Seismic Risk Consulting Report

by ImageCat, Inc.

Beach Cities Health Center

514 North Prospect Avenue
Redondo Beach, CA 90277

Prepared For:

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

October 21, 2021

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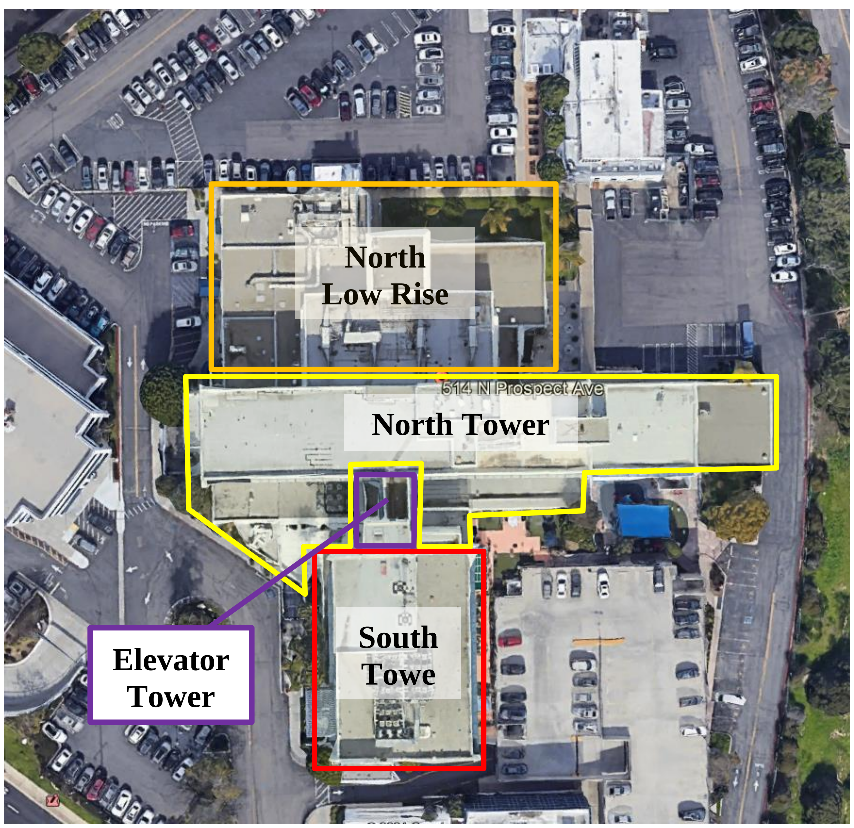
Beach Cities Health District
514 North Prospect Avenue
Redondo Beach, CA 90277

Attention: Tom Bakaly, Chief Executive Officer

Report: **Seismic Risk Consulting – Beach Cities Health Center**
514 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 Beach Cities Health Center towers, located at 514 North Prospect Avenue, in Redondo Beach, California (ZIP 90277). The property consists of a 4-story medical office building with 1 subterranean level. It is of reinforced concrete construction, composed of the North Tower (built in 1957 with a low-rise extension to north), the South Tower (built in 1967), and the Elevator Tower (built in 1967). The North Tower, the South Tower and the Elevator Tower are all separated by seismic joints. The low-rise extension of the North Tower is not part of the scope for this study. We understand that this study is needed to inform your decision-making process related to redevelopment/retrofit plans to achieve seismic safety while continuing to provide services to the community.



Site View

Purpose of the Study

BCHD has asked ImageCat, working together with Nabih Youssef Associates, to consider a number of different alternatives for the future of the buildings: 1) maintain status quo (i.e., no action to be taken or NO PROJECT to be planned or executed), 2) demolish today, 3) demolish in 3-5 years, with completion of the construction for a replacement facility, and 4) seismic retrofit of the existing buildings. This report addresses all four alternatives. For alternative 1, we present the estimated probabilistic risks associated with the structures in their status quo condition, examined for various durations of future usage. For the other three alternatives, ImageCat has qualitatively described the likely outcomes and various implications to BCHD, its customers, and other stakeholders. For each of the itemized implications, BCHD may refer to results of previous analyses conducted by financial consultants for quantitative information on costs and/or benefits.

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 various available Architectural and Structural design drawings (original and expansion sets), and the Seismic Evaluation report [Nabih Youssef Associates (NYA), 2018]. We conducted multiple discussions with Engineers from NYA to obtain a detailed understanding of their findings on the structures' characteristics and current conditions and shared our observations. A Structural Engineer from ImageCat conducted a visual survey at site 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 for individual sites. Results include tables and curves relating the severity of the estimated probabilistic risks for various durations of future usage (short- and long-term) along with corresponding information on building stability, and downtime.

ImageCat also qualitatively described the outcomes and implications of the other considered alternatives according to our understanding, conversations with BCHD, and review of preliminary financial feasibility studies conducted by other consultants (Cain Brothers, CBRE, 2020).

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 interest to BCHD are the Palos Verdes Fault and the Newport-Inglewood Fault. These are the closest and most active faults that can strongly affect the building. 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 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 Appendix B.

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

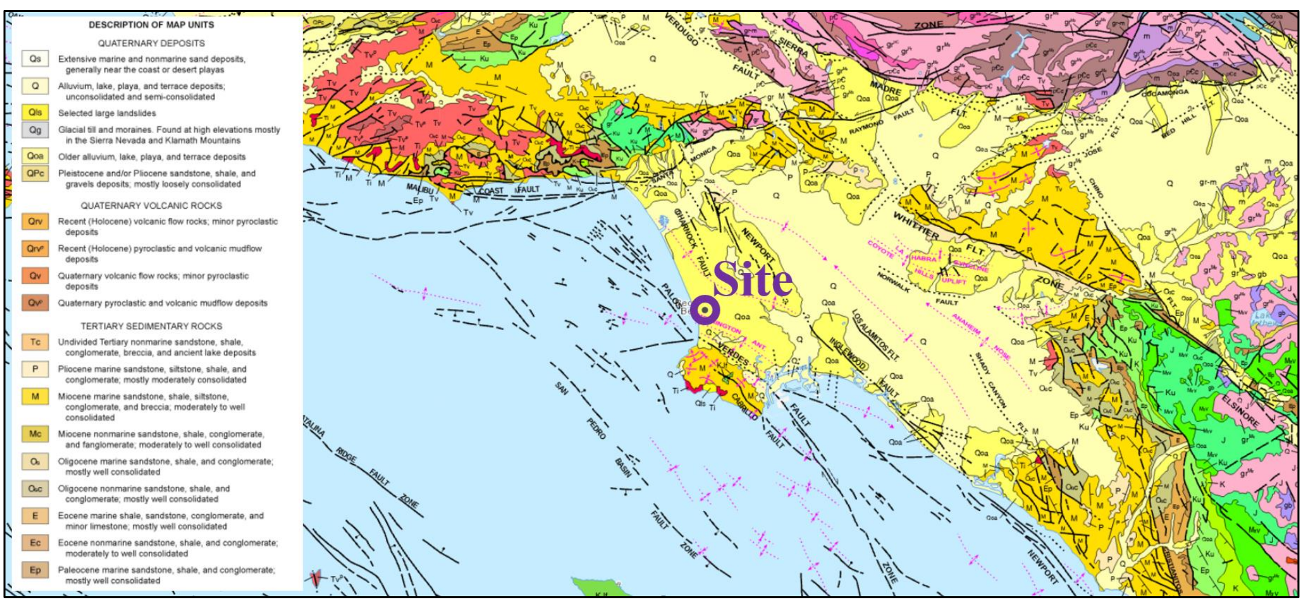


Figure 1 – Site Location, Geology and Local Faulting [CGS]

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 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 site soils and the absence of a shallow 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 (1957-1967). Prior to the construction of the towers, the site was strongly shaken in the 1933 Long Beach Earthquake (M6.4). Maps of the earthquake show shaking in the general area may have corresponded to Modified Mercalli Intensity (MMI) of VIII. See Appendix C – Earthquake Risk Glossary for a description of the Modified Mercalli Intensity scale, used prior to the deployment of widespread strong motion instrumentation. Other earthquakes occurring over the life of the existing structures include 1971 Sylmar (M6.6), 1987 Whittier-Narrows (M6), 1992 Landers (M7.3) and Big Bear (M6.8), and the 1994 Northridge (M6.7) event. Ground shaking intensities in these events were generally slight or slight to moderate, and we know of no reported damage 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 stronger than assumed in the original design codes (i.e., the 1955 and 1964 editions of the Uniform Building Code), and the buildings' design predates the Importance Factor (I-factor) in the code, which increased the ground motions and resulting design forces for essential facilities like hospitals. 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

All three structures (i.e., the North Tower, the South Tower, and the Elevator Tower) are of reinforced concrete construction. They all have complete gravity and lateral load resisting systems. The gravity loads are carried by reinforced concrete floors (concrete slab and pan joist system) that rest on concrete girders, columns, load-bearing walls, and columns that carry the loads down to the reinforced concrete foundations.

Lateral loads in buildings are caused by earthquakes or winds. In California, lateral loads from earthquakes often govern the design for this type of buildings. Reinforced concrete floor slabs act as rigid diaphragms and collect lateral loads in each floor. These loads are then distributed to the vertical lateral load resisting elements such as reinforced concrete shear walls and reinforced concrete moment resisting frames. These elements carry the loads down to reinforced concrete foundations. The North Tower has shear walls in both the north-south and east-west directions. It also has additional moment resisting frames in the east-west direction. The south tower has shear walls in the east-west direction, and moment resisting frames in the north-south direction. The elevator tower has a core system with shear walls around its perimeter.

All three of these buildings were designed and constructed before 1970. During the past 50 years, many substantial changes have occurred in analysis and design codes and procedures for reinforced concrete structures, including increases in seismic hazard levels and the resulting design forces. Most of these changes were the results of lessons learned from past earthquakes. The 1971 San Fernando Earthquake (M6.7) exposed major strength and ductility deficiencies in concrete structures designed under then-current provisions of the Uniform Building Code (UBC). Good earthquake performance requires both "strength" and "ductility." Strength is needed to keep the structure undamaged under low-to-moderate earthquake motions. Ductility ("toughness") requires reinforcement detailing to confine the concrete and withstand overloads and large deformations while maintaining strength and stability. These observations of failures in led to major revisions in requirements for design of new concrete buildings.

For existing buildings (similar to 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 study by NYA (dated 2018) 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 older, nonductile (or "brittle") reinforced concrete buildings under ordinances requiring evaluation of known typical deficiencies followed by seismic retrofit design and construction (or demolition) where these deficiencies are confirmed. At present, the City of Redondo Beach does not have such an ordinance in force, but it is possible in the future that the City will enact one. Any plans to continue use of these buildings over the long term should consider this possibility.

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 Building Seismic Vulnerability

2.1.1 North Tower

Basis:	Original Architectural and Structural design drawings (dated 1957); Site geotechnical investigation report [Converse Consultants, 2016]; Seismic Evaluation Report [NYA, 2018]; Visual site survey by R. Imani PhD, PE, SE of ImageCat on 8/11/2021.
Architect:	Walker, Kalionzes, Klingernan Architects, Los Angeles, CA.
Structural Engineer:	Henry M. Layne, S.E.
Geotechnical Engineer:	The original Geotechnical Engineer is not identified on the drawings.
Year Built:	1957
Design Code:	The 1955 Edition of the Uniform Building Code (UBC)
Height:	4-story with a roof-top mechanical penthouse and 1 basement level.
Materials:	Concrete has 28-day compressive strength (f'c) of 2,000 psi for slab-on-grade, and 2,500 psi for all other elements. Reinforcing steel conforms to ASTM A305, intermediate grade. All steel pipe columns are ASTM A53, Grade B.
Foundations:	Reinforced concrete spread footings, continuous strip footings and a 4" thick slab-on-grade. Maximum allowable soil bearing pressure is 5,000 psf.
Gravity System:	One way reinforced concrete slab spans over reinforced concrete pan joists resting on reinforced concrete girders that are supported by reinforced concrete columns or load-bearing walls. These elements transfer the loads down to reinforced concrete foundations.
Lateral System:	Reinforced concrete floor slabs act as rigid diaphragms, collecting and redistributing lateral forces to reinforced concrete shear walls acting in both directions of the building. Deep reinforced concrete spandrel beams frame into concrete columns to form moment-resisting frames on the exterior lines in the east-west direction. These elements transfer the loads down to reinforced concrete foundations.
Remarks:	Reinforced concrete shear walls are 6" to 12" thick with 2 layers of vertical and horizontal reinforcement (except for the 6" thick walls). Distributed horizontal and vertical reinforcing typically consists of #4 bars spaced at 11 to 17 inches on center. Spandrel beams have #5, #6 or #9 continuous bars at top and bottom, and #3 or #4 stirrups spaced at 16 or 17 inches on center. Reinforced concrete columns have square, rectangular, or circular sections, with #6, #7 or #8 vertical bars and #2 ties spaced at 8 or 12 inches on center, or 3/8" diameter spirals with a 1-3/4" pitch. Transverse reinforcing for both spandrels and columns are significantly less than the ductility and

shear strength requirements of the current codes, making them vulnerable to brittle shear failure.

The roof-top mechanical penthouse has reinforced concrete shear walls around its perimeter.

A seismic gap of 4” exists between the North Tower and the low-rise (1- and 2-story) expansion building to the north.

The building has vertical irregularity deficiency in parts of the lateral load resisting system where discontinuous shear walls are supported by beams or columns of lower floors (e.g., penthouse shear walls supported by roof beams and two columns along the north side of the building supporting another discontinuous shear wall). This condition may lead to overstress with increased seismic damage or collapse in the supporting members.

Condition: Fair to good.

Architectural Notes: Exterior walls have painted concrete surfaces. The building has a built-up roof system.

Equipment Notes: Various types of equipment were observed to be well-anchored (HVAC units on roof, supply fans in roof-top penthouse, water heaters, elevator machinery, etc.

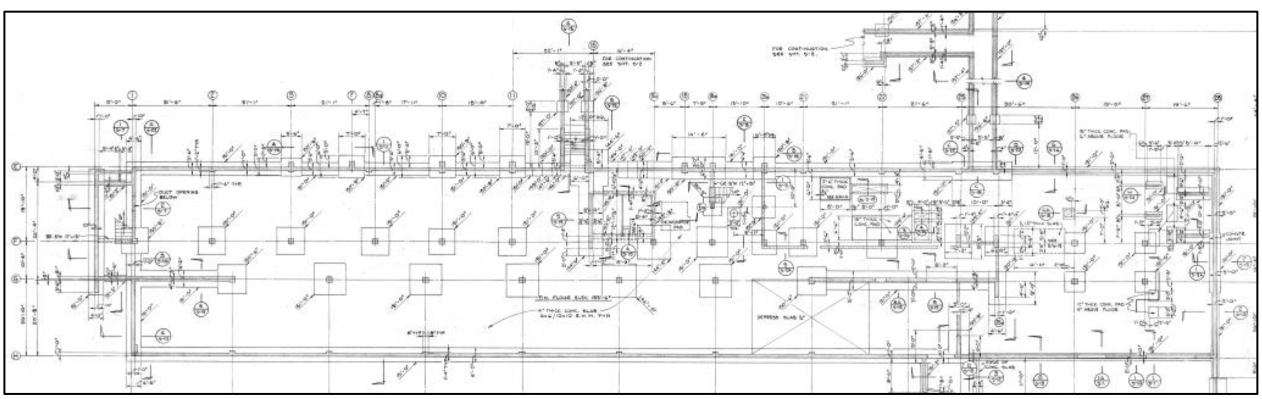


Figure 2 – Foundation and Basement Plan (North Tower)

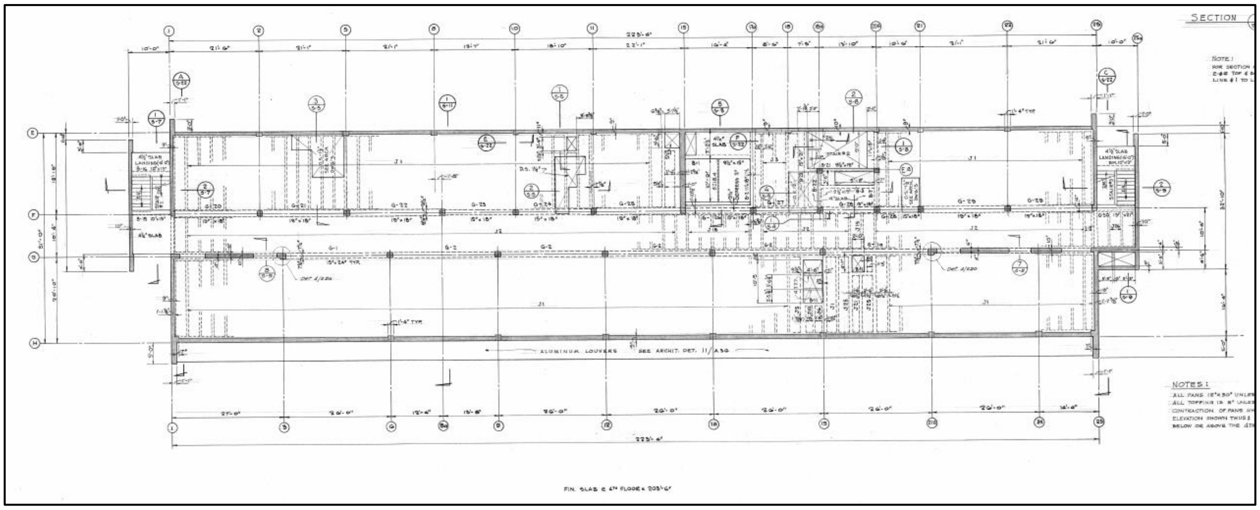


Figure 3 – 4th Floor Framing Plan (North Tower)

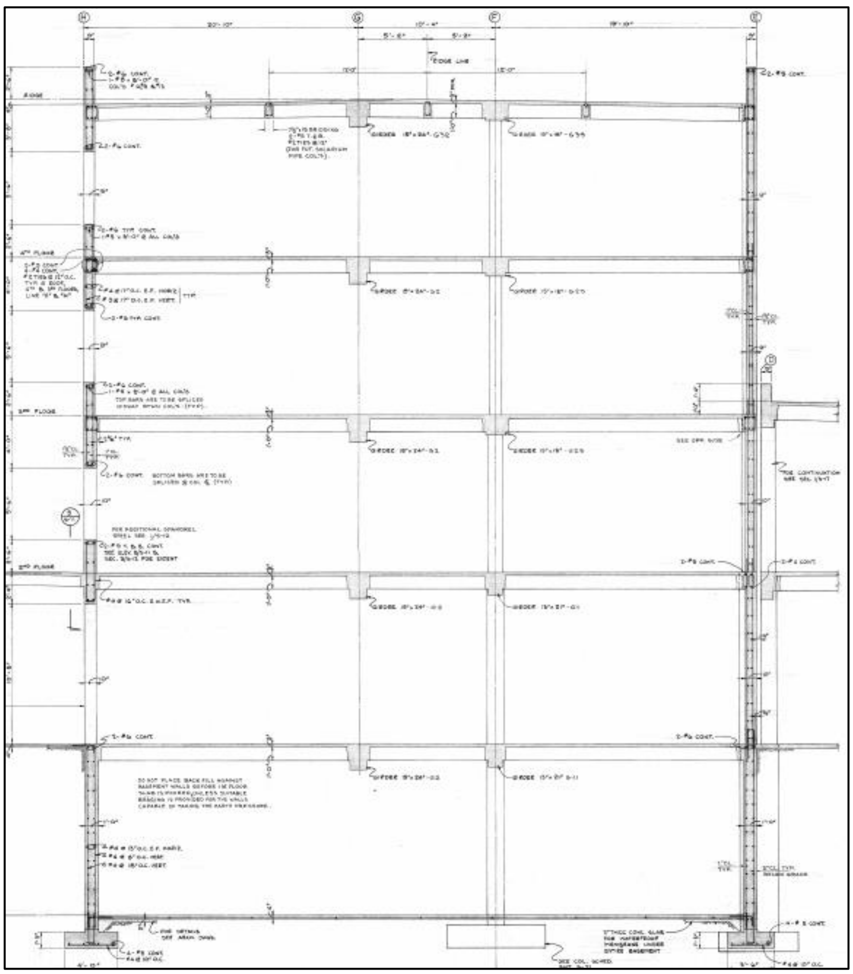


Figure 4 – Building Section (North Tower)

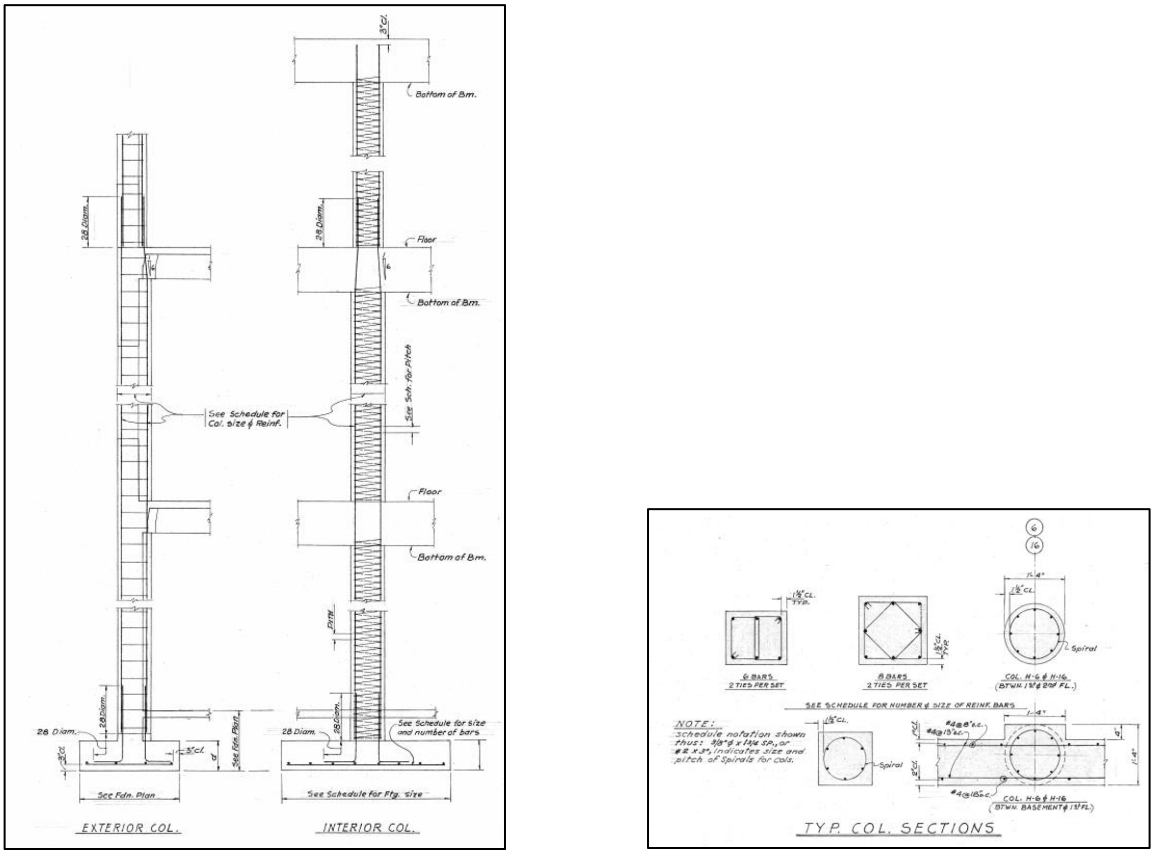


Figure 5 – Column Elevation and Details (North Tower)

2.1.2 South Tower and Elevator Tower

Basis:	Original Architectural and Structural design drawings (dated 1967); Site geotechnical investigation report [Converse Consultants, 2016]; Seismic Evaluation Report [NYA, 2018]; Visual site survey by R. Imani PhD, PE, SE of ImageCat on 8/11/2021.
Architect:	Kalionzes, Klingernan Architects, Los Angeles, CA.
Structural Engineer:	Henry M. Layne, S.E.
Geotechnical Engineer:	The original Geotechnical Engineer is unknown, but the Architectural drawings reproduce soil borings for the site.
Year Built:	1967
Design Code:	The 1964 Edition of the Uniform Building Code (UBC) assumed based on the year of construction. The Manual of Standard Practice for Reinforced Concrete Construction, Western Concrete Reinforcing Steel Institute is cited for concrete construction. The AISC Code (1963) is cited for steel construction.

Height:	4-story with a roof-top mechanical penthouse and 1 basement level.
Materials:	Concrete has 28-day compressive strength (f'c) of 2,500 psi for slab-on-grade and foundations, and 3,000 psi for all other elements. Reinforcing steel conforms to intermediate grade bar, with deformations per ASTM A305. Structural steel conforms to ASTM A53, Grade B for pipe columns and A36 for others.
Foundations:	Reinforced concrete spread footings, continuous strip footings and a 5" thick slab-on-grade.
Gravity System:	One way reinforced concrete slab spans over reinforced concrete pan joists resting on reinforced concrete girders that are supported by reinforced concrete columns. These elements transfer the loads down to reinforced concrete foundations.
Lateral System:	Reinforced concrete floor slabs act as rigid diaphragms, collecting and redistributing lateral forces to reinforced concrete shear walls in the east-west direction, and moment resisting frames (deep spandrel beams connected to columns) in the north-south direction of the South Tower. These elements transfer the loads down to reinforced concrete foundations. The elevator tower has a 3" seismic gap with the North and South Towers, with concrete shear walls around its perimeter that carry lateral loads to foundations.
Remarks:	Reinforced concrete shear walls are 10" thick (12" thick in the basement) with 2 layers of vertical (#4 bars spaced at 18" on center) and horizontal (#4 bars spaced at 16" on center) reinforcement. Reinforced concrete columns have rectangular sections of various sizes, with #7, #8 or #9 vertical bars and #4 ties spaced at 4 to 10 inches on center for columns on exterior lines. Interior columns have #3 ties spaced at 4 to 10 inches on center. Insufficient transverse reinforcement and lack of ductile detailing -- especially for the interior columns -- may lead to brittle shear failures when subjected seismic lateral movement (i.e., inter-story drift). Deep spandrels typically have #4 ties spaced at 12 inches on center (limited cases were seen with double #4 ties at 12 inches on center). These spandrels create captive columns along the east and west side the building that are prone to brittle shear failure during a seismic event. The roof-top mechanical penthouse has reinforced concrete shear walls around its perimeter. The building has vertical irregularity deficiency in parts of the lateral load resisting system where discontinuous shear walls are supported by beams or columns of lower floors (e.g., penthouse shear walls supported by roof beams and a column at the basement along the north

side of the building supporting another discontinuous shear wall). This condition may lead to additional seismic damage and overstress in the supporting members.

Condition: Fair to Good.

Architectural Notes: Exterior walls have painted concrete surfaces. The building has a built-up roof system.

Equipment Notes: Various types of equipment were observed to be well-anchored (HVAC units on roof, supply fans in roof-top pent-house, water heaters, elevator machinery, etc.)

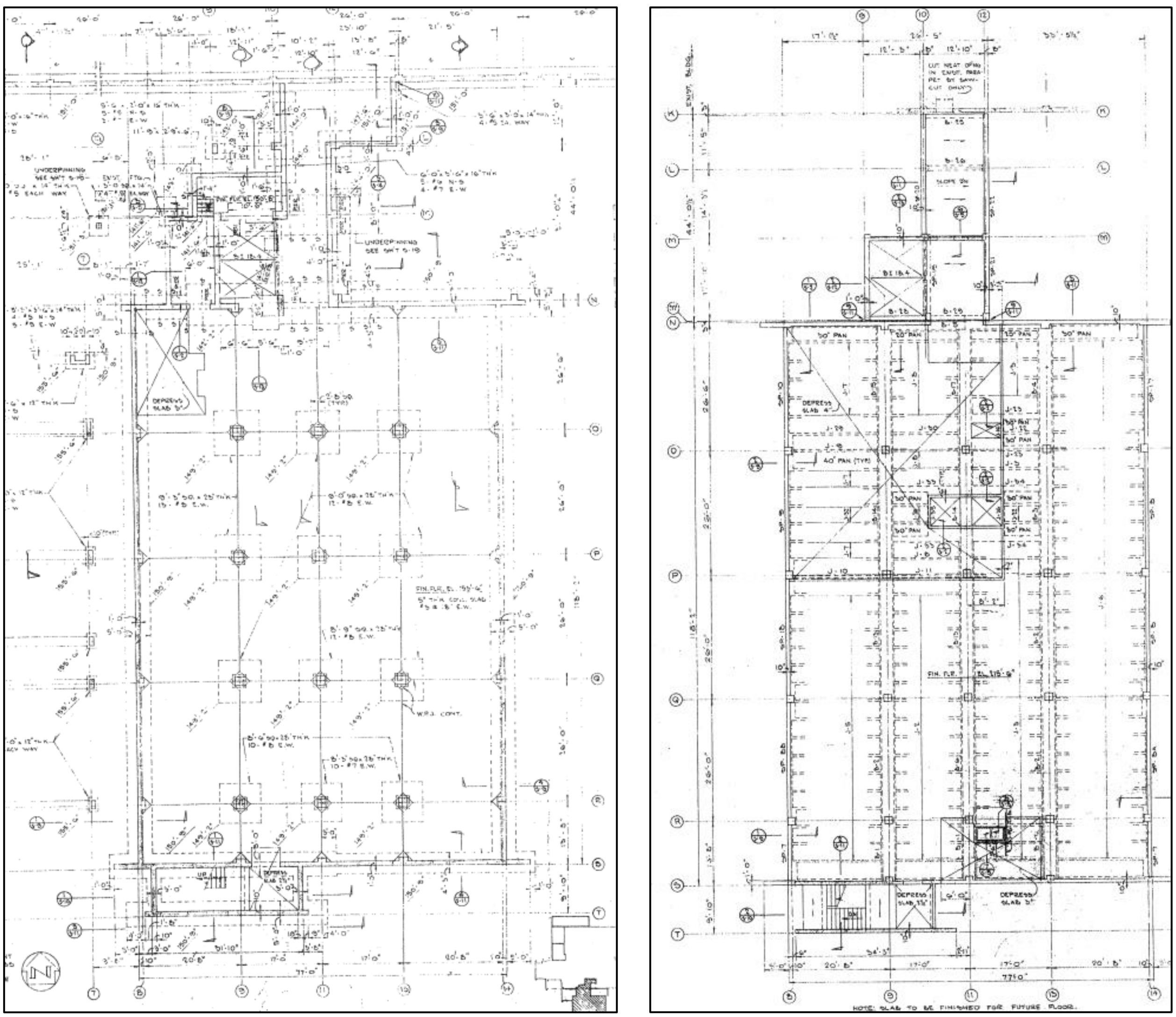


Figure 6 – Foundation and Basement Plan (Left), Roof Level Plan (Right) (South Tower and Elevator Tower)

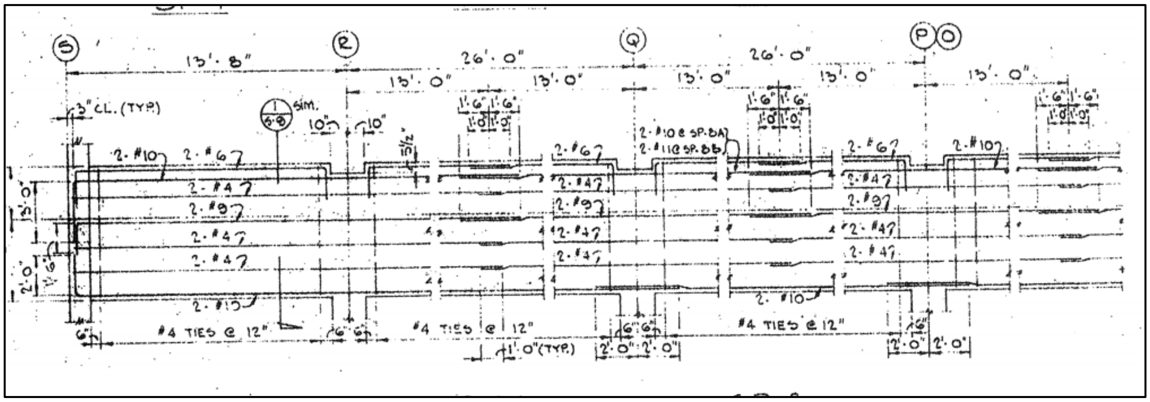


Figure 7 – Typical Spandrel Elevation (South Tower)

2.2 Additional Site Visit Notes

On August 11, 2021, R. Imani, Ph.D., P.E., S.E. of ImageCat conducted a visual survey of the 514 North Prospect building to observe current configuration, conditions, and usage. Dr. Imani met with Ms. Valerie Lee (Administrative Services Manager, BCHD) and a member of maintannce staff to walk the perimeter and inside of the buildings as well as on the roofs and in major equipment areas.

The site is generally flat. The exterior is mainly painted concrete surfaces and appears to be in good condition. The equipment at site is mostly at the same age as the buildings (with some new replacements) and appear to be anchored. These include HVAC units on the roof, supply fans and elevator machinery inside the mechanical penthouses, diesel fueled generators, transformers and other electrical panels inside rooms in the basement. Other equipment is located inside a separate building referred to as the Central Plant (located north-west of the North Low-Rise Building), which is not part of the scope for this study.

The buildings are in overall fair to good condition. Signs of age were observed, but no significant visible structural damage. Some rusting was visible on the exposed steel elements and anchorage material. The buildings are equipped with fire alarm and sprinkler systems. The main gas supply pipe observed outside the buildings is not equipped with an automatic earthquakle shut-off valve.

2.3 Building Stability and Qualitative Damage Discussion

All three structures (i.e., the North Tower, South Tower, and Elevator Tower) have complete and gravity load-carrying and lateral force-resisting systems. The North Tower was designed under the 1955 Uniform Bulding Code (UBC). The South and Elevator Towers were most probably designed under the 1964 edition of UBC. Both of these design codes pre-date the 1976 edition of UBC and, in addition to having a general seismic strength deficiency, can be classified in the non-ductile concrete structures, which are prone to brittle failure in seismic events due to lack of ductile detailing in various structural elements.

ImageCat has not performed structural calculations or developed detailed structural engineering models of the buildings. Instead, we have relied on the seismic evaluation performed by Nabih

Youssef Associates as documented in their report dated 2018. Their evaluation followed ASCE 41 methods, and included structural calculations and computer modeling.

Based on our review of the design documents and discussions with Engineers from NYA:

- In the North Tower, two columns along the north side of the building at level 2 are also supporting a discontinous shear wall. The elements supporting discontinous walls (i.e., beams, columns and diaphragm) can get overstressed during seismic events. Larger openings at first floor for some of the shear walls in the north-south direction may also lead to overstress in the shorter wall segments and a general lack of seismic strength in this floor. Captive columns created by deep spandrel beams along the north and south sides of the building are prone to brittle shear failure under seismic loading. The North Tower also has a vertical irregularity seismic deficiency caused by discontinuity of the shear walls around the roof-top penthouse, which are supported by roof-level beams.
- The South Tower has similar shear wall discontinuity issues (beams at roof level and a column in the basement are supporting shear walls above), and captive columns along the east and west sides of the building which are part of the moment frames as the only seismic load risisting elements in the north-south direction. These frames lack seismic strength and ductility and will be overstressed in seismic events.
- The elevator tower basically consists of a shear wall core that is continuous throughout its height to the foundations. Even though the level of seismic detailing is still below the minimums per current codes, the Elevator Tower should show generally adequate seismic performance.

Considering the deficiencies mentioned above, The North and South Towers in their current conditions may experience significant structural damage and do not meet the life safety requirements under the BSE-1E and BSE-2E hazard scenarios considered in the ASCE 41 standard for seismic evaluation of existing buildings.

In less technical terms, as these buildings undergo earthquake loads and experience lateral (sidesway) deformations, the lateral load resisting systems will get overstressed due to lack of strength. Overloading of these systems would lead to larger building deformations in ductile structures. However, since these buildings also lack ductility and cannot go through larger deformations, several elements including shear walls, columns and deep spandrel beams are expected to fail in a brittle manner (i.e., sudden breaking and failure rather than gradual deformation). For elements that are also carrying gravity loads, brittle failure from earthquake loads will lead failures in columns and other elements, resulting in partial or complete collapse. This translates to a significant life-safety concern. The significant damage or failure of structural systems is also combined by major damage to non-structural components (i.e., architectural finishes, ceilings, tiles, etc.) and building contents. A strong earthquake can lead to partial or complete collapse and loss of life, or result in damage that prompts the City to “red-tag” so that one or more of the buildings cannot be occupied. Even in less intense earthquake shaking, damage to non-structural components and contents can interrupt medical building operations for extended periods.

Estimated damage and collapse probablties (related to life-safety) under various hazard scenarios are studied in Section 3.

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 and Implications for Various Planning Alternatives

3.2.1 Maintain Status Quo – No Project to Be Planned or Executed (ALT 1)

Table A presents the probablistic seismic hazard intensities that have been used as input for the seismic risk assessment process for the buildings, examining time horizons of 3, 5, 10, 20, and 50 years. Each row in Table A provides various measures of intensity for a given probabilistic seismic hazard scenario. The intensity measures include Peak Ground Acceleration (PGA), the short-period (0.2 second) spectral acceleration (Ss), and the 1-second spectral acceleration (S1), all in units of g, where 1.0g is equal to the acceleration due to gravity.

Tables B and C below provide estimates of seismic risks for the buildings (i.e., North and South Towers) in their current condition, with no further actions taken. These estimates include building damage (a range of PL values as percentage of the total building replacement cost), downtime (a rough range of days to return to full operations), and probability of collapse (relevant to life-safety concerns). Results provided in each row only have a 10% probability of exceedance (i.e., becoming worse) during the period of considered exposure (i.e., 3, 5, 10, 20, and 50 years).

The ranges for the results attempt to indicate the level of uncertainty that should be considered for risk estimations of this type with complexities in characterization of both the seismic hazard and building vulnerability parameters.

Results are presented separately for the North and South Towers. As mentioned in the previous sections, even though the level of seismic detailing for the Elevator tower is still below the minimums per current design codes, it should generally provide adequate seismic performance due to the presence of continous shear wall core around its perimeter. The North and South Towers comprise the majority of value for the property and the major seismic deficiencies. As such, decisions for planning alternatives should be made according to results from the two towers.

Table A – Probabilistic Seismic Hazard Intensities

Seismic Hazard Scenario	PGA	Sa(0.2s)	S1
10% Probability of Exceedance in 3 Years	0.104g	0.265g	0.113g
10% Probability of Exceedance in 5 Years	0.146g	0.367g	0.163g
10% Probability of Exceedance in 10 Years	0.223g	0.544g	0.260g
10% Probability of Exceedance in 20 Years	0.318g	0.760g	0.398g
10% Probability of Exceedance in 50 Years	0.473g	1.090g	0.662g

Table B - Seismic Risk Estimates for the North Tower

Seismic Hazard Scenario	PL (%)	Downtime (Days)	Probability of Collapse
10% Probability of Exceedance in 3 Years	11-13%	135-175	1-3%
10% Probability of Exceedance in 5 Years	17-20%	210-255	3-8%
10% Probability of Exceedance in 10 Years	26-34%	270-345	9-19%
10% Probability of Exceedance in 20 Years	37-48%	390-525	20-34%
10% Probability of Exceedance in 50 Years	51-65%	570-750	37%-55%

Table C - Seismic Risk Estimates for the South Tower

Seismic Hazard Scenario	PL (%)	Downtime (Days)	Probability of Collapse
10% Probability of Exceedance in 3 Years	6-10%	110-140	1-2.5%
10% Probability of Exceedance in 5 Years	12-16%	165-205	3-7%
10% Probability of Exceedance in 10 Years	21-28%	255-330	8-16%
10% Probability of Exceedance in 20 Years	31-42%	350-465	18-30%
10% Probability of Exceedance in 50 Years	45-57%	510-690	35-49%

The ‘status quo’ alternative presents no upfront (immediate) costs or loss of service and income to BCHD, such as those that would result from demolition or retrofit construction. However, this exposes BCHD to significant levels of risk in terms of building damage and downtime losses and potential liability for loss of life, should an earthquake occur. **The building damage, downtime, and probability of collapse estimates with 10% probability of exceedance in the next 3 to 5 years are basically close to what would be expected, and deemed acceptable by most commercial lenders and institutional owners, from new buildings over a full lifetime (i.e., a 50-year exposure period).** Appendix E provides additional information on the objectives of seismic design codes and the corresponding acceptable risk. Appendix F provides information on common seismic risk criteria followed by commercial real estate lenders and institutional owners.

Beyond the next 3-5 years, the risk picture is different. Risk results presented for exposure periods of 10 to 50 years are significantly high, with probabilities of collapse that would likely be deemed unacceptable, especially for buildings that are used for assisted living, memory care, or other medical purposes.

3.2.2 Demolish Now (ALT 2)

This alternative would avoid any of the seismic risks described in the tables above. While a replacement building is being constructed (which may take 3 to 5 years), operations would need to be transferred to an alternative location, with the attendant costs and disturbance. The implications for this alternative include:

2a. Demolition costs - This includes permitting fees, basic demolition and disposal costs which can increase significantly if asbestos is confirmed to have been used during original construction, and debris hauling and landfill fees (if not included in the demolishing contractor's fees).

2b. Loss of service and income (temporarily or indefinitely) - As operations halt for demolition, and until a temporary off-site facility is procured or leased to transfer operations. Expected costs include:

- 2b.1 Initial setup and recurring annual costs of relocating BCHD's current operations (including community health and fitness programs which are separate from other private leases) to an off-site facility.
- 2b.2 Loss of annual rental income from various private leases currently active in the 514 N. Prospect building. In addition to loss of income, there may be additional implications for BCHD due to breaking of ongoing leases prior to their expiration dates, unless relevant exceptions were provided in the lease terms.
- 2b.3 If BCHD decides to construct a new replacement facility, costs of funding the planning and construction process would also apply to this alternative. These are described further in the next alternative.

3.2.3 Demolish in the Next 3-5 Years with Completion of a Replacement Facility (ALT 3)

This alternative balances near-term needs for service continuity with substantial progress toward seismic resilience. It presumes acceptance of the seismic risks described above for the next 3 to 5 years. Construction of a new facility could commence as the existing buildings continue current operations without loss in service or revenue, and with transfer of operations upon completion, followed by demolition and removal of the older buildings.

BCHD has already conducted preliminary studies on the market demand and financial feasibilty of constructing a new Assisted Living (AL) and Memory Care (MC) facility by considering two scenarios (i.e., a 5-story vs a 6-story building). The 6-story option was recommended to be pursued [Cain Brothers, 2020]. We note that those studies are preliminary and BCHD may conduct further reviews and updates based on the evolving market conditions, especially with regard to COVID 19.

If this alternative is pursued, Implications for BCHD include:

3a. No disruption of service or loss of income from the current activities as the existing buildings will remain operational until a coordinated transfer occurs upon completion of construction of the new facility.

3b. Construction of a new AL and MC facility (3 to 5 years):

3b.1 Project planning, financing (debt + equity from investors), design, and construction needs to be completed in the next 3-5 years, during which seismic risks for the existing buildings are acceptable.

3b.2 Since this is a new design project, BCHD would have the opportunity to set objectives for functionality (per current and future market demand), and for building performance, i.e., code-minimum or beyond current codes for Structural, Architectural, and for performance of Mechanical/Electrical/ Plumbing (M/E/P) equipment and medical service equipment. For instance, BCHD may wish to specify seismic performance criteria which is beyond minimum code requirement of achieving life-safety, leading to a design with a much-improved functional recovery time after a seismic event. This is highly recommended as relocation of residents of the AL and MC facilities can become extensively challenging post event. Having a higher seismic rating can also make the new facility attractive in a highly seismic area.

3b.3 BCHD will need to plan for a coordinated transfer of current operations to the new facility while minimizing potential disruptions. This includes operations run by BCHD or any long-term leases for tenants that would need to be transferred to the new facility.

3c. Demolition costs to remove the older building (similar to item 2a above).

3.2.4 Seismic Retrofit of the Existing Buildings (ALT 4)

Due to the complexities of the seismic deficiencies in these buildings, an effective retrofit design may require large portions or all of the buildings to be vacated during construction. As such, even though the cost of retrofit may be lower than cost of construction for a new replacement facility, much or all of the costs associated with relocation of current operations to another location may be incurred as for alternative 2 (i.e., demolish now). Further, there are limits to the improvements in seismic performance that can be achieved through retrofit at acceptable cost.

BCHD engaged NYA to conduct a seismic evaluation of the existing 514 N. Prospect building. NYA identified several seismic deficiencies for the North and South Towers, and provided a list of recommended seismic retrofit items. These recommendations were “conceptual” and intended to describe scope for rough order-of-magnitude cost estimation purposes [NYA, 2018]. According to ImageCat’s conversations with BCHD, Cain Brothers conducted a financial feasibility study for the seismic retrofit alternative, using cost estimations for the retrofit project that were provided by CBRE based on NYA’s recommendations. Considering retrofit costs and other financial information related to BCHD’s current and potential future operations and revenue, Cain Brothers concluded that the seismic retrofit alternative is not financially feasible [Cain Brothers, 2020]. ImageCat is not in a position to verify the accuracy of the retrofit cost estimates and has asked BCHD to share additional documents with NYA, so they can (if desired) verify that current cost estimates reasonably represent

NYA's list of recommended retrofits and the incidental costs that would be incurred. These estimates should also need to be updated for current market conditions. However, ImageCat can qualitativly describe the following implications for the seismic retrofit alternative:

4a. Loss of service and income (temporarily until completion of the retrofit project), costs incurred due to transfer of operations to an offsite facility and other implications regarding breaking of on-going private leases (see items 2b.1, 2b.2 and 2b.3 above for more details as this is a shared implication with the "demolish now" alternative).

4b. Retrofit Project

4b.1 Financing, design and construction for the retrofit program needs to be completed in a reasonable time to reduce negative financial impacts. This was deemed to be financially infeasible by other consultants as mentioned above.

4b.2 Seismic retrofit projects are usually restricted from various aspects (time, costs, space) as they need to be done within the existing conditions of the building and still end up more cost-efficient compared to new construction. Given these restrictions, there are limits to the improvements that can be made to the structure's seismic performance. For the current 514 N. Prospect building, a cost-effective seismic retrofit can improve the life-safety performance up to a reasonable extent. However, attempts to achieve higher performance objectives that may be desired by BCHD (e.g., improving the performance to current code level or beyond) would lead to costs that are comparable or more than new construction.

4b.3 Seismic retrofit will improve structural performance, but the functionality of the building will be constrained by its original configuration, layout and systems of the 1950s and 1960s. This will not be in line with the demands of the current market. This challenge can only be addressed by combining the structural retrofit with a comprehensive renovation project, which could increase costs to surpass new construction. Making significant changes in various building elements would also trigger requirements to upgrade many or all of the M/E/P equipment in the building.

4c. Once the project is over, BCHD would need to increase current rental rates significantly for many years to reach the break-even point with regard to retrofit costs and the income lost during the retrofit project. The project will also significantly deplete BCHD's cash reserves.

4d. Finally, the retrofitted building would still expose BCHD to a higher level of risk in terms expected damage and downtime from earthquakes over the remaining life of the building, compared to reduced risk levels that can be achieved via new construction.

3.3 Summary and Recommendation

The following table summarizes the risks and implications described above for the four alternatives considered in this study.

Table D – Summary of Risks and Implications for Various Alternatives			
No.	**Description**	**Seismic Risks**	**Implications**
1	No Action – No Project to be Planned or Executed (Maintain Status Quo)	***Next 3-5 years:*** See seismic risks described for alternative 3. ***Next 10-50 years:*** Estimated risks are significantly high, with probabilities of collapse likely deemed unacceptable, especially for buildings that are used for assisted living, memory care, or other medical purposes.	This alternative has no immediate costs, but will expose BCHD to significant (and likely deemed unacceptable) economic and life-safety risks due to future probabilistic seismic activity in the area.
2	Demolish Now	N/A	This alternative avoids seismic risks, but leads to loss of service and income (temporarily or indefinitely), as operations halt for demolition, and until a temporary off-site facility is procured or leased with the attendant costs to transfer operations.
3	Demolish in the Next 3-5 Years and Replace with New Buildings	The building damage, downtime, and probability of collapse estimates with 10% probability of exceedance in the next 3 to 5 years are generally consistent with those deemed acceptable by most commercial lenders and institutional owners, from new buildings over a full lifetime (i.e., a 50-year exposure period).	This alternative balances near-term need to maintain service with the long-term goal to improve seismic resilience. It presumes acceptance of the seismic risks described for the next 3 to 5 years. BCHD will have the opportunity to set objectives for building functionality (per current and future market demand), and performance (architectural, structural, and M/E/P). This option has been deemed financially feasible in preliminary studies by other consultants.
4	Seismic Retrofit of Existing Buildings	While the retrofit project is being planned and constructed, seismic risk levels are similar to those mentioned in alternative 3, except for the reduced life-safety concerns as the buildings will be vacated, leaving just the construction crew at site during the retrofit project. Seismic risks after the completion of the project will substantially reduce in terms of life-safety, with less likely reductions in the building damage and downtime categories due to the limitations of cost-effective retrofit projects.	Complexities of the retrofit construction will necessitate vacating the existing buildings, thereby requiring procurement of off-site temporary facilities with the attendant costs to transfer operations. There are limits to the improvements in seismic performance that can be achieved through retrofit at acceptable cost. The functionality of the building will also be limited by its original configuration from 1960s. This option has been deemed financially infeasible in preliminary studies by other consultants.

From the above table, it appears that Alternative No. 3, “Demolish in the Next 3-5 Years and Replace with New Buildings” provides the best choice among the four alternatives, consistent with BCHD’s defined objectives.

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 various available Architectural and Structural design drawings (original and expansion sets), and the Seismic Evaluation report [Nabih Youssef Associates (NYA), 2018]. We conducted multiple discussions with Engineers from NYA to obtain a detailed understanding of their findings on the structure's characteristics and current conditions and shared our observations. A Structural 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. Results include tables and curves relating the severity of the estimated probabilistic risk to various return periods (short- and long-term) along with corresponding information on building stability, and downtime.

ImageCat also qualitatively described the outcomes and implications of the other considered alternatives according to our understanding, conversations with BCHD, and review of various financial and feasibility studies conducted by other consultants [Cain Brothers, CBRE, 2020].

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.

- o O o -

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.

Reza Imani, PhD., P.E., S.E.
Manager, Structural Engineering & Risk Mitigation

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

Attached:

A. Nabih Youssef Associates, March 27, 2018, "Seismic Evaluation of Beach Cities Health District 514 North Prospect Avenue & Central Plant Redondo Beach, CA"
B. Fault Descriptions
C. Earthquake Risk Glossary
D. Qualifications
E. Seismic Design Code Objectives
F. Commercial Real Estate Lender and Owner Criteria for Seismic Risk

Appendix A – NYA's Seismic Evaluation Report

Nabih Youssef Associates, March 27, 2018, "Seismic Evaluation of Beach Cities Health District 514 North Prospect Avenue & Central Plant Redondo Beach, CA"

SEISMIC EVALUATION
Of

Beach Cities Health District
514 North Prospect Avenue & Central Plant
Redondo Beach, CA

Prepared for:

Beach Cities Health District
514 North Prospect Avenue, 1st Floor
Redondo Beach, CA 90277

Prepared by:

Nabih Youssef Associates
Structural Engineers
550 South Hope Street, Suite 1700
Los Angeles, California 90071
NYA Job # 17171.00

March 27, 2018

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1.0 BUILDING DESCRIPTION

The former hospital building at 514 North Prospect was originally constructed in 1958 and consists of a 4-story tower (referred to hereinafter as the north tower) and single-story extension to the north. The south tower and elevator tower were added in 1967 and each consists of 4-stories. The north tower, elevator tower, and south tower have a single story basement. There are seismic joints that structurally separate the north low rise, north tower, elevator tower and south tower into four discrete structures. The central plant is a stand-alone single-story building. Refer to Figure 1 for an aerial view of the project site.

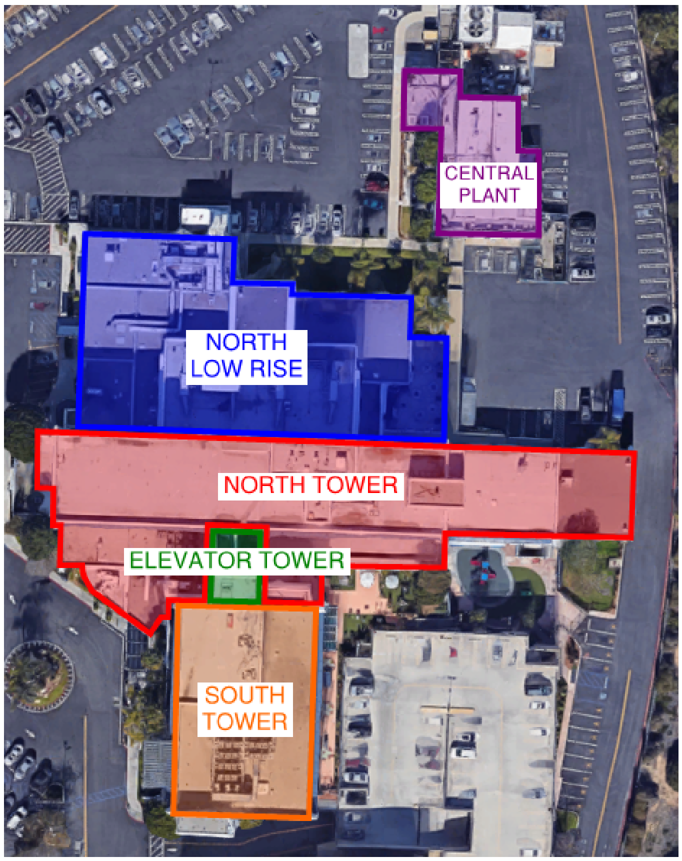

Figure 1 – Aerial View of 514 North Prospect and Central Plant

1.1 Gravity System

The gravity framing system for the north low rise, north tower, elevator tower, and south tower typically consists of concrete slabs 3-4 ½" thick supported by concrete joists and girders. The floor and roof framing is supported by concrete columns that extend down to the foundation.

The gravity framing system for the central plant consists of plywood sheathing at the roof supported by timber joists and girders. The timber girders are supported by steel pipe columns at the interior of the building and reinforced masonry walls along the perimeter.

1.2 Lateral System

The lateral force resisting system for the north tower consists primarily of concrete shear walls in both directions of the building. There are also deep concrete spandrels framing to concrete columns along the north and south sides of the building that act as moment frames (refer to figure 2). The floors and roof contain concrete slabs that form rigid diaphragms that distribute seismic induced forces to the walls and frames.

Figure 2 – View of South Side of North Tower

The lateral force resisting system for the east-west direction of the south tower consists of concrete shear walls located along the north and south sides of the building. In the north-south direction there are deep concrete spandrels framing to concrete columns (similar to the north tower) that act as moment frames. The floors and roof contain concrete slabs that form rigid diaphragms that distribute seismic induced forces to the walls and frames.

Both towers have a mechanical penthouse that sits on top of the roof that contains concrete shear walls around the perimeter. Most of the shear walls at both penthouses are discontinues and supported by concrete beams at the roof.

The lateral force resisting system for the north low rise building consists of multiple concrete shear walls in both directions of the building. The roof consists of a concrete slab that forms a rigid diaphragm that distributes seismic induced forces to the shear walls.

The lateral force resisting system for the elevator tower consists of concrete shear walls forming a core around the elevator that are continuous to the foundation.

The lateral force resisting system of the central plant consists of reinforced masonry shear walls around the perimeter of the building. The roof consists of a plywood diaphragm and anchors connecting the perimeter masonry walls to the timber framing (refer to figure 3).

Figure 3 –View of Central Plant

2.0 SEISMIC EVALUATION

A Tier 1 and deficiency only Tier 2 evaluation of the building's expected seismic performance was performed using ASCE 41-13, *Seismic Evaluation and Retrofit of Existing Buildings*. ASCE 41 is a national standard used to seismically evaluate existing buildings. The parameters used to for the evaluation are listed in Table 1. Assumed properties used in the evaluation were based on existing drawings and ASCE 41-13.

Table 1 – Evaluation Parameters

Performance Level	Life Safety Collapse Prevention
Seismic Hazard Level	BSE-1E (20% in 50 year event) BSE-2E (5% in 50 year event)
Level of Seismicity	High (S_{ds} > 0.5g and S_{d1} > 0.2g)
Building Type	C1 (Concrete Moment Frames) C2 (Concrete Shear Walls, Stiff Diaphragm) RM1 (Reinforced Masonry Bearing Walls, Flexible Diaphragm)
Soil Type	D
Seismic Parameters	$S_{XS,BSE-1E}$ = 0.762g $S_{X1,BSE-1E}$ = 0.419g $S_{XS,BSE-2E}$ = 1.192g $S_{X1,BSE-2E}$ = 0.660g

2.1 Identified Deficiencies

Based on the results of the analysis performed, extensive deficiencies were identified in both the north and south towers, and minor deficiencies were identified in the central plant. No deficiencies were identified for either the north low rise or elevator tower.

The identified deficiencies in the north tower include the following:

- The concrete beams at the roof that support the discontinuous shear walls in the penthouse above are overstressed in shear and flexure.
- Portions of the roof diaphragm are overstressed in shear.
- Two columns along the north side of the building at level 2 that support a discontinuous shear wall are overstressed.
- The deep concrete spandrels along the north and south sides of the building create captive columns that are susceptible to shear failure in a seismic event.
- Three concrete shear walls in the north-south direction have additional openings at the first and/or basement levels that result in the remaining wall being overstressed.

The identified deficiencies in the south tower include the following:

- The concrete beams at the roof that support the discontinuous shear walls in the penthouse above are overstressed in shear and flexure.
- One column along the north side of the building at the basement level that supports a discontinuous shear wall is overstressed.
- Many interior concrete columns have insufficient confinement reinforcement for seismic drift induced forces (i.e. deformation compatibility).
- The deep concrete spandrels along the east and west sides of the building create captive columns that are susceptible to shear failure in a seismic event. These frames are the only existing lateral system in the north-south direction of the south tower and are highly overstressed in flexure and shear.

The identified deficiencies in the central plant include the following:

- The existing ties between the perimeter reinforced masonry walls and plywood diaphragm are deficient.

3.0 RECOMMENDATIONS

Recommended seismic improvements have been developed based on the assessment of the existing building seismic performance using ASCE 41-13 criteria. The proposed strengthening is conceptual and is intended to identify representative scope for rough order of magnitude estimate of cost.

Recommended seismic strengthening for the north tower includes:

- Strengthen concrete beams below the discontinuous penthouse walls.
- Strengthen overstressed portions of the roof diaphragm.
- Strengthen columns at discontinuous shear walls.
- Slot cut the deep spandrel beams along the north and south sides of the building.
- Infill select openings in the north-south concrete shear walls.
- Strengthen foundations below the infilled concrete shear walls.

Recommended seismic strengthening for the south tower includes:

- Strengthen concrete beams below the discontinuous penthouse walls.
- Add new braced frames in the north-south direction. Two bays of braced frames at both the east and west sides of the building (four bays total) just outboard of the existing concrete frames recommended.
- Strengthen columns at new braced frames.
- Add new collectors along the east and west sides of the building to drag load into the new braced frames.
- Add fiber reinforced polymer (FRP) wrap around interior concrete columns.
- Slot cut the deep spandrel beams along the east and west sides of the building.
- Strengthen foundations below new braced frames.

Recommended seismic strengthening for the central plant includes:

- Add new Simpson straps and blocking at the roof to brace the perimeter reinforced masonry.

Appendix B – Fault Descriptions

Redondo Canyon Fault
Palos Verdes Fault
Compton Thrust Fault
Newport-Inglewood-Rose Canyon Fault Zone

400 Oceangate, Suite 1050 ■ Long Beach, California 90802 ■ Telephone (562) 628-1675 ■ FAX (562) 628-1676

Quaternary Fault and Fold Database of the United States

Redondo Canyon fault (Class A) No. 130

Citation Treiman, J.A., compiler, 1998, Fault number 130, Redondo Canyon fault, in Quaternary fault and fold database of the United States:

Synopsis There is little published information on this fault; it may receive some slip transferred from the Palos Verdes fault zone and is interpreted to accomodate uplift of the Palos Verdes Hills; location and activity based on marine geophyisical interpretation.

Name comments First located by Emery (1960 #6130) and later by Yerkes and others (1967 #6132) along axis of canyon; later work by Nardin and Henyey (1978 #6131) identified the fault as a reverse fault on the south flank of the canyon rather than along the canyon axis; to the east the fault the joins Palos Verdes fault zone [128].

Fault ID: Refers to number 436 (Redondo Canyon fault) of Jennings (1994 #2878); Fault ID 8 of Hecker and others (1998 #6118); number 36 (Redondo Canyon fault) of Ziony and Yerkes (1985 #5931).

County(s) and State(s) LOS ANGELES COUNTY, CALIFORNIA (offshore)

Physiographic province(s) PACIFIC BORDER (offshore)

Reliability of location Poor

Compiled at 1:100,000 scale.

Comments: Inferred trace digitized at 1:100,000 from photo-enlargement of original 1:250,000 map (Vedder and others, 1986 #5971).

Geologic setting High-angle, down to the north, reverse fault separates Palos Verdes Hills structural block from the Santa Monica basin to the north; may absorb some dextral slip from Palos Verdes fault zone [128] or may transfer this slip further offshore.

Length (km) 12 km.

Average strike N90°WW

Sense of movement Reverse

Comments: Described as a north-dipping normal fault by earlier workers.

Dip Direction S Comments: High-angle dip is assumed as summarized by Hecker and others (1998 #6118).

Paleoseismology studies

Geomorphic expression Fault zone may have provided structural control for Redondo Canyon (submarine), but fault is identified along south flank of canyon rather than along canyon axis; scarps and warps also summarized by Hecker and others (1998 #6118) from Nardin and Henyey (1978 #6131); in a larger sense, the Palos Verdes Hills may represent uplift of the south side of the fault.

Age of faulted surficial deposits Presumed Holocene sediments (Nardin and Henyey, 1978 #6131; Vedder and others, 1986 #5971)

Historic earthquake

Most recent prehistoric deformation latest Quaternary (<15 ka)

Comments: Timing of most recent movement based on marine geophysical interpretation.

Recurrence interval

Slip-rate category Between 0.2 and 1.0 mm/yr

Comments: Slip rate is inferred to be similar to the vertical uplift rates for Palos Verdes fault zone [128].

Date and Compiler(s) 1998

Jerome A. Treiman, California Geological Survey

Palos Verdes fault zone, Palos Verdes Hills section (Class A) No. 128b

County(s) and State(s) LOS ANGELES COUNTY, CALIFORNIA

Physiographic province(s) PACIFIC BORDER

Reliability of location Poor

Compiled at 1:250,000 scale.

Length (km) This section is 12 km of a total fault length of 73 km.

Average strike N57°W (for section)

Sense of movement Right lateral

Dip 50° SW. to 90°

Historic earthquake

Most recent prehistoric deformation late Quaternary (<130 ka)

Slip-rate category Between 1.0 and 5.0 mm/yr

Compton thrust fault (Class A) No. 133

Citation	Fisher, M.A., and Bryant, W.A., compilers, 2017, Fault number 133, Compton thrust fault, in Quaternary fault and fold database of the United States
Synopsis	The Compton thrust fault (blind) extends below the western Los Angeles Basin, lying entirely within Mesozoic metamorphic basement (Catalina Schist) (Shaw and Suppe, 1996). Most of the thrust fault is a ramp that rises to the southwest from depths as great as 10 km up to 5 km. The ramp connects the Central Basin Decollement, a thrust flat below the Los Angeles Basin, with shallower parts of the thrust fault near its tip below the Palos Verdes Peninsula. Leon and others (2009) identified 6 events in the past 14 ka, established event dates, and estimated a thrust fault slip rate of 1.2+0.5, -0.3 mm/yr.
Name comments	Variously referred to as the Compton Thrust, Compton ramp, Compton thrust ramp, and Compton thrust system by Shaw and Suppe (1996). Also referred to as the Compton-Los Alamitos trend in reference to the growth fold above the Compton ramp.
County(s) and State(s)	LOS ANGELES COUNTY, CALIFORNIA
Physiographic province(s)	PACIFIC BORDER
Reliability of location	Compiled at 1: scale. *Comments:* Location of fault from Qt_flt_ver_3-0_Final_WGS84_polyline.shp (Bryant, W.A., written communication to K.Haller, August 15, 2017) based on geometric representation of Compton Thrust Fault ramp is from Community Fault Model (Plesch and others 2007).
Geologic setting	The Compton thrust fault is one several blind thrust faults that pose an earthquake hazard to urban Los Angeles. Miocene through Quaternary sedimentary rocks within the Los Angeles Basin and the upper part of their Mesozoic basement are transported upward and southwestward along the Compton thrust fault.
Length (km)	km.
Average strike	
Sense of movement	Thrust
Dip	0–28° NE. *Comments:* Fault is flat lying beneath offshore and coastal areas and dips 22° NE. east of the coastal zone (Shaw and Suppe, 1996; Leon and others 2009).
Paleoseismology studies	Site 133-1 – Stanford Avenue site by Leon and others (2009) involved the interpretation of high resolution seismic reflection lines and the excavation of ten 25–35 m deep, continuously cored boreholes along Stanford Avenue, Los Angeles. Leon and others (2009) identified as many as 6 discrete fold scarps associated with displacement along the Compton thrust fault ramp, and estimated a slip rate (thrust) of 1.2+0.5, -0.3 mm/yr.
Geomorphic expression	
Age of faulted surficial deposits	The fault does not extend to the ground surface, but Quaternary sediment apparently is flexed upward in the kink band associated with the Compton thrust ramp, indicating Quaternary activity (Shaw and Suppe, 1996). Leon and others (2009) identified Holocene fluvial deposits deformed within back-limb fold structure during uplift events associated with displacement along the Compton thrust fault ramp. Ages, based on calibrated radiocarbon dates from 30 humic, charcoal, and bulk soil samples indicate sediment accumulation over the past 14 ka.
Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Possibly inactive during the late Quaternary (since about 1.5 Ma, Foxall, 1997); however, the Palos Verdes fault [128] is kinematically related to the Compton thrust fault and the Holocene activity along the Palos Verdes fault could suggest the underlying Compton thrust fault was active in the Holocene as well.
Recurrence interval	Leon and others (2009) identified six paleoseismic events at the Stanford Avenue [133-1] site: Event 1: 0.7–1.75 ka Event 2: 1.9–3.4 ka Event 3: 5.6–7.2 ka Event 4: 5.4–8.4 ka Event 5: 10.3–12.5 ka Event 6: 10.3–13.7 ka
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Shaw and Suppe (1996) estimated long term slip rate of 1.4±0.4 mm/yr. Leon and others (2009) calculated average Holocene (past 14 ka) slip rate of 1.2+0.5/-0.3 mm/yr using cumulative thrust displacement of 16.9+7.5/-6.9 m derived from dip of 28±3° dip of Compton thrust fault ramp.
Date and Compiler(s)	2017 Michael A. Fisher, U.S. Geological Survey William A. Bryant, California Geological Survey

Newport-Inglewood-Rose Canyon fault zone, south Los Angeles Basin section (Class A) No. 127b

Synopsis

General: Data on this fault zone is variable. Fault locations onshore and in some limited offshore areas are generally well located. The large central portion of the fault zone is offshore and less well defined. Urbanization in the San Diego area has also somewhat limited the accurate location of some of the fault strands. The northern onshore portion is demonstrably Holocene based on numerous geotechnical studies as well as the historic Long Beach earthquake. The southern onshore portion, through San Diego, is also demonstrably active based on geotechnical and research studies. The intermediate offshore portion is presumed Holocene based on sparse evidence of displacement of presumed young Holocene sediments offshore as well as its continuity to the better-defined onshore sections. There are three detailed study sites along the fault zone. Grant and others (1997 #1366) reported evidence for 3–5 earthquakes in the past 11.7 ka, but stated that the recurrence interval varied from 1,200 yr to 3,000 yr. Slip rate is not fully constrained, but appears to be approximately 1.0±0.5 mm/yr in the north, increasing to 1.5±0.5 mm/yr in the south.

Sections: This fault has 7 sections. Section designations after Fischer and Mills (1991 #6468) who designated three segments offshore, two segments onshore south of La Jolla and one southern segment within the Los Angeles basin (thereby implying a northern, 7th segment as well). Sections were distinguished based on asperities (bends), steps and seismicity. The division of the Los Angeles basin part of the fault zone into two segments is based on slight differences in geometry (discussed by several workers, including Wright (1991 #5950), seismicity differences (Hauksson, 1987 #6475), and the subsurface extent of the 1933 Long Beach earthquake rupture (Wesnousky, 1986 #5305; Hauksson and Gross, 1991 #6476). Fischer (1992 #6467) designates one additional segment offshore. Working Group on California Earthquake Probabilities (1995 #4945) and Petersen and others (1996 #4860) identify three sections: Newport-Inglewood, Newport-Inglewood offshore and Rose Canyon (the latter including offshore faults north to Oceanside).

Name comments

General: Entire fault zone referred to as Newport-Inglewood-Rose Canyon fault zone by Greene and others (1979 #6470). Newport-Inglewood fault: onshore structural zone first recognized as a zone of folding by Mendenhall (1905 #6488). Hamlin (1918 #6473) associated seismicity and faulting with the zone; first mapped and named by Taber (1920 #6491) as the Inglewood-Newport-San Onofre fault; called Newport-Inglewood fault by Hoots (1931 #5921). Eaton (1933 #6463) was first to suggest continuity to Rose Canyon fault in the San Diego area; offshore portion was called the South Coast Offshore fault by utility consultants (Southern California Edison Co. and San Diego Gas and Electric Co., 1972 #6490), and the South Coast Offshore Zone of Deformation by Woodward-Clyde Consultants (1979 #6496). Rose Canyon fault: Fairbanks (1893 #6466) suggested presence of fault and Ellis and Lee (1919 #6465) were the first to show part of the fault on a map. Hanna (1926 #6474) referred to the Soledad Mountain fault; Hertlein and Grant (1939 #6477) were the first to refer to the Rose Canyon fault; Kennedy (1975 #6478) and Kennedy and others (1975 #6480) mapped the fault in greater detail. See sections 127f and g for additional fault strands.

Section: Section name from Fischer and Mills (1991 #6468); includes Cherry-Hill fault, Northeast Flank fault, Reservoir Hill fault, Seal Beach fault, and North and South Branch Newport-Inglewood faults; North Branch fault has also been called the High School fault; section extends southeastward from the Dominguez Hills to Newport Beach.

Fault ID: Refers to numbers 434 (Potrero, Inglewood and Avalon-Compton faults), 439 (South Branch, Newport-Inglewood fault zone), 440 (North Branch, Newport-Inglewood fault zone), 441 (Cherry-Hill, Reservoir Hill and Seal Beach faults), 465 (Newport Inglewood-Rose Canyon fault zone, offshore), 487 (Mission Bay fault), 490 (Coronado fault, offshore), 490A (Spanish Bight fault, offshore), 491 (Rose Canyon fault zone), 492 (Old Town fault), and 493A (Silver Strand fault, offshore) of Jennings (1994 #2878). Also refers to numbers 30 (Newport-Inglewood, north section) and 31 (Newport-Inglewood, south section) of Hecker and others (1998 #6118), and to numbers 25 (Inglewood fault), 26 (Potrero fault), 27 (Avalon-Compton fault), 28 (Cherry-Hill fault), 29 (Reservoir Hill fault), 30 (Newport-Inglewood North Branch), 31 (Newport-Inglewood, South Branch), and 32 (Faults offshore of San Clemente) of Ziony and Yerkes (1985 #5931).

County(s) and State(s)

LOS ANGELES COUNTY, CALIFORNIA
ORANGE COUNTY, CALIFORNIA

Physiographic province(s)

PACIFIC BORDER

Reliability of location

Good
Compiled at 1:24,000; 1:31,680; 1:48,000 and unspecified scale.

Comments: Location of fault from Qt_flt_ver_3-0_Final_WGS84_polyline.shp (Bryant, W.A., written communication to K.Haller, August 15, 2017) attributed to Bryant (1985, 1988), California Department of Water Resources (1966), Guptil and Heath (1981), Morton and Miller(1981), and Poland and others (1956).

Geologic setting

This fault zone is a major structural element within the Peninsular Ranges. Both onshore, to the north, and in the offshore region the fault zone separates contrasting Mesozoic basement terrane-Catalina Schist on the west and metasediments, intrusives and volcanics to the east (Yerkes and others, 1965 #5930).

The onshore Los Angeles basin reach of the fault zone is marked by a northwesterly trending line of generally en echelon anticlinal folds and faults that extends 40 miles from Newport Mesa to the Cheviot Hills along the western side of the Los Angeles Basin (Barrows, 1974 #6460); the zone is tentatively extended northward to the Santa Monica [101] and Hollywood [102] faults by Wright (1991 #5950). The onshore structural zone is an important petroleum-producing region.

The offshore reach of the fault zone continues southeastward until offshore of Oceanside where it bends and steps and continues on a more south-southeast trend, paralleling the coastline. The Rose Canyon fault [127e, 127f] comes onshore at La Jolla and is characterized by zones of compression and extension associated with restraining and releasing bends in the faults. The fault zone is locally more than 1 km wide and is composed of both dip-slip and strike-slip en echelon faults that together extend from La Jolla Cove 50 km to San Diego Bay and beyond on the south (Treiman, 1993 #6494).

Length (km)

This section is 34 km of a total fault length of 209 km.

Average strike

N51°W (for section) versus N29°W,N27°W,N31°W (for whole fault)

Sense of movement

Right lateral

Comments: Legg and Kennedy (1991 #6486) report pure dextral strike slip; supported by seismicity as reported by Hauksson (1990 #6879).

Dip Direction

NE; SW

Comments: Dip assumed by Petersen and others (1996 #4860); generally high-angle to near vertical, but locally dips either NE or SW (Wright, 1991 #6878).

Numerous consulting studies (on file with the California Geological Survey, Alquist-Priolo Earthquake Fault Zoning project) have addressed location and recency of faulting.

Paleoseismology studies

Site 127-2: Huntington site by Grant and others (1997 #1366) involved drilling and analyzing 72 CPT borings, spaced between 7 to 30 m apart across the North Branch fault just northwest of Huntington Mesa. Grant and others (1997 #1366) identified at least three and possibly five surface-rupturing earthquakes in the past 11.7 ka. Dates of the events were established using 14C dates from samples collected from continuously cored borings.

Geomorphic expression

Large-scale features include a line of hills underlain by en echelon anticlinal folds and faults; small- to intermediate-scale features include scarps, pressure ridges, deflected drainages, linear drainages, closed depressions and troughs (Bryant, 1988 #6461).

Age of faulted surficial depos

Holocene alluvial deposits and soils; late Pleistocene Inglewood Formation; late Pleistocene marine and non-marine terrace deposits; Pleistocene Lakewood Formation (Bryant, 1988 #6461).

Historic earthquake

Most recent prehistoric defor

latest Quaternary (<15 ka)

Comments: Timing of most recent paleoevent is poorly constrained. Historic events (without surface rupture) include 1933 M6.3 Long Beach earthquake and perhaps 1812 (12/08/1812); no details available on individual or most recent pre-historic events.

Recurrence interval

1,200–3,000 yr

Comments: Recurrence interval reported by Freeman and others (1992 #6469) and Grant and others (1997 #1366). Grant and others (1997 #1366) recognized at least three and as many as five surface-rupturing earthquakes in the past 11.7 ka at the Huntington site. The two oldest Holocene events occurred within approximately 1,200 yr of each other, but at least 3,000 yr passed between early and middle Holocene events.

Slip-rate category

Between 1.0 and 5.0 mm/yr

Comments: 0.5 mm/yr long-term horizontal geologic slip-rate derived from offset facies in oil well logs (Freeman and others, 1992 #6469); Wesnousky (1986 #5305) and Working Group on California Earthquake Probabilities (1995 #4945) assume 1.0 mm/yr; Clark and others (1984 #2876) reported 0.6–1.2 mm/yr vertical slip rate at Bolsa Chica Mesa which may not be representative of total slip on the deeper seismogenic structure.

Date and Compiler(s)

1999
Jerome A. Treiman, California Geological Survey
Matthew Lundberg, California Geological Survey

Appendix C – 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 D – Qualifications

Reza Imani, Ph.D., P.E., S.E.

Manager, Structural Engineering & Risk Mitigation, ImageCat, Inc.

Reza Imani received his Ph.D. degree in Civil (Structural) Engineering from the University at Buffalo (SUNY) in 2014 and is a registered Professional Engineer (Civil) in the State of California.

Mr. Imani has 9 years of combined research and practice experience in analysis, risk evaluation and design of structures subjected to multi-hazard loading conditions (e.g. earthquake, fire, wind) and extreme events (e.g. post-earthquake fires). Reza's research and practice experience also involve application of the Performance-Based Design method to structures under seismic and fire loads. Clients include lenders, building owners, property insurers, government agencies, issuance brokers, municipal bond rating agencies and bond insurers. Prior to joining ImageCat, Reza was a Project Engineer with Thornton Tomasetti, Inc (San Francisco Office). During his 5 years in TT, Reza was involved in various seismic design, risk assessment/evaluation and retrofit projects both within and out of the U.S. from commercial, sports, education and healthcare sectors. Reza was also a member of TT's Forensics team, using advanced analytics and engineering principles to investigate causes of failure or other concerns in behavior of structures.

Relevant Publications include:

Imani R., Ghisbain P., Ashrafi A., (2016). "Performance-based Fire Engineering: Sensitivity Analysis on Design Parameters", Published in Proceedings of the 9th International Conference on Structures in Fire (SiF 2016), Princeton University, June 2016.

Imani, R., Bruneau., (2015) "Effect of Link-beam Stiffener and Brace Flange Alignment on Inelastic Cyclic Behavior of Eccentrically Braced Frames", AISC Engineering Journal, Vol. 52, No. 2, pp 109-124.

Imani, R., Mosqueda G., Bruneau, M., (2015) "Finite Element Simulation of Concrete-Filled Double-Skin Tube Columns Subjected to Post-Earthquake Fires", ASCE Journal of Structural Engineering, Vol.141, No.12, DOI: 10.1061/(ASCE)ST.1943-541X.0001301.

Imani, R., Mosqueda G., Bruneau, M. (2014), "Experimental Study on Post-Earthquake Fire Resistance of Ductile Concrete Filled Double-Skin Tube Columns", ASCE Journal of Structural Engineering, Vol.141, No.8 DOI: 10.1061/(ASCE)ST.1943-541X.0001168.

R. Rofooei, F., Imani, R., (2011). "Evaluating the Damage in Steel MRF under Near Field Earthquakes from a Performance Based Design Viewpoint", Procedia Engineering, 14: 3325-3230, The Proceedings of the Twelfth East Asia-Pacific Conference on Structural Engineering and Construction, Kowloon, Hong Kong.

Imani, R., Bruneau, M., (2014). "Post-Earthquake Fire Resistance of Ductile Concrete Filled Double-Skin Tube Columns" Technical Report MCEER-14-0008, MCEER, Univ at Buffalo, Buffalo, NY.

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 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 PML standards, ASTM E 2026 and E 2557. 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:

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 Jerry 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).

Appendix E – Seismic Design Code Objectives

Seismic Design Code Objectives for New Buildings

The provisions for seismic design of new buildings in building codes typically assume that a building will have a 50-year useful life. When these buildings were designed, the governing code in the Western United States was the Uniform Building Code, and the design motions were typically intended to capture the maximum intensity of shaking that might be expected for the site during its useful life. Redondo Beach was always in the highest seismic zone recognized by the Uniform Building Code. As ground shaking hazard models improved, the hazard level was further specified to have a 10% chance of exceedance within the 50-year assumed design life. This is equivalent to a ground shaking hazard level with a 475-year average recurrence (or a "return period" of 475 years). The objective of the seismic design code was not and is not to prevent all damage or render the building "earthquake-proof," but rather to prevent gross collapse and thereby to achieve an acceptable level of life-safety.

For "essential facilities" such as hospitals, building codes since the 1970s have required design for higher ground motions in an effort to reduce damage and ensure rapid (or immediate) resumption of essential services. After the 1971 Sylmar Earthquake, hospitals in California were designed under the supervision of the Office of the State Architect. In the early 1980s, the California Office of Statewide Health Planning and Development (OSHPD, now HCAI) took over oversight of acute-care hospital design in California. After the 1994 Northridge Earthquake caused damage to hospitals in southern California, Senate Bill 1953 was passed and administered by OSHPD, requiring the seismic retrofit of structural and nonstructural systems of older acute-care hospital buildings found to be seismically deficient. A summary of these regulations may be viewed at:

https://hcai.ca.gov/construction-finance/seismic-compliance-and-safety/program-overview/

Since January, 2008, the State of California has used the International Building Code (IBC) as the basis for seismic design of new buildings. The IBC defines the Maximum Considered Earthquake (MCE) ground motions as the hazard level associated with a 2% chance of exceedance in 50 years, or having a 2,475-year return period. Design-level motions are taken as 2/3 of the MCE level. The ground motions are further modified to result in designs for ordinary buildings that will resist the MCE with less than a 10% probability of collapse. *This design approach is viewed as having collapse probabilities of 1% or less in the 50-year typical building life.* Essential buildings are designed for higher loads, with the result that they should exhibit higher safety and damage resistance.

Seismic Evaluation and Retrofit Standards for Existing Buildings

The current national standard for seismic evaluation and retrofit of existing buildings is ASCE 41-17. It permits the selection of several levels of performance (e.g., life-safety, collapse preventions, etc.) for structural and nonstructural systems based on two hazard levels:

BSE-1E: Basic Safety Earthquake-1 for use with the Basic Performance Objective for Existing Buildings, taken as a seismic hazard with a 20% probability of exceedance in 50 years.

BSE-2E: Basic Safety Earthquake-2 for use with the Basic Performance Objective for Existing

Buildings, taken as a seismic hazard with a 5% probability of exceedance in 50 years.

ASCE 41 is cited by various jurisdictions in California for use in design to meet mandatory seismic retrofit ordinances, and is often used by Structural Engineers in voluntary seismic retrofits. A number of local building jurisdictions in California (e.g., City of Los Angeles, City of Santa Monica, etc.) have enacted mandatory seismic retrofit ordinances for older concrete buildings such as the towers at 514 North Prospect Avenue. The City of Redondo Beach has not indicated that it intends to pass such an ordinance.

Appendix F – Commercial Real Estate Lender and Owner Criteria for Seismic Risk

Seismic risk assessments for property transfer due-diligence generally follows two standards established by ASTM:

E2026-16a: Standard Guide for Seismic Risk Assessment of Buildings

E2557-16a: Standard Practice for Probable Maximum Loss (PML) Evaluations for Earthquake Due-Diligence Assessments

Seismic risk assessments are conducted by experienced Professional Engineers, working with other professionals (e.g., Geotechnical Engineers) as needed. Seismic risk assessments are typically conducted in seismically active areas (e.g., California, and western Washington and Oregon).

According to the Standards mentioned above, any seismic risk assessment as part of the due-diligence process includes:

1) A seismic hazard assessment to estimate ground motion intensities and an evaluation of site stability, considering surface fault rupture, soil liquefaction and earthquake-induced landslide.

2) A building stability assessment to assess safety and identify serious seismic deficiencies that might result in collapse under intense ground shaking in large earthquakes.

3) A building damage assessment to estimate the repair cost (as a fraction of building replacement value) under a scenario earthquake usually defined as the 475-year recurrent ground shaking and associated hazards.

Lenders and institutional purchasers typically require that both the building and the site be deemed “stable,” and that the damage levels be less than some acceptable level that they designate. The acceptable level differs for various lenders and investors, as some may have be willing to take more risks. For example, some lenders require a Scenario Expected Loss (SEL) values of less than 20%. Other with lower levels of acceptable risk may require a Scenario Upper Loss (SUL) value that is less than 20%. If a building is deemed unstable or the projected damage is surpassing the mentioned limits, mitigation measures are recommended, including seismic retrofit and/or earthquake insurance. When these mitigation measure are not financially feasible, some lenders or investors may decide not to pursue the deal.