Cal VIVA: Assessing the Seismic Vulnerability of California’s State-Owned Buildings

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Abstract

In the last 20 years, agencies and departments in the State of California have initiated seismic vulnerability programs for state-owned buildings with goals ranging from life safety to reduced post-earthquake disruption. Until now, there has not been an assessment of all state-owned buildings with the goal of identifying and assessing the seismic vulnerability of those buildings needed for response and recovery efforts after an earthquake.

The California Vital Infrastructure Vulnerability Assessment Project (Cal VIVA), sponsored by the California Emergency Management Agency (Cal EMA) and funded through FEMA, has developed a statewide approach to assessing the vulnerability of the state-owned building stock. Cal VIVA, undertaken by engineering faculty at California Polytechnic State University, San Luis Obispo, is assisting Cal EMA in preparing for natural disasters by identifying state-owned buildings that house critical functions and are vulnerable to earthquakes.

The initial phase of the project included the development of a methodology for identifying critical and vulnerable state-owned buildings. The methodology was tested with four departments; Caltrans, Department of Water Resources, California Highway Patrol and Cal FIRE. Later phases of Cal VIVA will expand to additional agencies, develop guidelines for individual departments programs and create a state-wide reporting mechanism. A critical outcome of Cal VIVA is to provide for a systematic basis to apply for federal hazard mitigation funding to reduce seismic vulnerabilities of state-owned buildings critical to response and recovery efforts after an earthquake.

This paper will describe the process of building selection, the pitfalls and successes, the preliminary conclusions and next steps.

Introduction

The California Vital Infrastructure Vulnerability Assessment Project (Cal VIVA), sponsored by the California Emergency Management Agency (Cal EMA) and funded through FEMA is a critical part of the 2010 California State Multi-Hazard Mitigation Plan also known as the State Hazard Mitigation Plan (SHMP). The purpose of the SHMP, is to significantly reduce deaths, injuries, and other disaster losses caused by natural and human caused hazards in California. The SHMP describes past and current hazard mitigation activities and outlines goals, strategies, and actions for reducing future disaster losses.

Cal VIVA, as part of the SHMP, has the overarching goal of assisting Cal EMA to prepare for natural disasters by identifying state-owned buildings that house critical functions and are vulnerable to earthquakes. The project began in early 2011 and is due to be completed in early 2013. The project has three main focus areas:

1) Develop a methodology to identify potentially vulnerable state-owned and operated buildings that are essential to response and recovery efforts after an earthquake.

2) Test the methodology on 15 – 20 state-owned and operated buildings. The testing process will include seismic assessments, and upgrade concepts with budgetary costing.
3) Develop plans for improvements to the methodology and recommendations regarding priorities for project funding and development.

Cal VIVA was undertaken as a joint effort by faculty of California Polytechnic State University (Cal Poly) and staff at Cal EMA. A Vulnerable Infrastructure Strategic Work Group (VISWG), composed of representatives from state agencies, planners and engineers, was established to assist with the development of approaches for the screening of state-owned buildings, the seismic assessment methodology and to provide oversight of the results and conclusions.

The seismic vulnerability of state-owned buildings has been a concern for many years. Some key programs that have focused on this issue include the California Proposition 122, Bonds for Seismic Retrofitting program in the 1990’s as well as programs by individual departments and entities such as the University of California, California State University, Administrative Office of the Courts and the California Department of Transportation. These have all differed from the Cal VIVA project in fundamental ways. The Proposition 122 program was state-wide, but was not focused on essential facilities required to provide post-disaster response services. The program instead focused on large occupancy buildings important to recovery efforts. Other programs have been limited to individual departments and entities with differing prioritization and assessment approaches.

**Methodology to Identify Vulnerable State Buildings**

In order to develop a methodology to identify the vulnerability of state-owned building it was necessary to understand the organizational structure of the State and its internal reporting mechanisms.

There are 13 primary agencies in the executive branch of the State with 62 departments within those agencies. In addition to these agencies and departments there are numerous commissions, and councils. The Department of General Services maintains the State of California State Property Inventory (SPI) which lists approximately 24,000 state-owned buildings, including those owned by the University of California and the California State University. For any specific building, SPI lists building size, location, estimated date of construction and use. Although SPI is intended to contain all state-owned buildings, the inventory relies on voluntary reporting by the various state agencies and departments, and therefore has been found to not be a comprehensive list.

A methodology was developed to systematically review the seismic vulnerability of such a large number of buildings. A screening method was developed that has three triggers: 1) Functionality, 2) Building Vulnerability and 3) Site Seismicity.

**Trigger 1 - Functionality.** Initially, two types of functionality triggers were proposed; personnel and building functionality. The personnel functionality trigger was for State personnel that had post-earthquake responsibilities that could be performed at other locations. These agencies/departments were preliminarily identified from the 2009 State Emergency Plan (SEP). To provide appropriate resiliency, the agencies/departments should be housed in facilities that provide life safety to occupants and have access to back-up facilities that would allow post-earthquake functions. Upon investigation, it was determined that the number of personnel and subsequent number of buildings covered under this criterion was extremely large. This subset of the functionality trigger was put on hold for later phases of Cal VIVA to allow the project to focus on the critical building functionality trigger.

The focus of Cal VIVA was the trigger: building functionality requiring an Immediate Occupancy performance level for essential facilities. This functionality trigger applies to state-owned and operated facilities where operations are considered essential during an emergency and the subsequent recovery effort. These facilities fall into the following broad categories: Emergency Operations Centers, utilities, and vital records.

In order to locate such critical buildings a two-step process was developed. First, agencies/departments would be selected that had first responder duties after an earthquake. Second, staff from the selected agencies/department would work with the Cal VIVA team to develop a list of critical facilities.

Exploration of the State’s specific emergency response and recovery plans indicated that these plans are undergoing significant revision and were not available for review. The State Hazard Mitigation Officer selected four departments with critical response and recovery responsibilities to test the Cal VIVA methodology. These four departments were confirmed by the VISWG. Specific buildings within each agency/department that house essential facilities were selected based on recommendations by the respective staff.

**Trigger 2 - Building Vulnerability.** The building’s vulnerability is determined largely by its structural system type and the structural building code provisions under which it was designed. The most likely source for determination of that information is the building’s construction drawings. However there is no central state repository for the construction drawings of state-owned buildings. Because many of these drawings were not archived in a central location, locating the drawings was difficult. If the building
was inventoried in SPI only the size, location, and age of construction was known not the type of construction. Individual departments were often able to provide anecdotal information as to the building’s age and type which allowed preliminary conclusions to be drawn as to the building’s vulnerability. This anecdotal information was used for the second trigger. Due to the difficulty in obtaining the drawing, the search for the building drawings did not occur until a building met all three triggers and was designated for an assessment.

Seismic assessments were generally not proposed for structures which were designed to standards substantially consistent with current building codes for essential facilities or had been seismically upgraded to such standards.

**Trigger 3 - Site Seismicity.** Cal VIVA focused on buildings located in areas of high seismicity. Buildings were selected from geographic areas that have high seismicity as defined by ASCE 31: $S_{D1} \geq 0.500$ and $S_{D2} \geq 0.200$. SPI contains the building address and latitude and longitude. For building not found in SPI the information was developed. Using Geographic Information system (GIS) the building location was superimposed on a map showing area seismicity. This broad definition of high seismicity resulted in a large number of buildings. For this first effort many buildings were selected from the San Francisco and Los Angeles areas to permit observations about area-wide vulnerability.

The use of these three triggers was reviewed by and received concurrence from the VISWG.

**Assessment Methods**

Assessments of vulnerability were based on *ASCE 31-03 Seismic Evaluation of Existing Buildings* (ASCE 31) a national standard that contains seismic assessment procedures. The intent of choosing this method is its wide general acceptance and its three-tiered system. The concept was that a large number of the buildings could be rapidly assessed as Tier 1 buildings which would provide a broad look at vulnerability.

The ASCE 31 assessments included reviews of the original structural drawings, site visits, the preparation of the limited structural calculations described by ASCE 31 and the completion of the ASCE 31 checklists. The assessments included reviews of potential site issues and the non-structural systems (based on site observations). The scope included the development of upgrade concepts which were based on the fundamental approaches of *ASCE 41-06 Seismic Rehabilitation of Existing Structures*.

Consistent with the *Benchmark* provisions of ASCE 31 Table 3-1, seismic assessments were not performed for structures which were designed to standards substantially consistent with current building codes for essential facilities or had been seismically upgraded to such standards. The use of ASCE 31, a national standard, was confirmed by the VISWG as the assessment method for the project. In addition, based on recommendations by the VISWG, supplemental HAZUS analyses using the Advanced Engineering Module are being undertaken for selected buildings. As stated on the FEMA website, “Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes.”

Although both ASCE 31 and HAZUS are recognized national standards for building seismic assessment they bring different information to the project. HAZUS will provide additional information including damage state probabilities rather than the compliant or not-compliant results of ASCE 31.

**Vulnerable Infrastructure Strategic Work Group**

The creation of the VISWG was an important component of the project. The VISWG was formed to assist with the development of approaches for the screening of state-owned buildings, the seismic assessment methodology and to provide oversight of the results and conclusions. Members were selected that had both technical and policy backgrounds allowing for input on both aspects of the Cal VIVA project. The VISWG includes representatives from applicable State agencies as well as experienced engineers and planners from private practice. The VISWG held several meetings in 2011 and will meet again in 2012. The VISWG confirmed the methods for selecting buildings and for their assessment and provided valuable comments and recommendations. The Cal VIVA team is grateful for their participation.

**Selection of Department Buildings for Assessment**

Challenges were encountered in selecting facilities for assessment from the inventory of state-owned buildings. One was that the state response and recovery plans were not available, limiting a test of Trigger 1 - Functionality. As a workaround, the State Hazard Mitigation Officer selected the four departments. The selections of the four departments were confirmed by the VISWG.

It was difficult to systematically use Trigger 2 - Building Vulnerability since drawings for many buildings were not archived in a central location and were difficult to locate. By working with individuals from the selected agencies/departments who had in-depth knowledge of their
building stock, it was possible to focus efforts on critical buildings.

Trigger 3 - Site Seismicity was successfully applied with the selection of buildings in areas of high seismicity.

The four departments chosen to test the Cal VIVA methodology are: California Department of Transportation (Caltrans), with responsibility for post-earthquake transportation; California Highway Patrol (CHP), also with responsibility for post-earthquake transportation; California Department of Forestry and Fire Protection (Cal FIRE), with responsibility for fire response coordination; and California Department of Water Resources (DWR), with responsibility for the state water project.

In each department, contact was made with a designated representative. This representative assisted with the selection of buildings, obtained drawings, and provided access to the buildings being assessed. These were often not easy tasks and the Cal VIVA team is grateful for their assistance.

The selection of buildings to be assessed was based on the three triggers described above: functionality, building vulnerability and site seismicity. The buildings selected with each department’s recommendations are described below.

California Department of Transportation. Caltrans is composed of twelve districts. Each district contains a building that houses a Traffic Management Center (TMC) and an Emergency Operations Center (EOC). Each district also has a building designated as an Alternate Emergency Operations Center (Alternate EOC). Of the twelve districts, approximately seven include areas of high seismicity. Because of the intent to primarily assess buildings from the San Francisco and Los Angeles areas, Districts 4 and 7 were selected. The facilities in these two districts include a variety of ages and structural types.

Two facilities were chosen in District 4. The District 4 TMC/EOC is a fifteen-story building, located in Oakland. It was constructed in approximately 1992 recently received a seismic upgrade. The District 4 Alternate EOC is a one-story building built in the 1960s in Walnut Creek.

Two facilities were chosen in District 7. The District 7 TMC/EOC is a four-story building located in Glendale. It was designed to meet essential facility code provisions and was completed in 2006. The District 7 Alternate EOC is a one-story building located in Commerce and designed in 1988.

A map of California showing seismicity and Caltrans district TMC/EOCs and Alternate EOCs is shown in Figure 1.

Figure 1 Caltrans District EOC & TMC Locations

California Highway Patrol. The CHP is composed of eight districts and operates approximately 100 Area Offices throughout California. They are typically one-story buildings with floor areas of 10,000 to 15,000 square feet. Construction is a mix of CMU, tilt-up concrete or wood walls generally with wood roof framing. Eight area offices were selected, three in the San Francisco area, two on the Central Coast and four in the Los Angeles area. The ones selected were designed in the 1960’s and early 70s and are representative of the building stock.
A map of California showing seismicity and CHP Area Offices is shown in Figure 2.

**Figure 2 CHP Area Office Locations**

Department of Water Resources. The DWR operates 20 pumping plants and four pumping-generating plants that supply water to approximately 25 million Californians. The pumping plants and pumping-generating plants are typically large structures with three to four stories below grade and a high bay superstructure. They were primarily built in the 1970’s with some undergoing expansions in the 1990’s. Five facilities were selected on the basis of seismicity and importance as determined by DWR staff.

A map of California showing seismicity and DWR pumping and pumping-generating plants is shown in Figure 3.

**Figure 3 DWR Plant Locations**

California Department of Forestry and Fire Protection. Cal FIRE operates a variety of facilities throughout the state including fire stations, lookout towers, communications facilities, headquarters and command centers. The state is divided into 21 areas, each with a unit headquarters and a command center. There are North and South Region Headquarters, located in Redding and Fresno. Many of the unit headquarters and command centers were replaced in the 1990’s and were designed to essential facility status so are assumed to be compliant. Several older facilities are slated for replacement in the near future. The four candidate facilities in Mendocino County being considered for assessments based on their age and area seismicity are a unit headquarters, command center, air attack base and helicopter attack base.
A map of California showing seismicity and Cal FIRE headquarters is shown in Figure 4.

Figure 4 Cal FIRE Headquarters Locations

Hazus Evaluation

As work continued on Cal VIVA it became evident that the methodology was valid, but the bottoms-up approach of looking at individual buildings within the context of an extremely large number of buildings meant a lengthy process. The Cal VIVA team felt that other options should be explored. One option is the use of Hazus, a methodology that estimates potential losses from earthquakes, floods, and hurricanes. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic, and social impacts of disasters.

While working on the assessments of the buildings within each department patterns of building types started to emerge. Specifically it was noted that the critical area offices for CHP, which number over 100, have strong similarities in basic ages and building type. This observation indicated that information obtained from the CHP site investigations could be effectively used as Hazus input. Currently the Cal Poly team is developing a Hazus Advanced Engineering Building Model for CHP that will be used to estimate average annual loss and annualized causalities.

Summary of Assessment Results

A total of 17 buildings from three departments have been assessed to date: four Caltrans buildings, five DWR buildings and eight CHP buildings. The assessments of the Cal FIRE buildings are pending.

As specified by ASCE 31, the assessments included reviews of the original structural drawings, site visits, the preparation of structural calculations and the completion of ASCE 31 checklists, including those for site hazards and non-structural systems. Some of the facilities underwent a Tier 1 assessment, some a Tier 2. The project scope also included the preparation of upgrade concepts and budgetary costs. The results for each department are summarized below.

California Department of Transportation. Caltrans is in the process of upgrading their TMC/EOC facilities and the Oakland and Glendale buildings are two examples of several such buildings.

The District 7 TMC/EOC is located in a four-story steel framed building located in Glendale. The drawings state that the structural system as well as the bracing and anchorage of non-structural elements were designed to provide compliance with essential facility code provisions for a fixed base building. Prior to construction the building design was apparently modified and constructed with a seismic isolation system. The site visit confirmed the general construction of the building, the general compliance of non-structural components and that the detailing of building systems at the plane of isolation could accommodate the specified movement. On this basis the building meets the requirements for an immediate occupancy facility.

A photo of the building housing the District 7 TMC/EOC is shown in Figure 5.
The District 4 TMC/EOC is in a fifteen-story steel moment frame building constructed in approximately 1992 in Oakland. The building received a seismic upgrade, completed in 2010, that was composed of the upgrade of selected bays of the original moment frames and the installation of viscous dampers. The viscous dampers were installed in two bays along each perimeter face for the full height of the building.

The upgrade of the existing moment frames was composed of strengthening of the existing beam-to-column connections and column splices. All of the bays of the original steel moment frames were upgraded from the first through the seventh floor and a majority of the bays were upgraded at the levels above. The criteria set for the seismic upgrade design was to a State of California Risk Level III with performance goals as stated on the drawings of “minor, repairable” structural damage and “moderate damage” with “extensive repairs” to non-structural elements for the “Design Basis Earthquake”. The State of California Risk Level III does not have direct correlation with ASCE 31 or 41 performance levels. Risk Level III lies between the Life Safety and Immediate Occupancy performance levels and can essentially be considered as Life-Safety plus. The existing bracing and anchorage of non-structural elements was not upgraded.

The site visit confirmed the general construction of the upgraded building and that the existing bracing and anchorage of the non-structural systems appeared to be appropriate for a normal occupancy building. Although the seismic upgrade appears to have been well conceived and implemented and will greatly improve the building’s seismic performance, the upgrade criteria was explicitly not to an immediate occupancy level and the bracing and anchorage of the systems serving the TMC/EOC are not to essential facility status. Further study was recommended to review these issues.

The buildings designated as the District 4 and 7 Alternate EOCs are older buildings that have not been upgraded as might be appropriate for their proposed function and their seismic performance is anticipated to be poor.

The District 4 Alternate EOC, in Walnut Creek, was constructed in the 1960s with masonry walls and steel and wood roof framing. Following the requirements of ASCE 31, the building was assigned a Building Type RM1 and assessed using a Tier 1 Evaluation. Significant seismic deficiencies include inadequate CMU shear walls, inadequate diaphragms, lack of load path, lack of CMU wall anchorage and deficient partition and ceiling construction.

The District 7 Alternate EOC, in Commerce, was constructed in the 1980s with wood framed walls and roof. Following the requirements of ASCE 31, the building was assigned a Building Type W2 and assessed using a Tier 1 Evaluation. Significant seismic deficiencies include inadequate shear walls and inadequate load path and deficient bracing of cabinets and equipment.

Significant upgrade measures would be required to bring either building to an immediate occupancy status. Given the anticipated good performance of the primary TMC/EOCs, an Alternate EOC that is operational after a major earthquake may not be critical.

California Highway Patrol. The CHP has undertaken a program to replace many of the approximately 100 Area Offices it operates throughout California. The replacement program has been based primarily on a need for more program space in the buildings, but the seismic vulnerability of many of the Area Offices has been a contributing factor. Eight area offices were selected for assessment, three in the San Francisco area, two on the Central Coast and four in the Los Angeles area. The three triggers described earlier, functionality, building vulnerability and site seismicity, were used in their selection. The Area Offices all have the critical function of acting as staging and communications hubs. Older buildings, designed in the 1960s and early 70s, were selected and the locations were all of high seismicity.

The buildings are of similar size, one-story with floor areas of 10,000 to 15,000 square feet. The construction is a mix of CMU, tilt-up concrete or wood walls with generally wood roof framing. The structures were Building Types W2, PC1 or RM1, as defined by ASCE 31. Tier 1 Evaluations were
used. The site visits confirmed the general construction of the buildings and noted the bracing and anchorage of the non-structural elements. Many of the noted deficiencies were typical of designs of buildings of their vintage. The buildings with CMU and tilt-up concrete walls typically had deficient wall anchorage, diaphragms and load paths. The buildings with wood walls typically had deficient wood shear walls. The tall communication towers on the roofs of the buildings were guyed with cables with uncertain or deficient connections and deserve further review.

Recommended upgrade measures include new connections to address the wall anchorage deficiency and new diagonal bracing to reduce diaphragm span. The possibility of interim upgrade measures such as strengthening wall anchorage to reduce risk was discussed with CHP. The seismic assessments may result in CHP adjusting their focus for building replacement to buildings in areas of high seismicity and with CMU and tilt-up concrete walls.

There were also site hazards noted for most of the Area Offices assessed with six identified using state maps showing liquefaction potential. The liquefaction potential needs to be confirmed by a geotechnical investigation. If the site is liquefiable it may make some upgrades infeasible.

A photo of a typical CHP Area Office is shown in Figure 6.

Figure 6 Representative CHP Area Office (photo by the authors)

Department of Water Resources. The facilities selected for assessment were representative of the 20 pumping plants and 4 pumping-generating plants operated by DWR. The plants house multiple large pump or turbine generators sets. They were typically built in the 1970s although some were expanded during the 1990s. Five facilities were selected in consultation with DWR staff on the basis of seismicity and functional importance.

The buildings are typically large structures with three to four stories below grade constructed of massive reinforced concrete sections. The below grade concrete structures support the above grade high bay superstructures. The superstructures include bridge cranes used to service the pumps and other machinery. The high bay superstructures are of structural steel construction with steel moment frames in transverse direction and braced frames in the longitudinal direction. The buildings were assigned Building Types C2 for the below grade structures and S1A and S2A for the superstructures, as defined by ASCE 31. Tier 1 Evaluations were used for the below grade structures and Tier 2 for the above grade structures as required by ASCE 31. The site visits confirmed the general construction of the buildings and noted the bracing and anchorage of the non-structural elements.

The below grade structures were determined to be compliant with ASCE 31 with expectedly low concrete stresses. The above grade structures were generally compliant. Stresses in the steel members were generally acceptable. Connections, although not fully compliant with current requirements had generally low stresses and were generally judged to be acceptable. Calculated drifts were less than 0.015 and were therefore compliant. The superstructure of one pumping plant however was non-compliant, a result of heavy precast cladding that was not present on the other buildings. Potential upgrade measures consisting of reinforcement of the steel frames and member and base connections were developed.

The bracing and anchorage of non-structural systems were also reviewed and appeared to be generally adequate. The non-structural systems were very extensive and further investigation was recommended. In addition, potentially vulnerable non-building components were observed but were not included in the scope of this assessment. These included the piping into and out of the facility, the switchyard and transmission lines and roads to the facility.

A potential for a surface fault rupture that passes through an outlet canal at one of the facilities was noted. The liquefaction potential could not be determined from available information.

With the exception of the one facility with the precast cladding, the results of the assessments were consistent for all facilities – compliant structures and generally good bracing and anchorage of non-structural elements.
A photo of a typical DWR pumping plant is shown in Figure 7.

Figure 7 DWR Pumping Plant (photo from http://www.water.ca.gov/swp/swptoday.cfm)

California Department of Forestry and Fire Protection. Four facilities in Mendocino County, a unit headquarters, a command center, an air attack base and a helicopter attack base, were selected as potential assessment candidates based on their age and the area seismicity.

Conclusions

Several conclusions can be drawn from the work done to date.

1. A methodology has been developed and successfully used to select buildings for assessment; however, the methodology is most effective at a department level not a state-wide level.

Because the State of California owns in excess of 24,000 buildings an approach was needed to prioritize the order of assessment. A screening method was developed with three triggers: 1) Functionality, 2) Building Vulnerability and 3) Site Seismicity. Although this is a reasonable approach for selecting buildings for assessment, application of the methodology on a state-wide basis has encountered obstacles in the use of Trigger 1 – Functionality and Trigger 2 – Building Vulnerability.

It was difficult to apply Trigger 1 - Functionality, due to a lack of access to the State’s specific plans for response and recovery. The workaround of utilizing the knowledge of the State Hazard Mitigation Officer was successful. Once the department was identified it was necessary to obtain an interagency request for assistance due to the personnel time commitment from the chosen department.

Trigger 2 - Building Vulnerability was also difficult to use. There is no central repository for information on structural building system. The Department of General Services maintains a vault of buildings documents. However, maintenance of the vault has not been funded for years. Many agencies/departments do not retain the construction documents of their buildings. Using only age and building location is only a start to understanding the seismic vulnerability of older buildings.

The project was successful when buildings were selected with the assistance of individual departments. The departments were able to assist with the selection of buildings by providing information on their functional importance and on the building age and type. In addition, the departments obtained drawings for the majority of the buildings and provided access to those buildings.

2. The Cal VIVA project identified distinct differences between the departments in their building stock and their ability to respond after a major earthquake. These observations, summarized below, will help departments better focus their mitigation efforts.

The Caltrans building assessments indicated that their modern or recently upgraded TMC/EOCs should provide good seismic performance with perhaps limited upgrade work. Future seismic upgrades of a relatively small number of older TMC/EOCs should provide the department with a high level of resiliency. The same high performance was not observed in the Alternate EOCs that were assessed. This indicates that the Alternate EOCs should perhaps be only relied on for local, non-seismic disasters.

The CHP buildings present a somewhat different picture. CHP has a large stock of critical buildings and many of them are older and are seismically vulnerable. The CHP has embarked on a replacement program that should in time reduce their vulnerability and provide them with a high level of resiliency. The Cal VIVA project provided an additional focus on the seismicity, building type and site hazards that the CHP did not have previously.

Cal FIRE replaced many of their critical buildings in the 1990s and many of their other older buildings are scheduled for replacement. However they still have several older building that house critical functions. Their replacement or upgrading should leave them also with a high level of resiliency.

DWR provides water to 25 million Californians, clearly a vital function. Key components of their system are the twenty pumping plants and four pumping-generating plants they operate. Although many of the buildings were constructed in the 1970’s, their seismic performance is anticipated to be good. Further studies should focus on the non-structural elements and perhaps on the cladding type to see if the deficiencies noted in the one facility with precast
cladding might occur in other buildings. The effect of the potential surface fault rupture on one facility’s operation should also be reviewed.

3. **Site hazards were uncovered that may affect the performance of the buildings.**

Two types of site hazards were noted that may affect facility safety and post-disaster operation. One is the potential surface fault rupture at one DWR site. The other is the potential for liquefaction noted at many of the CHP Area Offices that were assessed. If the liquefaction potential is confirmed by Geotechnical Investigations, it may affect the feasibility seismic upgrades and alter the priority of facility replacement.

4. **Revising the Cal VIVA methodology to accommodate the State’s organizational structure will improve the state’s ability to implement Cal VIVA.**

The State’s organizational structure is along agency and departmental lines. The lack of state-wide building documentation coupled with this organizational structure suggests that a revised Cal VIVA methodology with each agency/department taking the lead within their organization to assess building vulnerability could be very effective. Each department would report to a state-wide Cal VIVA system which would serve as a central repository for the information. This concept is being explored in a smaller follow-on Cal VIVA project.

Increasing the resiliency of the state is a goal for all of us. In the past, an enormous amount of work has been done in California to reduce seismic vulnerability and improve the safety of its citizens. That work continues today in state agencies, counties, cities, businesses and homes across all public and private sectors. Unfortunately due to the fragmented approach there is no real understanding of the total vulnerability of the state. Utilizing methodologies such as Cal VIVA and working together we can improve our knowledge, work to secure funding and systematically reduce the seismic vulnerability of California.

**References**


ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Structures*, American Society of Civil Engineers, Reston, Virginia.