Although these features may not be strictly defined as faults, they involve large and sometimes deep cases of ground dislocation. The subsurface potential effect of such processes on a 100-foot deep tunnel or ancillary structures beneath the sloping alluvial plain has not been discussed in the DEIR. Nor does the DEIR discuss the potential at the north end of the Palmdale-Burbank line, notwithstanding the potential for deep earth fissures caused by changes in ground water level.

Significant Impacts Not Addressed Adequately in the DEIR

1. Tunnel portal problems including gas, slope instability, and track buckling or breakage are not discussed. Tunnel portals are especially susceptible to damage because they are constructed at mountain fronts formed by persistent faulting. Stations and other related structures are vulnerable to this damage.

2. Auxiliary underground works including ventilation works, cross passages, and escape shafts. Cross passages may be particularly dangerous because the tunnel cross section will cross the path of the major principal stress.

3. Seismic impacts on viaducts and their transitions.

4. Seismic impacts on track built on or close to ground surface with sudden earthquake displacements of as little as an inch or two.

5. Some potential groundwater issues: the impact of deep tunnel dewatering on surface hydrology and ecology are discussed, but not for shallow tunnels beneath the San Fernando Valley. Ground subsidence and associated stretching and cracking of track caused by wells in the Pearland-Palmdale-San Andreas areas is not analyzed or flagged for mitigation.

6. Gas problems are mentioned in a perfunctory way, but the deadly 1971 methane gas explosion

occurred in a MWD tunnel project[26] west of and close to the CHSR line (the gas leak was at the foot of the mountain north of Barry J. Nidorf Juvenile Hall) and with similar geology to the HSR line. This case, with 17 fatalities, served as a safety warning to tunnel contractors on the LA Metro project and led to large claims, as yet unresolved, for hundreds of precautionary TBM shutdowns from undisclosed gas conditions in the Wilshire Boulevard area. We have found that tampering with deep water pressures at other compressive environments in the Los Angles Basin often leads to unexpected (and catastrophic) ground deformations and migration of methane gas.[27] The Sylmar tunnel explosion demonstrates that potentially adverse hydrologic problems may be found, especially at the base of the San Gabriel Mountain front.

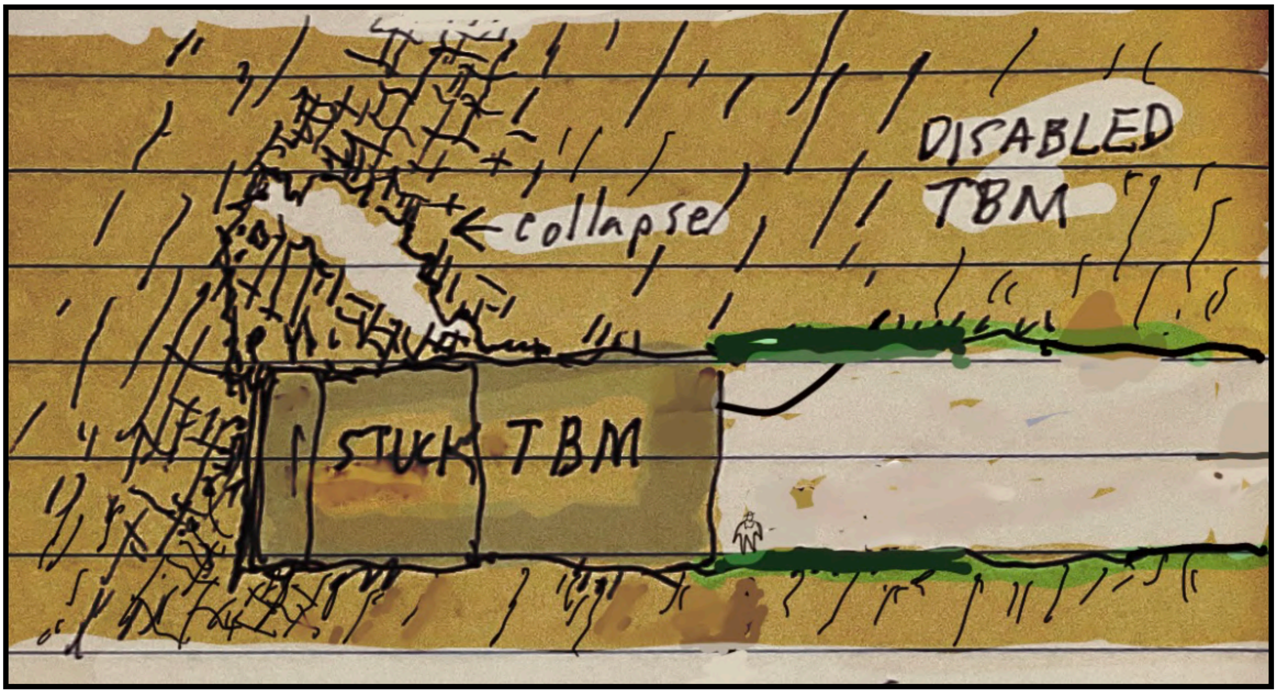
[26]The Fireman's Grapevine, 2014 LAFD History – The Sylmar Tunnel Explosion: June 23, 1971 https://www.lafra.org/lafd-history-the-sylmar-tunnel-explosion-june-23-1971/

https://www.latimes.com/visuals/photography/la-me-fw-archives-blast-in-sylmar-water-tunnel-kills-17-htmlstory.html

[27] Hamilton, DH, Meehan, RL. (April 23, 1971): "Ground Rupture in the Baldwin Hills," Science. 172, no. 3981, 333-344.

Hamilton, DH, Meehan, RL. "Cause of the 1985 Ross Store Explosion and Other Gas Ventings, Los Angeles" Association of Engineering Geologists, Special Publication No. 4, 1992.

Construction Problems Could Cause Unacceptable Accidents, Large Cost Overruns, or Even Project Abandonment



Would tunneling conditions be so difficult that the project might face abandonment or very large cost overruns?

Under the best of conditions, modern tunneling can often be carried out by TBMs with lower cost and more speed than traditional tunneling practices. Case studies testify to the success of TBMs utilized in the construction of many modern tunnels arguably similar to the Palmdale to Burbank line in Asia (especially China), Europe, and even in Los Angeles. However, in large part because of the extreme earthquake potential at the Palmdale-Burbank alignment, there are exceptional possible barriers to the use of TBMs. Among these barriers is the possibility of having a TBM that is stuck 2000 ft below ground in bedrock and cannot be moved or retrieved because of the depth and lack of access to the machine. Tectonic forces have produced not just the few significant faults mentioned in the DEIR, but also high lateral stresses in the rock mass (which may not have shown up in the limited downhole testing), as well as creating fractured zones in non-plastic rock such as granite, which experience has shown can lead to caving and stoppage of TBM progress.

The geotechnical investigations carried out prior to the issuance of the DEIR provide some limited amount of data on the 2016 subsurface conditions at the proposed tunnel reach. These are quite well documented in the field testing program, including pressure tests. Examples of rock conditions at the tunnel depth in 3 borings, at the base of the foothills near Pacoima Reservoir, give a fair sense of the distribution of intact versus broken zones of rock. Given the otherwise relatively uniform character of the granite, one might expect good TBM progress in unbroken zones. Broken or shattered zones could be problematic, and the potential for a stuck TBM would be highly adverse given the greater depth and poor access for rescue operations.

Ground squeezing is appropriately flagged in the DEIR as being a matter of TBM construction problems, though the consequences of loss of a TBM are not addressed.

Feasibility and economy of TBM operations is an advanced topic because of the rapid advancement of tunneling technologies in recent years, and sound judgement on the matter is beyond the experience of most engineering geologists and geotechnical engineers, including the authors. However a few remarks on the topic are worth noting.

Question: *What is the plan to extricate a TBM if it gets stuck?*

Question: *What else might CHSRA encounter that would stop the project (i.e., other than a stuck TBM), and what will CHSRA do if/when that happens?*

General Construction Problems with TBMs in Bad Rock

Following the 2006 completion of a 14-meter diameter hard rock tunnel project at Niagara Falls, comparable in some ways to the HSR project but with much more favorable rock conditions, the president of the US Robbins Company which provided the TBM made some notable comments:

> *The main lesson: In all but homogeneous sedimentary formations, there is a very high degree of rock fallout at the face. This means that at any one time, up to 50% or more of the face falls out in advance of boring. The effect is a result of jointing, bedding planes and fissures which occur normally in most rock formations.... problems occur when the voiding progresses outside the cut diameter. This often occurs in severely jointed ground, causing voids or cathedralling above the TBM. This phenomenon occurs whether the machine is an Open TBM or a shielded TBM. Such voids left untreated can cause the TBM to be stuck or eventually, if not properly back filled, can cause segment failure. This recently occurred on a project in Ecuador. As the diameter increases, the increase in face fallout goes up exponentially.*[28]

British tunneling engineer Nick Barton, considered a world class expert on TBMs, compiled the best known study of TBM performance in the late 1990s which described the risks of TBM failures as subsequently summarized by Barton:

> *The writer has been fortunate to get involved in the last stages of several TBM projects where the choice of TBM has clearly been incorrect, and the machine remains in the mountain forever. He has also been involved in projects where drill-and-blast from the other end has been advised at an early stage, but ignored until very late, with adverse consequences on completion dates, due to too late abandonment of the TBM, and fatal consequences for some workers. Reducing risk in long deep tunnels by using TBM and drill-and-blast methods in the same project–the hybrid solution. Nick Barton*[29]

Barton goes on to describe various TBM failures:

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28 *Modern large diameter rock tunnels.* Apr 2010, Lok Home, President, The Robbins Company http://www.tunneltalk.com/ Large-diameter-rock-tunnels- Apr10-Robbi ns.php

29 Barton, N, http://www.rockgeotech.org/qikan/manage/wenzhang/ 20120202.pdf

......The writer (Barton) knows of several permanently buried, or fault destroyed TBM (Pont Ventoux, Dul Hasti, Pinglin) and rockburst damaged or destroyed TBM (Oleos, Jinping II). There are certainly many more...The 7 km head-race tunnel for the Pont Ventoux HEP in the mountains in the northwest of Italy, was driven parallel to a marked NW-SE trending valley, and also parallel to swarms of faults hidden under slope screes. They represented the ultimate repeated challenge. At one location, the "fault zone performance" was 7 months for only 20 m of advance....During 2004 the tunnel was completed by drill-and-blast from the other end of the tunnel, by-passing the abandoned rusting TBM.

We note that the proposed method of using TBMs working from both ends of the tunnel toward a middle meeting point would make the kind of rescue completion that Barton suggests impossible.

The geotechnical investigations carried out by CHSRA in 2016 provide some data, limited but high quality, on the subsurface conditions at the proposed tunnel. These are quite well documented in the field testing program, including pressure tests and boring logs. Examples of rock conditions at the tunnel north of the base of the foothills near the Pacoima Reservoir give a fair sense of the distribution of intact versus broken zones of rock at the tunnel depth. Given the otherwise relatively uniform character of the granite, one might expect good TBM progress in unbroken zones. Indicated broken or shattered zones could be problematic, and the potential for a stuck TBM would be highly adverse given the greater depth and poor access for rescue operations.

We offered to share some of our information with a major contractor client, perhaps the premier tunnel contractor operating in California, hoping that he might offer comments on the overall feasibility of the project, but the client understandably declined on the grounds that he might eventually become involved with the project. Even so, we recommend as a minimum the earthquake impacts on construction of this reach of the HSR be reviewed by a high-level panel of professional engineers, geologists and contractor consultants with both positive and negative experience in modern TBM tunnel construction and no investment in future contracts before the project moves to the contract phase. If it is concluded that disastrous cost overruns, delays or cancellations of the project are likely, then the entire route should be reconsidered. A Bakersfield-to-Burbank more direct route might offer a better prospects for construction within a reasonable budget, though we have not studied this alternative.

Probabilistic Risk Analysis: Preliminary Thoughts

In theory, the risk of a fast-moving train encountering a geologic fault-induced track failure can be understood by considering three points.

1. What is the likelihood of sudden and serious fault rupture track damage occurring at some point on the Lower East San Gabriel Mountains-San Fernando Valley reach (a 15 km stretch, the location of two “surprise” earthquakes, 1971 and 1974) during the operation of the trains? I would say that this is a realistic possibility in the first year of operation and fairly likely in the first 20 years of operation. (This can probably be verified by interviewing experts at the USGS, California Geological Survey, etc.)

2. Neither the exact time nor the location of such a track break or breaks can be known in advance. If a fast approaching train is within 2 miles of the break, even with the instant warning, the train will still be moving at a dangerous speed when it hits the fault-induced break or blockage. This is because it takes a high-speed rail train at least 2 miles (critical braking distance) after the fastest possible warning to come to a halt.

3. The odds of one or more trains being active on the Palmdale to Burbank reach at any time are almost certain. The probability of track disruption within a particular train's critical braking distance would be fairly high, say 2 miles/15 miles, or 6%. If several trains are active, or several track disruptions occur, a derailment becomes more likely than not. On this basis we can claim that the probability of a catastrophic tunnel accident following a local earthquake is quite high, perhaps 50% or more.

One can be easily convinced that such an disaster would be even worse than the worst aviation or rail accidents in history, all the more so because whatever attempts would be made to rescue or recover remains from the wreckage 2000 feet below ground could be hampered by the occurrence of aftershocks for weeks and months after the initial earthquake. Arguably any passenger taking the train would be facing odds of being a casualty on the order of 1:30,000 per trip. By comparison, the odds of any commercial airline flight ending in a passenger’s death are much lower, about 1:11 million. Inference: travel on the HSR would be far more dangerous than flying.

Reportedly events such as the San Fernando earthquake occur roughly every 200 years, so one could go through the motions of a traditional probabilistic analysis by beginning with the assumption that operation of the railroad for 20 years would expose the track to a single San Fernando type event and, in other words, a 10% chance of occurrence in 20 years of operation. It seems to the authors quite likely that such an event would produce serious track offsets at several locations. The only events that would cause catastrophic derailment by fault-induced track misalignment would be those that occur within the stopping distance of the train. With the trains’ separation at 20 miles and a train stopping distance of 2 miles, the chances of a catastrophic hit would be about 10% for each moving train and each track offset of more than an inch or two. The combined odds for two trains with say five fatal offsets would be quite high, approaching 100%. This line of argument might be advanced to a conclusion that there would be about 20% chance of a San Fernando type event with catastrophic fault rupture track accident occurring in the first 20 years of train operation. On the order of 10 billion passenger miles would be provided during those 20 year, so the fatality rate would be about 1 in 10,000 passenger miles.

All of this ignores the fact that the cause of geologic fault track offset might not be a local reverse fault such as the San Fernando 1971 event, but rather the threatening “big one” occurring on the San Andreas Fault (currently estimated at 1% chance per year) or a larger (Magnitude 7+) earthquake on combined reverse faults, either case triggering myriad movements on local faults, known and unknown.

A proponent might enthusiastically conclude that the long-term risk of passenger deaths from the geological fault theory is quite low, comparable to the standards that have been explicit in Great Britain or tacitly found acceptable to the public in the US and Great Britain. Or the number of bicycle deaths likely in the same area. So what's the big deal?

The big deal is that the world would regard such an event in the same spirit as the sinking of the Titanic. It would be concluded with some justification, echoing the views of some commentators in China, that excess speed is the villain and this should be radically reduced. If the eventual conclusion is that speed must be radically reduced, this raises the question of the fundamental purpose and continuing viability of the project, now estimated at more than $100 billion. Failure of the Palmdale-Burbank link, whether by construction infeasibility, excessive risk, reduced speed limits, or major cost overruns, could jeopardize value of the entire CHSR project.

Question: *Has the CHSRA done an analysis to predict the probability of Magnitude >5.0 and >4.0 earthquakes or aftershocks (which produce measurable fault displacement) occurring at or near the proposed tunnels within the next 20 - 30 years? How has this analysis impacted CHRSA’s plans?*

Question: *What if design and build fails (i.e., either CHSRA does not get a contractor to bid, or the contractor bids, and the alignment turns out to be impossible to construct due to subsurface or other issues)? What are the alternatives for completing this project?*

Conclusions

The DEIR means to establish public confidence by claiming that in the absence of US experience, CHSRA will emulate what are believed to be success stories with high-speed rail in seismic areas of Japan, China, and Europe. However, recent problems including derailing and serious seismic tunnel damage in China and elsewhere in the world have brought on a much more cautious approach by government and experienced railway operators in those countries. The idea of tunnels being immune from seismic problems is no longer acceptable.

All of the routes from Palmdale to Burbank proposed in the DEIR pass through the mountainous terrain of the San Gabriel Range, which presents geology and and seismicity conditions of exceptional difficulty, even for California.

Geotechnical investigations by CHSRA in 2016 produced some high quality data, but the scope and number of borings (two for each alignment) is completely inadequate for a 30 mile tunnel in complex geology that is found in Palmdale-Burbank part of the project (50 to 150 borings will ultimately be necessary, at a cost of at least $10 million). This will prevent contractors from producing reliable bids. It also misleads the public by suggesting that such a limited investigation suffices for approval of the project at this time. We are not confident that the technical and economic feasibility of any of the routes proposed has been established with reasonable assurance, and other routes north of the Palmdale-Burbank section may ultimately have to be considered.

The extensive tunnel damages experienced 2008 in China's Wenchuan tunnels are particularly relevant to this review because those tunnels are in terrain of exceptional high seismicity with high lateral stresses similar to the San Gabriel Range. China has acknowledged that their extensive network of high-speed trains in these western mountainous areas faces serious earthquake risks.

Local ground rupture or seismic overstressing causing tunnel track damage remains an unaddressed and possibly unsolvable problem that has a significant possibility of rendering all of the alternatives offered in the DEIR as infeasible from a safety and construction standpoint.

The extreme intensity of seismic ground motions (approaching 2g) in the San Gabriel Mountains area is unprecedented for any high-speed rail project that we know of. We question whether it is possible to design a train to remain on track for the level of ground motion expected in this "blind thrust" area.

Although rock bursts are often associated with tunnels and mines deeper than 2000 feet, they also occur at shallow depths of less than 2000 feet where horizontal stresses in the rock mass are very high, as in the San Gabriel Mountains. These events can be as destructive to tunnel linings and track as fault movements. The likelihood of rock bursts can be assessed if the lateral stresses in the surrounding rock can be measured. Unfortunately in the field testing program in 2016, most of the planned tests failed to provide usable results. Lacking this essential information, CHSRA did not address this important hazard in the DEIR. Escape routes at cross passages and portals are likely the most endangered by rock bursts.

Although the DEIR discusses at some length various problems that could arise as a result of the dewatering deep high-pressure zones during construction or later operation of the tunnel, it does not mention or discuss of the influence of changed groundwater pressures on rock deformation. For example, in cases where there could be water or brine injection, fault movements will likely be triggered. Dewatering at tunnel depth will also increase effective stresses which can create rock bursts and stimulate even local faulting.

By minimizing the potential for construction problems — including losing TBMs during construction and tunnel accidents during the lifetime of the project — the CHSRA is misleading contractors who may thereby have a basis for very large cost overruns due to incrementally changed conditions encountered and costly remedial measures necessitated during construction.

Groundwater issues are partially discussed in the DEIR, but not the problems of concern of individual or community property owners relying on water supply for wells, or for groundwater changes that could trigger fault movements, earthquakes, and gas releases.

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Hamilton and Meehan Qualifications

Douglas Hamilton is an engineering geologist with sixty years experience, mostly in California. For many years he was principal advisor on earthquake faulting hazards for PG&E at their Diablo Canyon and other state-wide nuclear power plants. His role in redefining hazards from oil and gas production in Southern California (e.g. Baldwin Hills) is widely recognized. He has worked on many tunnel projects beginning with his experience in the 1950s with deep uranium mines. He has also worked as a consultant on several California tunnel projects (most recently in 2021, the LA Metro line in the Wilshire Boulevard area). He made the original proposal in 2002 to bypass the Devils Slide area in South San Francisco using a vehicular tunnel and has been a continuing consultant to Caltrans on several other forward-looking projects. He holds undergraduate and PhD degrees from Stanford University, working in his younger years under the guidance of Richard Jahns, pioneering engineer geologist of Southern California.

Richard Meehan holds engineering degrees from MIT and Imperial College, University of London, where he developed, under the direction of engineers Norbert Morgenstern and Nicholas Ambraseys, an interest in fluid flow in fractured rock systems and its applications in engineering seismology. In the mid-1960s he formed a California partnership with Douglas Hamilton and has continued to be active in their hundreds of joint consulting projects. Over the past decades, he developed a specialty in safety problems of critical infrastructure facilities including dams and levees. He was principal plaintiffs' expert consultant and witness on the Paterno case, which redefined State responsibility for potentially hazardous public flood control facilities. He represented General Electric as an expert witness in safety hearings, in its successful quest to relicense under the Atomic Energy Commission the Vallecitos nuclear reactor facility in Northern California, which had been determined to be exposed to a geologic faulting hazards; Meehan memorialized that controversy in a book, *The Atom and the Fault* (MIT press) published in 1982. He was an adjunct/consulting professor at Stanford University School of Engineering for twenty-five years.