ImageCat, Inc.
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March 23, 2023

Beach Cities Health District
514 North Prospect Avenue
Redondo Beach, CA 90277

Attention: Tom Bakaly, Chief Executive Officer

Report: **Seismic Risks – Beach Cities Health District MOB and Parking Structure**
510 and 512 North Prospect Avenue, Redondo Beach, CA 90277

Dear Mr. Bakaly,

ImageCat, Inc. (ImageCat) is pleased to present this report to Beach Cities Health District (BCHD) for seismic risk consulting regarding the Medical Office Building (MOB) and adjacent parking structure, located at 510 and 512 North Prospect Avenue, in Redondo Beach, California (ZIP 90277). The 3-story MOB was built in two phases – 1976 and 1979. The 2-story (3-level) parking structure was built in 1990. We understand that this study is needed to inform your decision-making process to maintain seismic safety while continuing to provide services to the community.

Site View

Scope of Study

In this study, ImageCat reviewed the earthquake hazards for the subject site (ground shaking, liquefaction, and surface fault rupture) using published geological maps and a recent geotechnical investigation report [Converse Consultants, 2016].

We reviewed the original Architectural and Structural design drawings for the MOB (original building and addition) and the parking structure, as well as Seismic Evaluation reports from Nabih Youssef Associates (NYA), dated 2020. We discussed the building structures, computer models and retrofit recommendations from NYA. A Professional Engineer from ImageCat met with the on-site Senior Project Manager (Consultant) and members of maintenance staff to conduct a visual survey of the buildings to assess existing configuration, conditions, and usage of the structures.

To examine seismic risks for the structures in their status quo conditions, ImageCat performed risk analysis using SeismiCat, ImageCat' earthquake risk tool. Results include risk estimates, discussions of stability and retrofit, and recommendations.

Reliance

This report may be used and relied upon by Beach Cities Health District (BCHD) and each of its respective successors and assigns.

Organization of This report

This report summarizes the results of ImageCat's seismic risk review and is organized as follows:

1. Site Seismic Hazards
2. Building Vulnerability
3. Seismic Risk Results
4. Limitations

Appendices

1. Site Seismic Hazards

The earthquake hazards we considered include strong ground shaking, soil liquefaction, surface fault rupture and slope instability. Findings are drawn from published maps, a recent site geotechnical investigation report [Converse Consultants, 2016] and the ground shaking models of the U.S. Geological Survey (USGS).

1.1 Seismic Setting

California is the most seismically active of the United States. The San Andreas Fault strikes north-northwest from the Mexican border, past Los Angeles, and San Francisco, until it veers offshore near Eureka. The San Andreas forms the active boundary between two tectonic plates in relative motion. To the west of the San Andreas Fault extends the Pacific Plate, while to the east lies the North American Plate. Along most of the fault, the boundary is held locked by tremendous forces as the plates build up strain energy. Eventually, the constraining forces are overcome along stretches of this boundary, allowing sudden relative motion between the two sides of the fault. The strain energy stored in the rock is violently released as seismic waves, radiating outward from the rupturing fault segment. At the ground surface, hazards that accompany large earthquakes may include strong ground shaking and surface fault rupture, liquefaction, and landslide.

Within the Los Angeles basin, a set of faults including the Malibu Coast, Hollywood, Santa Monica, Sierra Madre and Cucamonga faults, forms the boundary between two physiographic provinces. To the north of the boundary is the Transverse Ranges Province, where seismic activity dominated by reverse and thrust faulting, giving rise to the Santa Monica and San Gabriel mountains. To the south is the Peninsular Ranges Province which features strike-slip faulting such as the Newport-Inglewood and the Elsinore fault systems, and blind thrust faults, such as the San Joaquin Hills Thrust and the Puente Hills Thrust. The site is found south of the boundary, within the Peninsular Ranges. All of these local faults give rise to frequent earthquakes, with attendant strong ground shaking, soil liquefaction, surface fault rupture, landslide and other hazards.

Of particular significance to the BCHD site are the Palos Verdes Fault and the Newport-Inglewood Fault. These are the closest and most active faults that can strongly affect the buildings. The Newport-Inglewood Fault displays strike-slip motion and produced the 1933 Long Beach Earthquake (M6.3). It can produce an earthquake of M7.1 if its onshore segments rupture together. It is thought to link with offshore segments that continue south to the Rose Canyon Fault and are capable of producing a very large event if they rupture together. The Palos Verdes Fault has been active in late Quaternary time and is capable of a M7.3 earthquake. Further details and technical fault descriptions from the USGS for the four closest faults are included in ImageCat's report on the 415 North Prospect Building (2022).

1.2 Local Faulting

The closest significant regional faults and their distances to the project site are tabulated below. Figure 1 shows the site location with respect to regional faults. These known faults all contribute to the ground shaking hazard and associated hazards at the site. Other, hidden faults also contribute to the hazard, and all of these faults are comprehensively considered in the USGS model.

Distance from Site to Regional Faults

Fault Name	Type	Limiting Magnitude	Distance (mi.)
Compton	RV	7.4	1.8
Palos Verdes	SS	7.3	2.4
Redondo Canyon	SS	6.2	3.0
Newport-Inglewood	SS	7.1	6.5
San Pedro Escarpment	RV	7.1	9.5
Puente Hills	RV	6.8	11.7
Santa Monica	SS	6.7	13.2
Elysian Park	RV	6.8	13.7
San Pedro Basin	SS	7.0	14.6
San Vicente	SS	6.2	14.6
Malibu Coast	SS	6.6	14.7
Anacapa-Dume	SS	7.1	15.2
Hollywood	SS	6.6	15.7
North Salt Lake	RV	6.0	16.0
Anaheim	SS	6.2	18.1
Raymond	SS	6.6	20.6

SS = Strike-slip; RV = Reverse

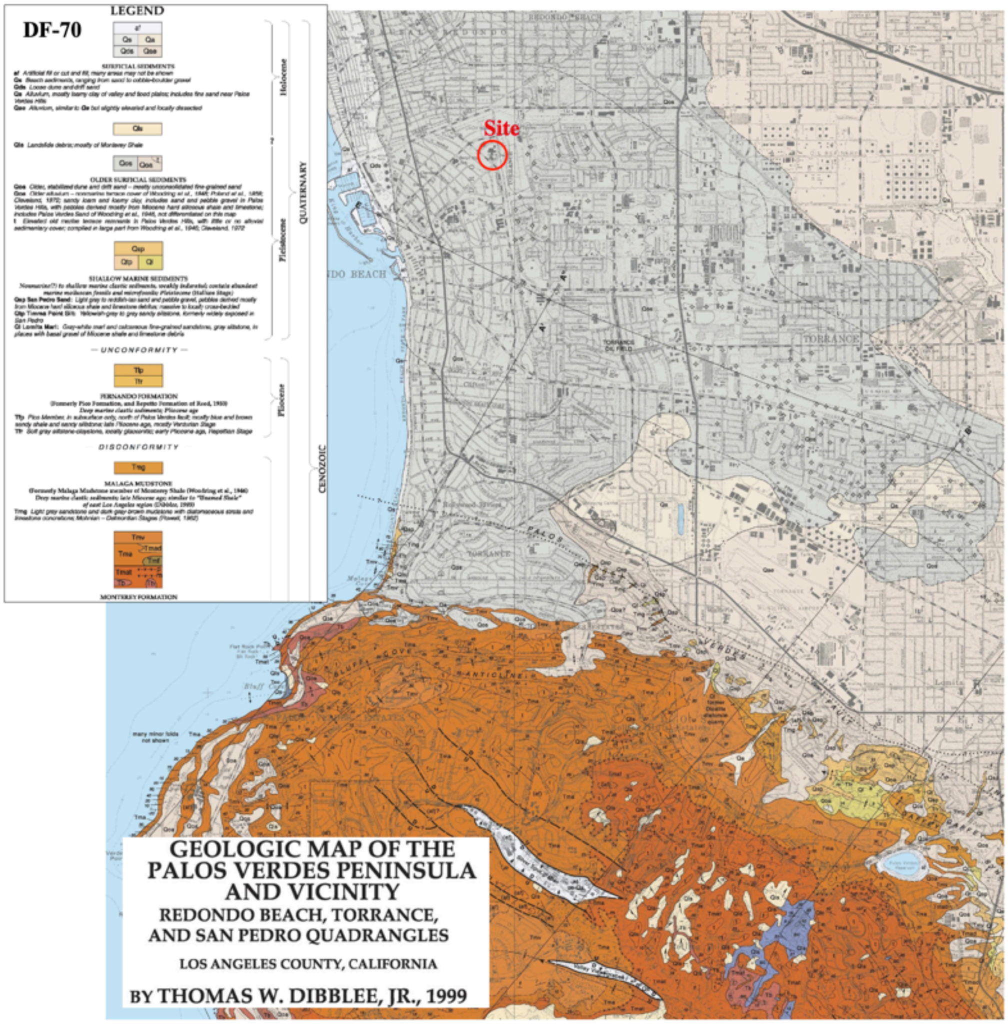

Figure 1 – Site Location, Geology and Local Faulting [CGS]

1.3 Surface Fault Rupture

Surface fault rupture can cause vertical and horizontal offsets that damage underground utilities and structural foundations that cross the fault. The State of California maintains maps of active faults known to rupture the ground surface [California Geologic Survey, SP-42] for the purpose of preventing structures from being built across the potential surface fault rupture. No known surface-rupturing faults cross the site [Redondo Beach quadrangle, CGS, 1999]. Based on this brief screening review of local faulting, we do not expect local surface fault rupture to contribute to the seismic risks at the site during the useful life of the buildings. BCHD's Geotechical Engineer, Converse Consultants, came to the same conclusion.

1.4 Landslide

Historically, landslides triggered by earthquakes have been a significant cause of earthquake damage. Areas that are most susceptible to earthquake-induced landslides are steep slopes in poorly cemented or highly fractured rocks; areas underlain by loose, weak colluvial soils; and areas near or within previous landslide deposits. The relatively flat site is NOT found within a Zone of Required Investigation for Landslide as defined by the State of California [Redondo Beach quadrangle, CGS, 1999]. We do not expect the site to be subject to earthquake-induced slope instability. BCHD's Geotechical consultant, Converse Consultants, also concluded that the site should not experience earthquake-induced slope instability.

1.5 Liquefaction

Earthquake-induced liquefaction is a ground failure phenomenon in which loose, sandy soils below the water table lose shear strength when subjected to many cycles of strong ground shaking. The effects of liquefaction may include settlement, lurching and lateral spreading. Where liquefaction occurs beneath building foundations, large settlements or dislocations can cause high levels of structural damage.

The site is NOT found within a Zone of Required Investigation for Liquefaction as defined by the State of California [Redondo Beach quadrangle, CGS, 1999]. According to the recent Geotechnical investigation report [Converse Consultants, 2016], the site soils consist of a fill layer underlain by older alluvial soils extending to the maximum explored depth of 61.5 feet Below Ground Surface (BGS). The fill layer consist of silty sand and clayey sand to depths ranging between 3 to 13 feet BGS. The alluvial sediments consist of older dune and drift sand. Groundwater was not encountered during site explorations. Considering the relatively dense soils and the deep groundwater table, the Geotechnical Engineer concluded that potential for liquefaction risk at site is low.

1.6 IBC Classification of Soils

Site ground conditions affect the intensity and duration of ground shaking, as well as the shape of the ground motion response spectrum. In comparison to rock sites, soft soils amplify moderate ground motions, extending the duration of ground shaking, and shifting seismic energy to longer periods.

Based on the soil characteristics describe above and the site geotechnical report [Converse Consultants, 2016], ground conditions correspond to Site Class D as described in the International Building Code (IBC) and ASCE-7. The earthquake motions used in this study were computed directly for this condition.

1.7 Strong Ground Shaking

1.7.1 Previous Ground Shaking

The Redondo Beach site has not been subject to high levels of ground shaking since the construction of the buildings in question (1976, 1979, 1990). Prior to their construction, the site was strongly shaken in the 1933 Long Beach Earthquake (M6.4). Other earthquakes occurring over the life of the existing structures include the 1987 Whittier-Narrows (M6), 1992 Landers (M7.3) and Big Bear (M6.8), and 1994 Northridge (M6.7) events. Ground shaking in these events was generally slight or slight-to-moderate, and we know of no reports of damage at the site from any of these past events.

1.7.2 Future Ground Shaking

Using the comprehensive probabilistic seismic hazard model from the U.S. Geological Survey [Petersen, Frankel, et al, 2014; Schumway et al., 2018], ImageCat has estimated the site ground shaking hazards. This model includes all of the major known surface faults. It also accounts for the scattered seismicity that is not associated with these major faults.

As an example of the level of seismicity and ground shaking at this site, we have estimated the levels of motion that have a 10% chance of being exceeded within the 50-year exposure. This level of ground shaking may be viewed as having an average return period of 475 years. The peak ground acceleration **(PGA) is 0.47g**, the short-period spectral acceleration **(Ss) is 1.09g**, and the 1-second spectral acceleration **(S1) is 0.66g**. In our risk estimates in Section 3, we make use of probabilistic hazards for this site at a wide range of annual probabilities (or equivalently, for a wide range of return periods).

1.8 Other Seismic Hazards

The existing site grade is at elevations more than 150 feet above mean sea level. The site is not within a tsunami inundation zone [CGS] and we conclude that it should not be affected by tsunami hazards. Other seismic hazards such as fire and blast do not appear to affect this site.

1.9 Discussion of Hazards

The seismic hazards for the site at 514 North Prospect Avenue, in Redondo Beach are dominated by frequent strong ground shaking. Other hazards such as earthquake-induced landslide, soil liquefaction or surface fault rupture do not appear to be significant at this site. The ground shaking hazard is somewhat stronger than assumed in the original design codes (i.e., the 1973 and 1985 editions of the Uniform Building Code). New design and construction at the site to current codes can easily account for the seismic hazards at the site to provide a higher level of earthquake resistance and more resilent performance.

2. Building Vulnerability

The MOB and parking structure have complete gravity and lateral load resisting systems. Lateral loads in buildings are caused by earthquakes or winds. In California, lateral loads from earthquakes generally govern the design for this type of buildings.

For existing buildings (like the subject buildings), national standards like ASCE 41-17 “Seismic Evaluation and Retrofit of Existing Buildings” provide appropriate methods to identify the existence and severity of various seismic deficiencies that can affect building’s performance in future events in terms of damage and stability. The standard also provides guidance on the retrofit methods. The seismic evaluation studies by NYA (dated 2020) followed this standard to identify deficiencies that can lead to stability issues affecting life-safety, as well as affecting structural and nonstructural damage, with implications for repair costs and downtime. ImageCat’s review of NYA’s report and discussions with NYA have improved our understanding of these buildings.

We note that several cities in California (e.g., Los Angeles, San Francisco, Santa Monica, etc.) are now citing certain older buildings under ordinances requiring evaluation and seismic retrofit where significant deficiencies are confirmed. At present, the City of Redondo Beach does not have such an ordinance in force, and these buildings are not types known as poor seismic performers.

The sections below present findings from our review of original Structural drawings, visual site survey, and discussions with Structural Engineers from NYA in more detail and in technical terms.

2.1 Design Review Notes, Medical Office Building (MOB), 510 North Prospect Avenue

Basis:	Seismic Evaluation of Beach Cities Health District Medical Office Building, 510 N. Prospect Avenue Redondo Beach, CA,” NYA Report, 1/21/2020 Structural drawings for Prospect I Medical Building, as prepared by Theodore E. Anvick, dated December 8, 1975, with revisions through 1976. S-1 through S-11 Architectural drawings for Prospect I Medical Building, as prepared by Gene D. Smith, AIA, 1975, with 1976 revisions. Structural drawings for Prospect I Medical Building Addition, as prepared by Reiss and Brown, dated 1978. S-1 through S-7. Architectural drawings for Prospect I Medical Building Addition, as prepared by Reiss and Brown, dated 1978. A-1 through A-19. Geotechnical study report for 514 N. Prospect Avenue, Converse Consultants, June 24, 2016. Visual site surveys by ImageCat on August 11, 2021 and February 2, 2023.
Architect:	Gene D. Smith, AIA
Structural Engineer:	Reiss and Brown, Tarzana, CA

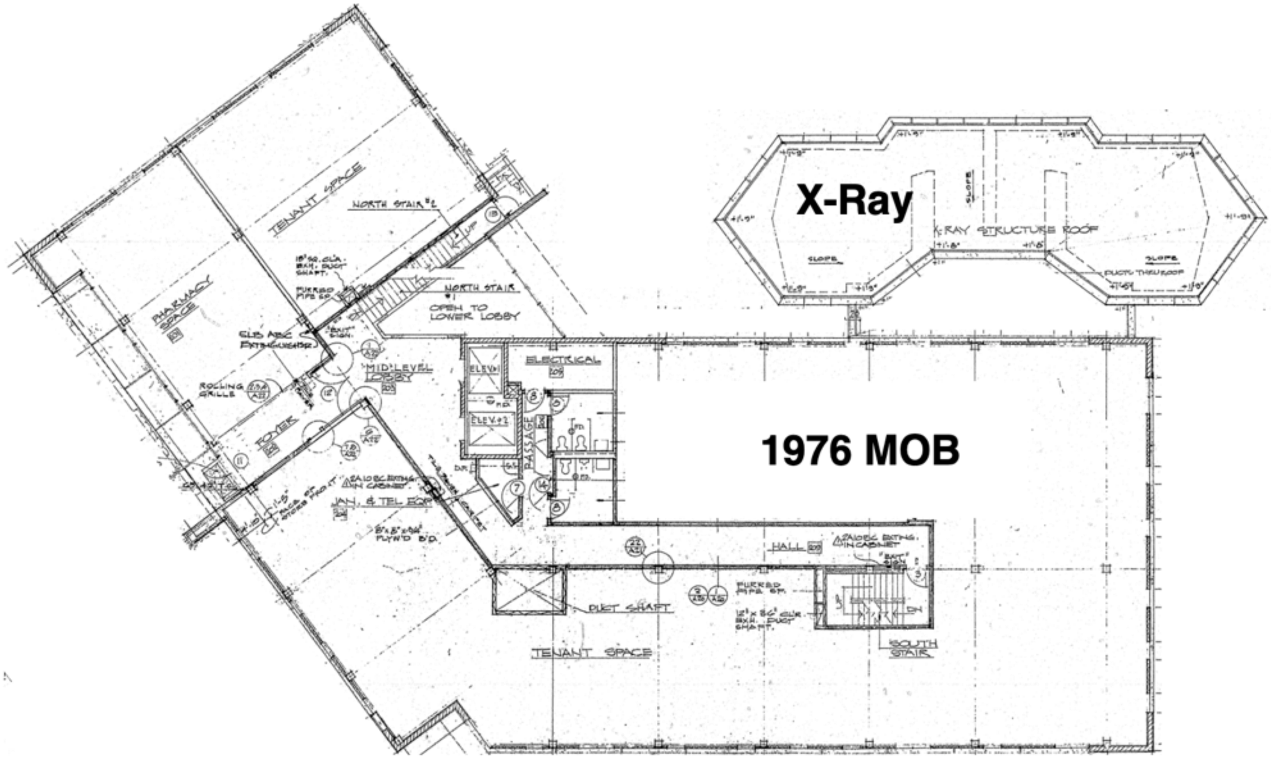

Figure 2 – Plan: Original 1976 MOB, Including X-Ray

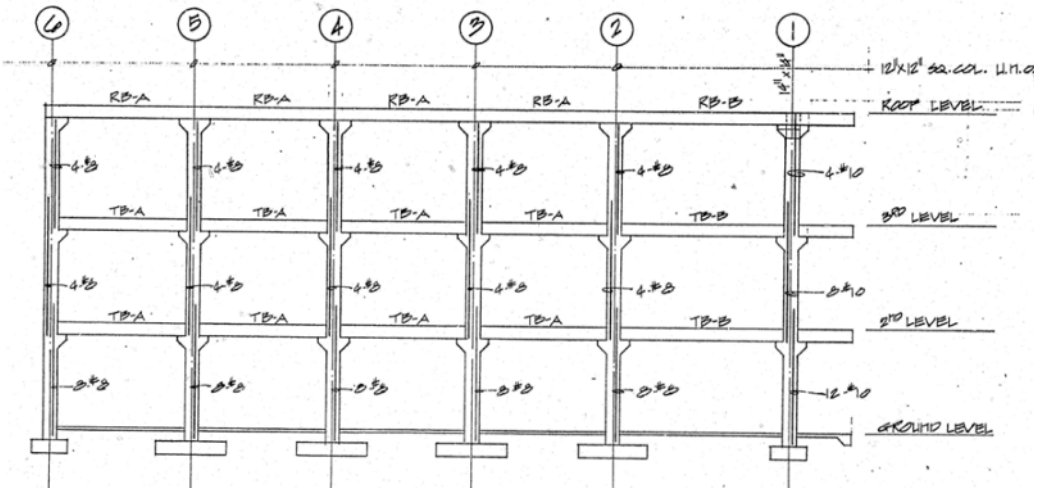

Figure 3 – Elevation: MOB Gravity Framing Showing Precast

Geotechnical Engineer:	Leroy Crandall & Associates, 3/31/75 report cited. Allowable bearing pressure given as 4,000 PSF for footings 24" below grade.
Year Built:	1976 for the original MOB; 1979 for the addition
Design Code:	Uniform Building Code, 1973 Edition cited for both.
Height:	3 stories (part of 1976 MOB is subterranean). The addition has 12'-0" story heights.

Materials:	(1979 Addition) Concrete compressive strength f’c = 2,000 for foundations; 3,000 psi for lightweight concrete topping on Robertson steel deck. Reinforcement is ASTM A615, Grade 40 bar. Structural steel is ASTM A36 for wide-flange shapes, and A=53 Grade B for pipe columns.
Foundations:	(Both) Spread footings, strip footings and 4” slab-on-grade.
Gravity System:	(1976 Original Building) The roof and floors of the original building are constructed of pre-stressed precast concrete planks with concrete topping slabs that span to pre-cast concrete beams and reinforced concrete masonry unit (CMU) walls. The beams are supported by pre-cast concrete columns that are continuous to the foundation. (1979 Addition) Plywood roof sheathing spans to 2x10 rafters at 16” on center, supported on wide-flange steel beams. Metal deck floors with concrete fill spans to steel wide-flange steel beams. Steel columns and steel pipe columns carry the loads down to the foundations.
Lateral System:	(1976 Original Building) The pre-stressed spancrete planks with concrete topping slabs serve as rigid diaphragms to collect and redistribute lateral forces to reinforced masonry (CMU) shear walls. (1979 Addition) The flexible roof diaphragm is plywood and the rigid floor diaphragms have metal deck with concrete fill. The diaphragms collect and redistribute lateral forces to nonbearing reinforced masonry (CMU) shear walls, which in turn deliver the forces to the concrete foundations.
Remarks:	(1976 Original Building) The building has an obtuse L-shaped plan. The north wing is subterranean, with masonry retaining walls at the perimeter. Other walls are provided at the building corners and central stairwell. NYA’s structural modeling with ETABS showed structural periods of 0.26 to 0.35 seconds. Linear dynamic response analysis was performed for BSE-1E and BSE-2E spectra. (1979 Addition) The addition is light in weight. The two buildings are separated by a 2-inch seismic joint. (18/S-5; 19/S-5 from 1979 Addition Structural drawings). The wood roof diaphragm has tension cross-ties.
Condition:	Good condition was observed in the locations inspectable. Better structural and nonstructural condition was observed than in the old hospital (514 N. Prospect).
Architectural Notes:	(1976 Original Building) Lightweight exterior panels with “marblecrete” finish and ribbon windows. (1979 Addition) Glass-clad at 2nd and 3rd floor.
Equipment Notes:	HVAC equipment is secured to the roof

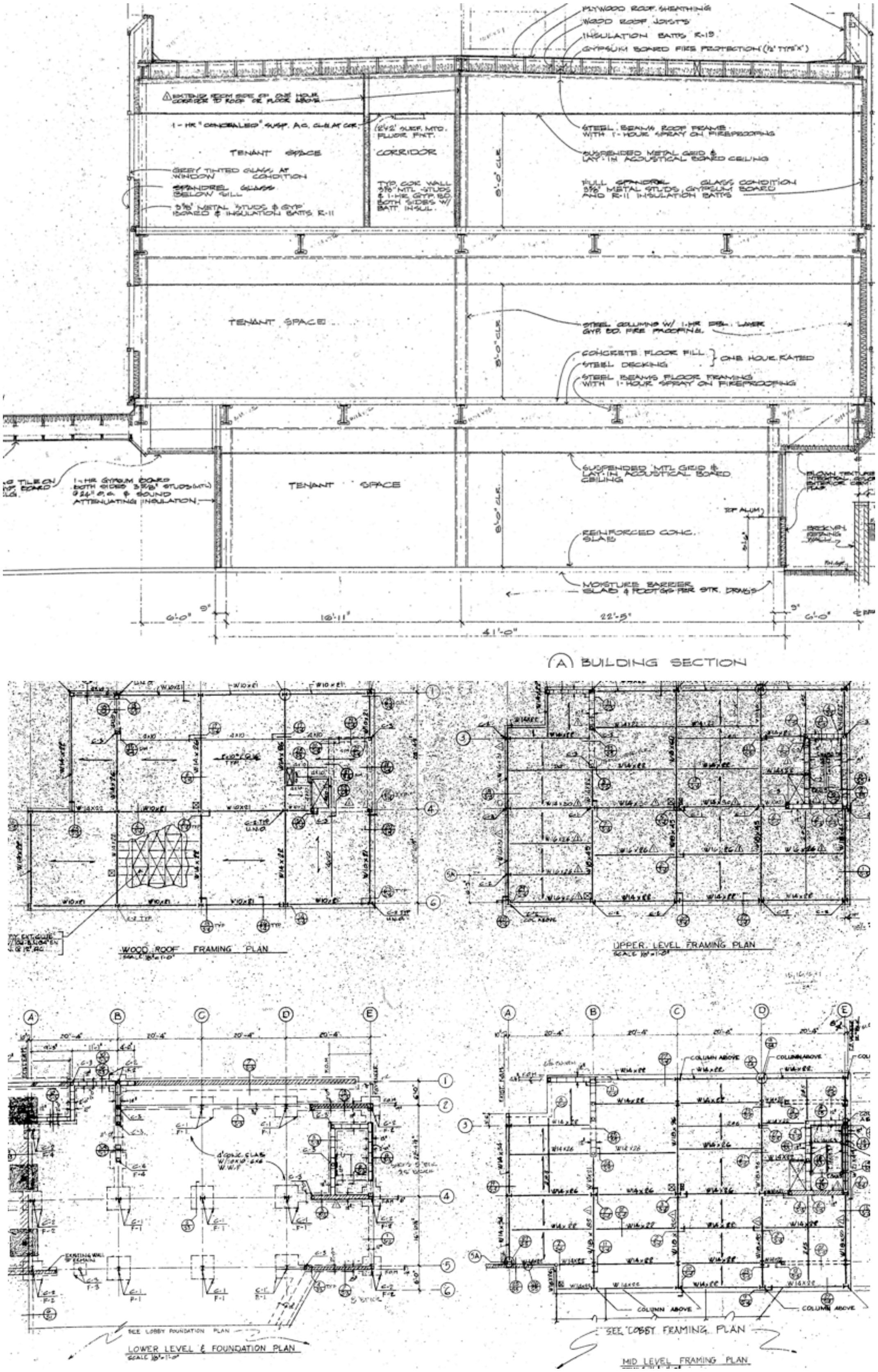

Figure 4 – 1979 Addition: Building Section and Floor Plans

Fig 10 – 1976 MOB Exterior

Fig. 11 – 1979 Addition & HVAC Equipment

2.2 Design Review Notes, X-Ray Room

The "X-Ray Room" is shown in drawings for the Original Medical Office Building (1976). It is a concrete building, 13'-10 feet tall to the top of the roof slab, with massive reinforced concrete walls to provide shielding. The minimum wall thickness is 2 feet, and walls at the ends of the building reach a thickness of nearly 9 feet. The roof is a 2-foot thick flat reinforced concrete slab. A 6" thick reinforced slab-on-grade forms the floor. It is essentially a rigid box structure, with very low structural vulnerability. It appears to be structural connected to the original MOB. The connecting slab uses spancrete planks and a topping slab, but does not appear to be specially reinforced to transfer loads to the X-Ray building. Therefore, differential movements between the mid-level MOB floor and X-Ray building roof may cause damage to the connecting slab. HVAC equipment is anchored to the roof and to the slab interconnecting it to the original MOB.

Fig 12 – 1976 MOB Exterior & X-Ray Roof

Figure 13 – Parking Structure Top Deck

Cracking at Pier/Spandrel Joint

Figure 14 – Exposed Rebar, Parking Structure Top Deck; Narrow Masonry Piers and Spandrels

2.3 Design Review Notes, 512 North Prospect Avenue Parking Structure

Basis:	"Seismic Evaluation of Beach Cities Health District - Parking Structure, 512 N. Prospect Avenue Redondo Beach, CA," NYA Report, 1/17/2020. A-1 through A-14.

	Structural drawings for South Bay Hospital Parking Garage, Albert G. Presky & Associates dated March 3, 1989. S-1 through S-17.
	Geotechnical study report for 514 N. Prospect Avenue, Converse Consultants, June 24, 2016.
	Visual site surveys by ImageCat August 11, 2021 and February 2, 2023.
Architect:	Benton/Park/Candreva AIA, Santa Monica, CA
Structural Engineer:	Albert G. Presky & Associates, Los Angeles, CA
Geotechnical Engineer:	Leroy Crandall & Associates, foundation report dated 6/23/88; allowable soil pressure is 5,000 psf
Year Built:	1990
Design Code:	1985 Uniform Building Code (UBC)
Height:	2 stories above grade + basement (3-4 levels)

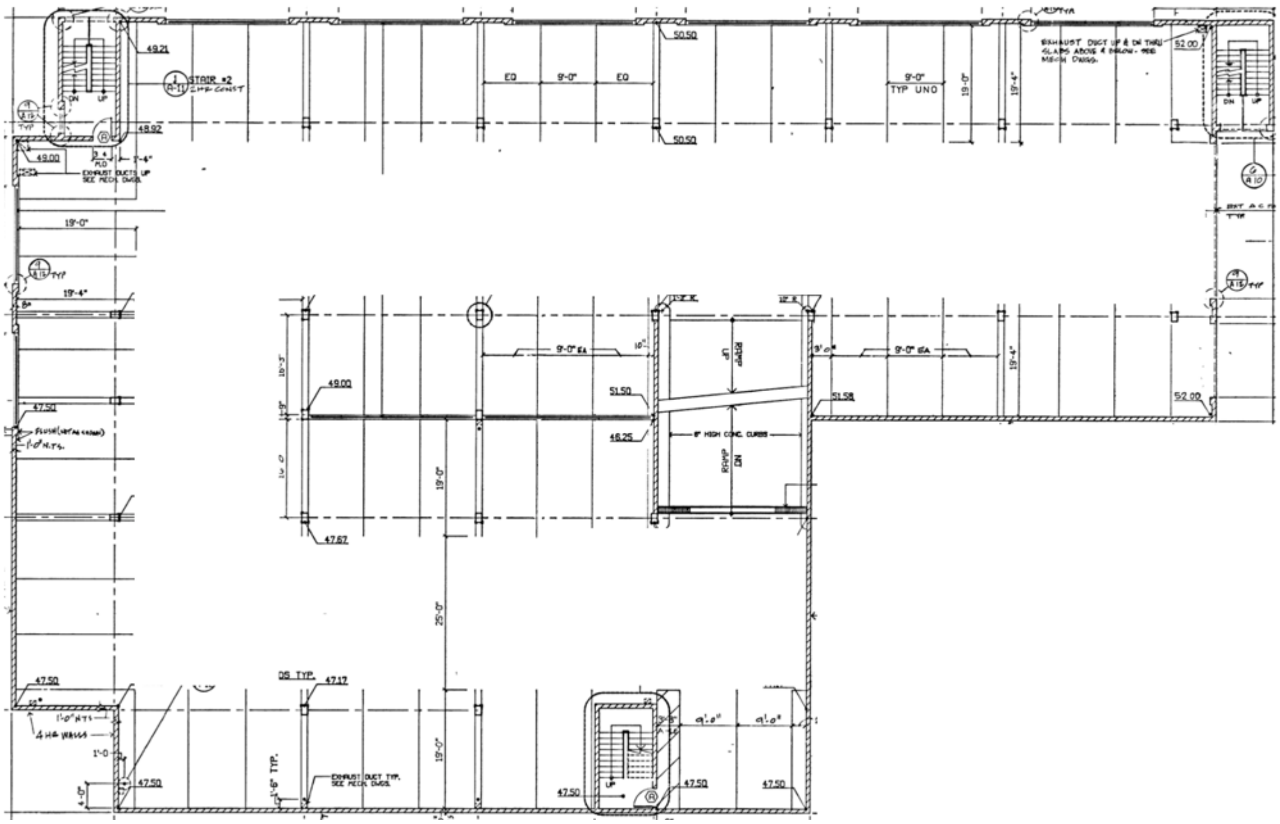

Figure 15 – Parking Structure Plan

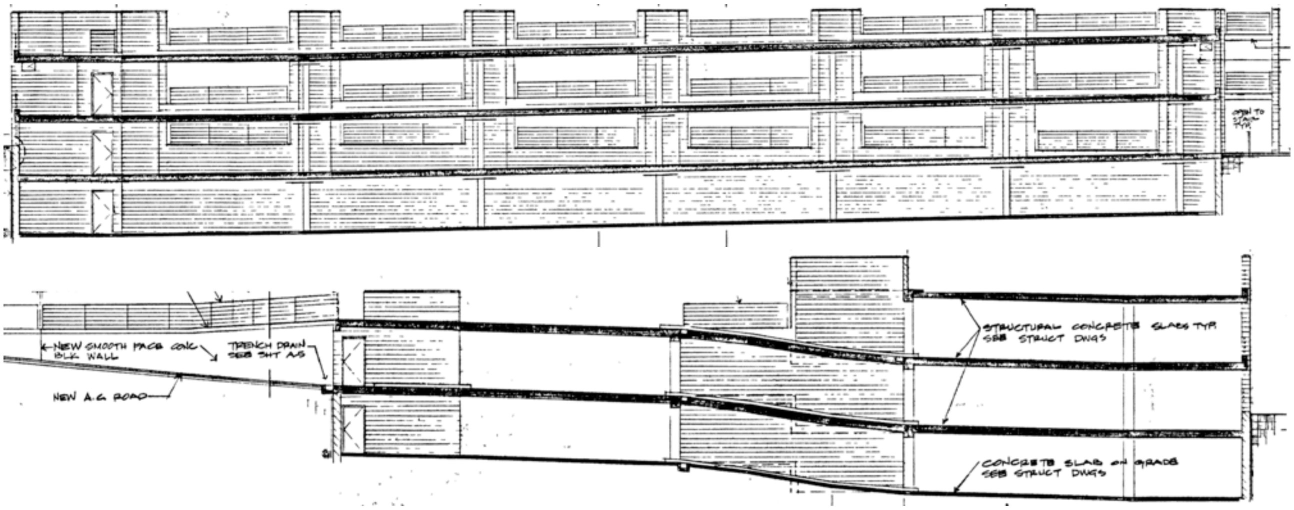

Figure 16 – Parking Structure Sections

Materials: Concrete compressive strength f’c = 2,500 psi for slab-on-grade and retaining wall footings; f’c = 3,000 psi for column footings, slabs, beams, etc.; f’c =4,000 psi for columns. Reinforcing steel is A615 Grade 40 in masonry walls, stirrups and ties, and wall dowels; Grade 60 for concrete flexural steel. Masonry units are ASTM C90, Grade N. Compressive strengths for mortar and grout are 1,800 psi and 2,000 psi respectively.

Foundations: Spread footing, strip footings and 4” slab-on-grade.

Gravity System: The parking structure slabs are reinforced concrete slabs spanning to reinforced concrete columns at the interior and to reinforced masonry walls at the perimeter. Slabs are 11 inches thick typically, with a few areas 13 inches thick.

Lateral System: The reinforced concrete floor slabs collect and redistribute lateral forces to the concrete masonry unit shear walls located around the parking structure’s perimeter, and along the sides of the ramp.

Remarks: The parking structure has 200 parking spaces. The structure has an L-shaped plan that wraps around the medical office building (510 N. Prospect). Floors are flat slabs spanning to columns with drop panels. A seismic joint at center of the ramps keeps the ramps from serving as an unintentional brace between floors.

Tall narrow CMU piers are seen along the long side. Thick slabs and perimeter spandrels may make this exhibit unintended frame action. NYA found that the slab-to-wall connections are slightly overstressed.

NYA’s structural modeling with ETABS showed structural periods of 0.10 to 0.14 seconds. Linear dynamic response analysis was performed for BSE-1E and BSE-2E spectra.

Condition: The structure has some exposed rebar at the top of slab in a few locations from inadequate cover in the original construction. There is no seismic joint between the tall, narrow CMU wall piers and the concrete spandrels at the edge of the slabs. Cracking is observed where the spandrel abuts the CMU walls.

Equipment Notes:	There is very limited equipment in the parking structure – some HVAC equipment, lighting and fire sprinklers. There are three stairs but no elevator.

2.4 Building Stability and Qualitative Damage Discussion

All three structures (i.e., the original MOB, the 1979 Addition and the 1990 Parking Structure) have complete and gravity load-carrying and lateral force-resisting systems.

2.4.1 Medical Office Building

The seismic evaluation from NYA (2020) found the following *(see NYA's Executive Summary):*

> The methodology of ASCE 41-17, Seismic Evaluation and Retrofit of Existing Buildings, was used to evaluate the seismic performance. The results of the analysis indicate that the CMU walls have inadequate shear and/or flexural strength, and the diaphragm-to- CMU wall connections have inadequate strength to transfer expected seismic forces for both the original building and the 1979 Addition.
>
> The plywood roof diaphragm of the 1979 Addition has an extensive cantilever on the south side and there are no chord elements to resist/transfer seismic loads. In addition, approximately 40% of the footings and grade beams of the 1979 Addition have inadequate strength.
>
> The maximum combined displacement response of the original building and Addition exceed the provided separation joint and impact between buildings is likely. Since the roof and floors align vertically the damage due to pounding is likely to be limited/localized and unlikely to compromise structural integrity.
>
> The results indicate that the office building does not meet the Basic Performance Objective for Existing Buildings (BPOE), as defined by ASCE 41-17. The BPOE, or objectives close to it, has been used for characterizing seismic performance in other standards and regulations. The BPOE accepts a lower level of safety and a higher risk of collapse than would that provided by similar standards for new buildings.

Retrofits were recommended to remedy these weaknesses and provide adequate life-safety performance. There may be alterative schemes to achieve similar improvements in the seismic performance of the buildings. For example, roof- and floor-to-wall anchorage and diaphragm strengthening as recommended for the 1976 section of the MOB might be done with fiber composites, rather than with concrete saw cutting the existing topping slab and replacing it. We recommend authorizing further study by NYA to explore such alternatives that would have lower cost and reduced impact on tenant spaces.

Using an approximate methodology, we have estimated the probability of collapse for each building for scenario ground motions having a 10% probability of exceedance within a exposure period of 20, 30 or 50 years. Section 3.2 presents these results with the associated damage estimates.

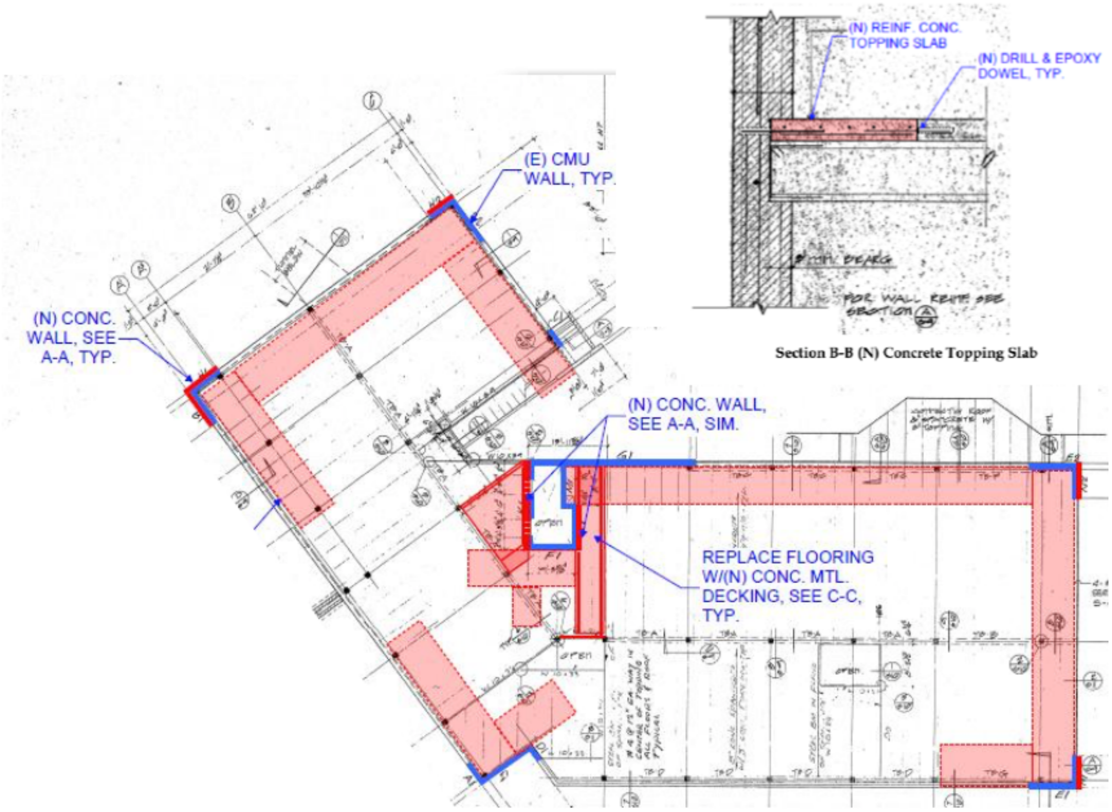

Figure 17 – Diaphragm Reinforcement and Shear Transfer to Masonry Shear Walls

2.4.2 Parking Structure

The parking structure was designed to a more recent code (1985 UBC), and NYA found it to be a good structure. The sole concern was for a slight overstress in the slab-wall connections for BSE-2E ground motions. NYA recommended reinforcing slab-to-wall connections to meet the BSE-2E ground motions, under which they are 20% overstressed. We note that the BSE-2E ground shaking is stronger than the current code levels, so the overstress most likely does not exist for the design basis earthquake (DBE). We interpret this to mean that the parking structure is close to conformance with current codes and should be expected to provide stability and life-safety performance near to that of current code. Our stability screening methods indicate that the parking structure has about a 10% probability of collapse in the 2,475-year recurrent ground motions, consistent with the Maximum Considered Earthquake under ASCE 7 and IBC – consistent with current code life-safety performance.

ImageCat has not performed only screening calculations for the buildings. Instead, we relied substantially on the seismic evaluation performed by Nabih Youssef Associates as documented in their report dated 2020, which included detailed structural engineering models (using the ETABS software). Their evaluation followed ASCE 41 methods, and included structural calculations and computer modeling.

3. Seismic Risk Results

3.1 Brief Overview of Methods Used and Definitions

ImageCat performed seismic risk analysis based on the findings from review of the seismic hazards and the vulnerability assessment. In ImageCat's loss estimates, we have used ground motions from the 2014 USGS National Seismic Hazard Mapping Project. Structural damage models are adapted from "Code-Oriented Damage Assessment for Buildings" or CODA [Graf & Lee, EERI Earthquake Spectra Journal, February, 2009] and ATC-13, "Earthquake Damage Evaluation Data for California," [Applied Technology Council, Redwood City, CA, 1985 and ATC 13-1, 2002]. Seismic risk terminology follows guidelines issued by the American Society of Testing and Materials [ASTM E 2026-16a].

These models are semi-empirical, combining actual historical building performance data from past earthquakes, expert opinion, and other means to produce loss estimates for a particular class of structures. The models relate damage to seismic design parameters: building period (T), base shear (V/W or Cs), overstrength and ductility (through the R-factor). Engineering judgment is used to account for other building-specific structural features that affect structural performance (regularity, continuity, etc.). In this study, a Professional Engineer from ImageCat assessed the specific features of the building that affect seismic performance and adjusted the vulnerability models so that the risk results can reflect the particular building being examined.

Probable Loss (PL) describes the level of building damage from earthquake, expressed as a fraction of the building replacement value, having a stated probability of exceedance within a given exposure period. Alternatively, a level of earthquake damage having a stated return period. Probable Loss is found by considering all levels of earthquake hazard that may occur for the site in question, the building damage associated with each hazard level, and the variability of building damage within each hazard state. ImageCat recommends 'Probable Loss' (PL) as the best index of risk, since it relates loss directly as a function of probability.

3.2 Loss Estimates, Status Quo

The following risk estimates are based upon ground shaking scenarios with 10% probability in a defined exposure period. The exposure period may correspond to a period of usage, or to a remaining useful life of the building. We examine exposure periods of 20 years, 30 years, and 50 years, correspondint to return periods of 190, 285 and 475 years, respectively. We present the mean or expected loss (SEL), as well as the 90th-centile nonexceedance loss (SUL). The loss estimates consider the collapse potential for each structure. The collapse probability (Pcol) is also noted.

	50 Years			30 Years			20 Years		
Building	SEL	SUL	Pcol	SEL	SUL	Pcol	SEL	SUL	Pcol
1976 MOB	31%	44%	16%	25%	36%	10%	20%	30%	6%
1979 MOB	23%	35%	9%	18%	28%	5%	15%	23%	3%
Parking Structure	16%	25%	2%	13%	20%	1%	11%	17%	1%

The recommended seismic retrofits, in addition to improving the life-safety of the MOBs, would generally reduce the expected damage and downtime. Post-retrofit, MOB expected losses (SEL) may be in the 12% to 18% range, and collapse probabilities would also be substantially reduced.

4. Limitations

All work was performed by Professional Engineers (Civil and Structural). The scope of work performed included assessment of geologic hazards based on published maps, the recent geotechnical investigation report [Converse Consultants, 2016], and ground shaking models adapted by ImageCat from the U.S. Geological Survey.

We reviewed the original Architectural and Structural design drawings and the Seismic Evaluation reports [Nabih Youssef Associates (NYA), 2020]. We conducted discussions with NYA to understand their findings on each structures' characteristics and behaviors in computer models. A Professional Engineer from ImageCat conducted a visual survey at site to assess existing configuration, conditions, and usage.

To examine seismic risks for the structures in their status quo conditions, ImageCat performed risk analysis using SeismiCat, ImageCat' earthquake risk tool for individual sites.

ImageCat did not design the buildings, and design and construction professionals bear responsibility for the structure. Additional design deficiencies may be revealed through detailed structural analysis and calculations -- beyond the scope of the current review. Our seismic risk findings assume that the construction will utilize good materials, conforming to the prevailing code and good practice. Additional risk (unexpected earthquake damage) may result if poor materials or construction practices are used, or if the completed construction deviates from the approved designs. Construction quality should be verified upon completion.

Seismic risk assessment is subject to many uncertainties – in the estimation of seismic hazards, and in estimating building performance given the seismic hazards. The models used reflect the current state of knowledge and its limitations.

ImageCat warrants that its services are performed with the usual thoroughness and competence of the consulting profession, in accordance with the current standard for professional services, in the location where the services are provided. No other warranty or representation, either expressed or implied, is included or intended in its proposals or reports.

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We are pleased to have the opportunity to provide seismic risk consulting services to BCHD. Should you have any questions regarding the results of this seismic risk assessment, please email or call.

Sincerely,

ImageCat, Inc.

William P Graf

William P. Graf, P.E. Civil
Vice President, Engineering

Attached:

A. Earthquake Risk Glossary
B. Qualifications

Appendix A – Earthquake Risk Glossary

Acceleration	The rate of change of velocity. As applied to strong ground motions, the rate of change of earthquake shaking velocity of a reference point. Commonly expressed as a fraction or percentage of the acceleration due to gravity (g), wherein g = 980 centimeters per second squared.
Active Fault	An earthquake fault that is considered to be likely to undergo renewed movement within a period of concern to humans. Faults are commonly considered to be active if they have moved one or more times in the last 10,000-11,000 years, but they may also be considered potentially active when assessing the hazard for some applications even if movement has occurred in the Quaternary Period (2M years). See also *fault.*
Aggregate Loss Curve	Also known as risk curves. A curve that present risk severity (dollars lost, lives lost, injuries, days of business interruption, etc.) versus frequency or probability. The plots in this report show annual probability of exceedance as the Y-axis, and portfolio-wide loss ($) as the X-axis. The Y-axis (probability of exceedance) is also translated into average return period – the average time between loss levels of the same severity.
Alluvium	A soil type consisting of loosely compacted gravel, sand, silt, or clay deposited by streams.
Amplification	An increase in seismic wave amplitude as the waves propagate through certain soils, in sedimentary basins, or in certain topographic configurations (e.g. along ridge lines).
Average Annual Loss	The loss per annum due to hazards, calculated as the probabilistic loss contribution of all events. The expected annual loss is the expectation of the probability distribution of loss per annum, and under certain assumptions may be calculated as the probability-weighted average-of loss due to all possible hazard events.
Alquist-Priolo (A-P) Special Studies Zone	More recently known as Earthquake Fault Zone (EFZ). In California, these are defined areas surrounding active faults, as defined by the State Geologist, within which it is necessary to perform fault location studies in order to construct buildings for human occupancy. Buildings for human occupancy may not be constructed within a prescribed distance of the identified fault rupture trace. Details of the regulations are presented in Special Publication 42, published by the California Division of Mines and Geology (CDMG).
Attenuation	The rate at which seismic, wind, or water intensities decrease with distance from their sources or shoreline landing points.
Average (Expected) Annualized Loss	See Average Annual Loss.

Business Interruption (BI) Loss	Economic loss associated with loss of function of a commercial enterprise.
Cat Bond	Catastrophe Bond. An alternative risk financing instrument which exploits the capital markets for insurance capacity. A number of different forms exist. In a parametric Cat bond, investors purchase the bonds at a face value, and will receive principal and interest after a specified period, provided a defined event does not occur. The event is defined by objective parameter, determined by a neutral, authoritative third party. For an earthquake Cat bond, the event may be defined according to magnitude and epicenter location, and the degree of forfeiture by the bond investor typically varies according to a schedule of event thresholds and geographic bounds.
Damage	Physical disruption, such as cracking in walls or overturning of equipment (often used synonymously but erroneously with Loss).
Damping	The dissipation of energy in the process of viscous flow, deformation of viscoelastic materials, frictional sliding, or permanent material deformation or yielding (hysteretic damping).
Deductible (Insurance)	The amount of loss above which an insurance payment is due to the insured.
Deterministic	A method of engineering and decision-making evaluation based solely on the selection of a few natural hazards events used as scenarios. For instance, an historical earthquake may be taken as a scenario to see what would happen if that earthquake recurred. Deterministic methods are typically based on source models and intensity propagation methods that exclude random effects.
Ductility	The ability to sustain deformation beyond the elastic limit (yield) without material failure.
Ductile Detailing	Design details specifically intended to achieve an intended stable yielding mechanism in a building structure or equipment support structure. For example, special requirements for the placement of the reinforcing steel within structural elements of reinforced concrete and masonry construction necessary to achieve non-brittle, ductile behavior (ductility). Ductile detailing may include close spacing of transverse reinforcement to attain confinement of a concrete core or to prevent shear failures, appropriate relative dimensioning of beams and columns and 135 degree hooks on lateral reinforcement.
Duration	The time interval in earthquake ground shaking during which motion exceeds a given threshold. For example, the measure of duration to be used as a measure of damage potential to buildings might be the time interval over which acceleration at the base of a building exceeds, say, 5 percent of the acceleration of gravity.
Earthquake	A sudden ground motion or trembling caused by an abrupt release of accumulated strain acting on the tectonic plates that comprise the Earth's crust. A sudden motion or trembling in the earth caused by the abrupt release of slowly accumulated strain.

Earthquake Fault Zone	See also Alquist-Priolo Special Studies Zone. In California, these are defined areas surrounding active faults, as defined by the State Geologist, within which it is necessary to perform fault location studies in order to construct buildings for human occupancy. Buildings for human occupancy may not be constructed within 50 feet of the identified fault rupture trace. Details of the regulations are presented in Special Publication 42, published by the California Division of Mines and Geology (CDMG).
Earthquake Hazard	The representation of an earthquake hazard can cover ground shaking, response spectra (peak spectral acceleration, peak spectral velocity, peak spectral displacement), peak ground velocity, peak ground acceleration, duration of significant shaking, time-history evaluation, and/or permanent ground deformation including fault offset.
Energy Dissipation Systems	Various structural devices that actively or passively absorb a portion structures of the intensity in order to reduce the magnitude or duration (or both) of a structure response. These devices include active mass systems, passive viscoelastic dampers, tendon devices, and base isolation, and may be incorporated into the building design.
Epicenter/Hypocenter	The point of initial rupture of a fault in an earthquake occurs deep beneath the ground surface at a location referred to as the hypocenter. The point at the ground's surface which is vertically above the hypocenter is called the epicenter. These locations may be estimated by triangulation from a number of different seismographic stations. For uniform ground conditions, ground shaking tends to decrease in intensity with increasing distance from the part fault which ruptured. Since the horizontal extent of fault rupture is short for small-magnitude (e.g. M<5.5) earthquakes, ground shaking tends to decrease with the distance of a site from the epicenter for such events. However, for larger earthquakes (M>6.5), the rupture extends for a significant distance (tens to hundreds of kilometers), making epicentral distance an unreliable estimator of ground shaking intensity.
Exposure	The number, types, qualities, and monetary values of various types of property or infrastructure, life, and environment that may be subject to an undesirable or injurious hazard event. Exposure Period The period of time over which risk is to be computed; the period of time over which a facility or population at risk is subjected to a hazard.
Fault Rupture	The differential movement of two land-masses along a fault. A concentrated, permanent deformation that occurs along the fault trace and caused by slip on the fault.
Fault Scarp	A step-like linear land form coincident with a fault trace and caused by geologically recent slip on the fault.
Fault Trace	An intersection of a fault with the ground surface; also, the line commonly plotted on geologic maps to represent a fault.

Fault Types	*Strike-slip* - a fault along which relative movement tends to occur in a horizontal direction parallel to the surface trace of the fault. The San Andreas is one of the most well known strike-slip faults, although some segments exhibit other kinds of fault behavior. The strike of the fault refers to the angle between the surface trace of the fault and north. *Dip-slip* - A fault for which relative motion occurs parallel to the direction of dip (the deviation of the fault plane from the vertical) of the fault, e.g., motion occurs perpendicular to the surface trace of the fault, at some angle with the vertical. Such faults produce scarps when fault rupture reaches the surface. *Normal* - Dip-slip movement in which the overhanging side of the fault moves downward. *Reverse* - Dip-slip movement in which the overhanging side of the fault moves upward. *Thrust* - A low-angle reverse fault. The 1987 Whittier-Narrows and 1994 Northridge earthquakes occurred on blind thrust faults - thrust faults with no surface expression. *Oblique* - A fault combining strike-slip and dip-slip motion.
Frequency	In the context of risk analysis, this refers to how often an event or outcome will occur, given a specified exposure period. For example, annual frequency is the number of events per year.
Fundamental Period	The longest period of oscillation for which a structure shows a maximum response (the reciprocal of natural frequency).
Geographic Correlation Index (GCI)	An index developed by URS Corporation [W. Graf, 7NCEE, 2002] to indicate the relative severity of risks from a particular building or site on the aggregate losses of a geographically distributed portfolio of buildings or other values at risk from earthquake hazards.
Ground Failure	A general reference to fault rupture, liquefaction, landsliding, and lateral spreading that can occur during an earthquake or other land movement causes.
Ground Shaking	The energy created by an earthquake as it radiates in waves from the earthquake source. A general term referring to the qualitative or quantitative aspects of movement of the ground surface from earthquakes. Ground shaking is produced by seismic waves that are generated by sudden slip on a fault and travel through the earth and along its surface.
Hazard	A natural physical manifestation of the earthquake peril, such as ground shaking, soil liquefaction, surface fault rupture, landslide or other ground failures, tsunami, seiche. These hazards can cause damage to man-made structures. This is an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss.
Irregularity (see also Regularity)	

	Describes deviations from optimal seismic structural configuration. Common irregularities are divided into vertical and plan irregularities: Plan irregularities - common cases include reentrant corners, non-symmetric distribution of mass, strength or stiffness within any given story. Vertical irregularities - abrupt changes in plan dimensions, weight, strength or stiffness from one story to another. One common vertical irregularity is the soft or weak story, often the first story, which may lead to structural collapse as earthquake ductility demands concentrate in one story, rather than distributing more uniformly over the height of the building.
Lateral Spread	The landsliding of gentle, water-saturated slopes with rapid fluid-like flow movement caused by ground shaking and liquefaction. Large elements of distributed, lateral displacement of earth materials.
Limit of Liability	(Insurance) The maximum payment amount which an insured may receive for a covered loss.
Liquefaction	When the pressure of the pore water, water located in spaces between soil particles, exceeds particle friction forces, particularly in loose sands with high water content. The soil becomes a soil-water slurry with significantly reduced shear strength. The result can be foundation bearing failure, differential settlement, lateral spreading, or floating of underground components. A process by which water-saturated soil temporarily loses shear strength due to build-up of pore pressure and acts as a fluid.
Local Seismic Hazards	The phenomena and/or expectation of an earthquake-related agent of damage, such as vibratory ground motion (i.e., ground shaking), inundation (e.g., tsunami, seiche, dam failure), various kinds of permanent ground failure (e.g., fault rupture, liquefaction), fire or hazardous materials release.
Loss	The human or financial consequences of damage, such as human death or injury, cost of repairs, or disruption of social, economic, or environmental systems.
Magnitude (M)	Magnitude (M) is the most widely used measure of the size of an earthquake (see also Richter Scale). Magnitude scales are logarithmic, found by taking the common logarithm (base 10) of the largest ground motion recorded at the arrival of the type of seismic wave being measured (a typical seismogram will display separate arrival times for a P-wave - compressional - , an S-wave - shear -, and a train of Rayleigh waves) and correcting for the distance to the earthquake's epicenter. Thus, an increase in magnitude by one unit would correspond to a tenfold increase in measured wave amplitude. Moreover, the energy released by an earthquake increases by a factor of about 30 for each unit increase in magnitude.
Mean	Arithmetic mean or average value in a statistical distribution.
Median	The value in a distribution for which 50% of the distribution values are greater or less than the median value.

Mitigation	Sustained action taken to reduce or eliminate long-term costs and risks to people and property from hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from a specific event.
Model	A representation of a physical system or process intended to enhance our ability to understand, predict, or control its behavior
Modified Mercalli Intensity (MMI) (abridged)	A numerical scale ranging from I to XII which describes local ground earthquake intensity in terms of local earthquake effects. In many historical earthquakes (1900 to 1970's), few ground shaking instruments were deployed, and ground shaking maps were compiled on the basis of observed effects, using scales like the Modified Mercalli Intensity (MMI) scale. As a result, most building damage statistics are correlated to the MMI scale, since instrumental strong motion data was rare (see Peak Horizontal Acceleration). I-V Not significant to structures or equipment. VI Felt by all; many are frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. VII Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Chimneys, factory stacks, columns, monuments, and walls fall. Heavy furniture overturned. Disturbs persons driving motorcars. IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; damage great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. X Some well-built wooden structures destroyed; most masonry and frame structures destroyed, along with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land dips in soft ground. Rails bent greatly. XII Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.
Peak Ground Acceleration (PGA).	The maximum amplitude of recorded acceleration. If not specifically stated, this usually refers to horizontal accelerations.
Peak Horizontal Acceleration (PHA)	An instrumental measure of earthquake ground motion intensity, normally taken from a triaxial earthquake accelerogram as the maximum value recorded from

	either of the 2 horizontally-oriented axes. See also Peak Ground Acceleration and Acceleration.
Portfolio	Within the context of typical building seismic risk studies, this refers to a geographically-distributed set of facilities or values-at-risk.
Probability and Frequency	Frequency measures how often an event (including a natural hazard event, a state or condition of a component, or a state or condition of the system) occurs. One way to express expected frequency is the average time between occurrences or exceedances (non-exceedances) of an event. The mean annual rate of occurrence of a hazard parameter within a range of values is another way to express expected frequency of a hazard. Probabilities express the change of the event occurring or being exceeded (not exceeded) in a given unit of time. Whereas probabilities of occurrence cannot exceed 1.0, expected frequencies (for a given time unit) can exceed 1.0. For instance, expected frequencies of an auto accidents in Washington D. C. for a given year are far in excess of 1.0 even though the probability of an auto accident within a given year can only approach very closely 1.0.
Probabilistic Methods	Scientific, engineering, and financial methods of calculating severities and intensities of hazard occurrences and responses of facilities that take into account the frequency of occurrence as well as the randomness and uncertainty associated with the natural phenomena and associated structural and social response.
Probable Loss	A level of building damage from earthquake, expressed as a fraction of the building replacement value, having a stated probability of exceedance within a given exposure period. Alternatively, a level of earthquake damage having a stated return period. Probable Loss is found by considering all levels of earthquake hazard that may occur for the site in question, the building damage associated with each hazard level, and the variability of building damage within each hazard state.
Probable Maximum Loss	A term used in the past to characterize the risk of earthquake damage to buildings.
Probability of Exceedance	In the context of these risk reports, this is the probability that a specified level of damage will be surpassed within the exposure period (related to building life or investment term), given the site's earthquake environment and the facility's seismic vulnerability. The probability of exceedance and exposure period are related to the average return interval of the loss. For example, a loss level that has a 10% chance of exceedance in a 30-year exposure period may be described as having a 285-year average recurrence interval. A loss level that has a 10% chance of exceedance in a 50-year exposure period has a 475-year average recurrence interval.
Recurrence Interval	See Return Period.
Redundancy	The ability of more than one component to fail prior to system failure. In the 1997 Uniform Building Code, a Reliability/Redundancy Factor is defined as the ratio of the design story shear in the most heavily loaded element, divided by the total story shear. In this definition, a low ratio (say 0.1 or less) would imply greater

	redundancy, since a single element failure would be unlikely to produce a lateral force system failure at that story.
Regularity	For optimum seismic performance, a building structure should be regular, with: - balanced earthquake resisting elements (in strength and stiffness) - symmetrical plan (to reduce torsion or twisting) - uniform cross section in plan and elevation - maximum torsional resistance - short member spans - direct load paths - uniform story heights - redundancy (no single component failure should cause system failure)
Residual Risk	The remaining risk after risk management techniques have been applied.
Response Spectrum	A plot of maximum amplitudes (acceleration, velocity or displacement) of a damped, single degree of freedom oscillator (SDOF) as the natural period of the SDOF is varied across a spectrum of engineering interest (typically, for natural periods form 0.03 to 3 or more seconds, or frequencies of 0.3 to 30+ hertz). Response spectra are tabulated or plotted for specified levels of equivalent viscous damping, typically 5%.
Return Period	The average time span between like events (such as large hazard intensities exceeding a particular intensity) at a particular site or for a specific region (also termed return period). Return period provides a clear and convenient way to express probability. For non-varying random processes, a Poissonian model provides the relationship: $P = 1 - \exp(-t/T)$ P = Probability of exceedance in exposure period, t [years] T = Average return period [years]

For a 50-year exposure period (t), the normal useful life of a building:

Probability of Exceedance	Return Period
50%	72 years
10%	475 years
5%	950 years
2%	2,475 years

Richter Scale	A system developed by American seismologist Charles Richter in 1935 to measure the strength (or magnitude) of an earthquake, indicating the energy released in an event. Owing to limitations in the instrument used (a Wood-Anderson Seismograph) and the waves it measures, this scale has been supplement by other, more comprehensive measure of earthquake size (often moment magnitude).
Risk	The chance of adverse consequences. The combination of the expected likelihood (frequency) and the defined consequences)severity) of incidents that could result from a particular activity. The chance or probability that some defined undesirable outcome, such as injury, damage or loss, will occur during a specified exposure period.

Risk Assessment	An evaluation of the risk associated with a specific hazard. Quantitative elements of this assessment are defined in terms of probabilities and/or frequencies of occurrence and severity of consequences.
Risk Reduction Measures	Those activities that reduce overall the costs and risks associated with specific hazards.
Scenario	A type of event as defined by its natural hazard source parameters. That is, a scenario is defined by the source (the initiating event, e.g., the initial location and its severity expressed in such terms as magnitude or wind velocity), which may have many variable consequences dependent on random factors. A simulation is the assessment of these random factors to define specifically the consequences of the specific source event.
Scenario Loss	The loss from one scenario event (given specific values of the random values for other factors not defining the specific scenario). Alt., per ASTM Standard Guide E 2026-16a, a level of building damage from earthquake, expressed as a fraction of the building replacement value, associated with a stated earthquake hazard scenario. In these reports, probabilistic seismic hazards are used, and the stated scenario is based on the level of ground shaking that has a 10% chance of being exceeded in the exposure period specified by the user. Scenario Loss is further specified as the mean loss (Scenario Expected Loss or SEL) or the 90% nonexceedance loss (Scenario Upper Loss or SUL) for the stated hazard.
Seiche	A standing wave oscillation of an enclosed water body that continues, pendulum fashion, after the cessation of the originating force, which may have been either seismic or atmospheric.
Seismicity	The geographic distribution of past historic or future expected earthquakes, based upon historical or instrumental records, geologic evidence, or other means. The annual rate of occurrence of earthquakes, greater than or equal to a given magnitude, within a defined geographic area.
Seismic Zonation	Geographic delineation of areas having different potentials for hazardous effects from future earthquakes. Seismic zonation can be done at any scale—national, regional, or local. For example, California has two Seismic Zones as identified in the 1997 Uniform Building Code (UBC): Zone 3 and Zone 4. Zone 3 is the less seismically active area and is located in the northern-central valley of the State extending from the northern border to Bakersfield, plus a portion of the desert area east of the San Bernardino Mountains. This is a large portion of the State and includes Sacramento. Zone 4 is the most seismically active area and is located along the western coast of the state extending from Eureka to San Diego.
Slip	The relative displacement of formerly adjacent points on opposite sides of a fault, measured on the fault surface.
Slip Model	A kinematic model that describes the amount, distribution, and timing of slip associated with a real or postulated earthquake.

Slip Rate	The average rate of displacement at a point along a fault as determined from geodetic measurements, from offset man-made structures, or from offset geologic features whose age can be estimated.
Soil Profile	The vertical arrangement of soil horizons down to the parent material or to bedrock. Under current building codes (e.g., the Uniform Building Code, the International Building Code) and FEMA NEHRP guidelines, the soil profile may be categorized by average shear wave velocity in the upper 30m of sediments.
Source	The geologic structure that generates a particular earthquake or class of earthquakes.
Subduction Zone	An area in the earthquake lithosphere (crust) in which two tectonic plate are converging, and one plate is being thrust (subducted) under the other. Where a continental plate and an oceanic plate converge, generally the thinner oceanic plate is subducted. A subduction zone may exhibit seismicity in the form of large interplate events, in which slip occurs along the shallow dipping surface between the plates, or intraplate events (i.e., occurring within either plate, rather than along the boundary (Benioff zone) between the plates. Shallow seismicity may occur in the upper plate. Volcanic activity is usually associated with subduction zones, from the melting of the subducting plate creating buoyant magmas.
Vulnerability	The susceptibility of a building, equipment item or component to damage or loss from a specific hazard. Syn.: Fragility
Tsunami	Seismic seawave. Tsunamis may be generated from earthquakes beneath the ocean, by submarine volcanic eruptions, and by slope failures in underwater canyons. Regions of the Pacific with subduction zones (such as the Pacific Northwest, the Aleutian Islands or the area east of Japan) present tsunami hazards to the Pacific coastline. Tsunami waves may travel great distances and cause damage many hours after the causative earthquake or slide. As fast traveling deep-ocean waves approach shallow areas along the shore, they slow down and increase in height. Near-shore bathymetry and onshore topography control run-up. Structures may be damaged by inundation, impact from fast-moving water and the debris it transports.

Appendix B – Qualifications

W. P. Graf, M.S., P.E., Vice President of Engineering, ImageCat, Inc.

William P. Graf, P.E. received an M.S. degree in Structural Engineering from UCLA (1981) and is a registered Professional Engineer (Civil) in the State of California.

Mr. Graf has more than 40 years of experience in seismic and other natural hazard and risk analyses for individual buildings, building portfolios, and lifeline structures. Bill also performs analyses of structures subject to earthquake or other loads and develops seismic strengthening schemes. Bill is a member of the Earthquake Engineering Research Institute, and a member of the subcommittee for seismic risk assessment standards, ASTM E2026 and E2557. Clients include lenders, building owners, property insurers, government agencies, issuance brokers, municipal bond rating agencies and bond insurers. Prior to joining ImageCat, Bill was with the Los Angeles of URS Corporation for 24 years, where he managed of earthquake risk services. Bill started his engineering career with Bechtel Power Corporation, designing buildings and utility structures for 7 years.

Bill has conducted field surveys for damage to buildings and equipment from the following earthquakes: 1987 Whittier-Narrows, 1989 Loma Prieta, 1991 Sierra Madre, 1992 Desert Hot Springs, 1992 Landers/Big Bear, 1994 Northridge and 1995 Tauramena (Colombia) earthquakes.

Publications include:

CODA-Collapse – A Screening Method for Building Stability in Earthquakes, with R. Imani and Y. Lee, Proceedings of the 12th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Salt Lake City, UT, 2022.

Characterizing the Epistemic Uncertainty in the USGS 2014 National Seismic Hazard Mapping Project (NSHMP) (second author, with Y. Lee and Z. Hu), Bulletin of the Seismological Society of America, 2018.

“Collateral Damage from the Collapse of Tall Buildings from Earthquakes in an Urban Environment,” with Jerry Lee and Michael Eguchi, Third International Conference on Urban Disaster Reduction, 2014.

“Epistemic Uncertainty, Rival Models, and Closure,” with C.E. Taylor, R. Murnane and Y. Lee (3rd author), Natural Hazards Review, February, 2013.

"Earthquake Damage to Wood-Framed Buildings in the ShakeOut Scenario," with Hope A. Seligson, Earthquake Spectra Journal, May 2011

“Code-Oriented Damage Assessment,” EERI Spectra Journal, February, 2009 (with Yajie Lee).

“A Geographic Correlation Index for Portfolio Seismic Risk Analysis,” 7th U.S. National Conference on Earthquake Engineering, Boston, July, 2002.

“Developments In Single-site Earthquake Risk Assessment,” 6th International Conference on Seismic Zonation, Palm Springs, California, November, 2000.

"Analysis and Testing of a Flat Slab Concrete Building", Tenth World Conference on Earthquake Engineering, Madrid, Spain, July 1992 (co-authored with M. Mehrain).

"Dynamic Analysis of Tilt-up Buildings", Fourth U.S. National Conference on Earthquake Engineering, Palm Springs, California, May 1990 (co-authored with M. Mehrain).

"Lenders, Insurers, and Earthquake Loss Estimation", Fourth Annual National Earthquake Hazards Reduction Program Workshop, Puget Sound, Washington, April, 1990 (co-authored with C. Taylor and C. Tillman).