Title: **Mitigation of Potential Impacts of Large Seismic Events on a Regional Water Supply Conveyance System**

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Mitigation of Potential Impacts of Large Seismic Events on a Regional Water Supply Conveyance System

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Abstract

The Metropolitan Water District of Southern California owns and operates the Colorado River Aqueduct (CRA), which is one of the main imported water conveyance facilities for Southern California. The aqueduct traverses a seismically active area and crosses a number of active faults, including the San Andreas Fault. During design and construction of the CRA, which occurred from 1933 to 1941, accommodations were provided to mitigate the risk posed by active fault traces and to enable rapid repair of the aqueduct. However, since that time, knowledge regarding geology and seismicity within Southern California has greatly increased, while significant advancements have occurred in earthquake engineering and design. Due to this continual increase in knowledge, Metropolitan maintains a program to periodically reassess the seismic vulnerability of its facilities. The most recent evaluation of the seismic vulnerability of the CRA assessed the potential vertical and horizontal surface deformation that could occur from a Magnitude 7.8 earthquake on the San Andreas Fault, and the potential impacts of this deformation on the CRA. This paper will present Metropolitan's strategy for improving the seismic reliability of the CRA, along with steps being taken to mitigate the potential impacts of a large earthquake on the aqueduct.

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INTRODUCTION

The Metropolitan Water District of Southern California is a consortium of 26 cities and local water agencies that provides drinking water to 18 million people over a 13,470 square kilometer (km) (5,200 square mile) service area within Los Angeles, Orange, Ventura, Riverside, San Bernardino, and San Diego Counties. On average, Metropolitan delivers 6.4 million cubic meters (1.7 billion gallons) of water per day to its customers. Metropolitan owns, operates, and maintains five conventional water treatment plants, nine pumping plants, 15 hydroelectric plants, 33 dams and reservoirs, over 1,335 km (830 miles) of large diameter pipelines and tunnels up to 6.25 m (20.5 feet) in diameter, and the 390 km (242 mile) Colorado River Aqueduct (CRA).

Metropolitan imports Colorado River water from the border of California and Arizona into coastal Southern California via the CRA. Metropolitan also imports water from Northern California, which is conveyed through the California Department of Water Resources' (DWRs) California Aqueduct. In an average year, these two conveyance facilities supply 50 percent of the water used within Southern California.

Metropolitan's service area is crossed by a number of known faults with varying degrees of activity. The major imported water conveyance systems into Southern California and the major regional faults are shown in Figure 1. The recently released Uniform California Earthquake Rupture Hazard Forecast (UCERF) [1] estimates a 93 percent likelihood of a magnitude (M) 6.7 or greater earthquake occurring within Southern California within the next 30 years. Specifically for the Southern San Andreas Fault, which is crossed by all of the water conveyance facilities into the region, UCERF estimates a 19 percent likelihood of a M 6.7 or greater earthquake within 30 years.

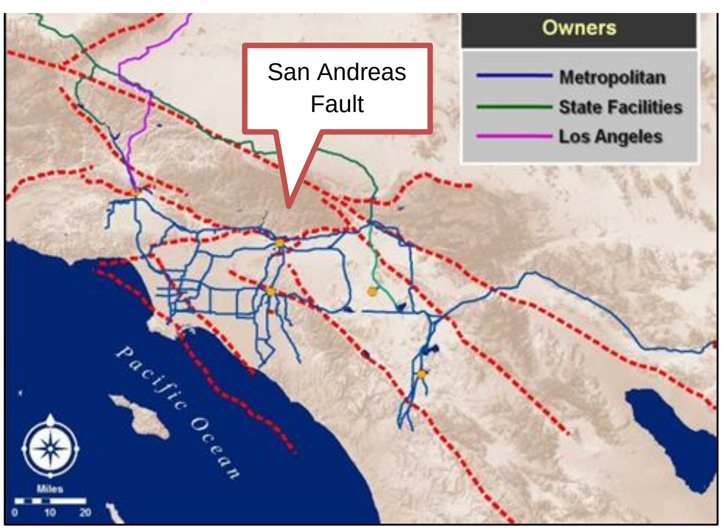
As a regional provider of drinking water, Metropolitan recognizes the importance of continued water deliveries following a major seismic event. Water will be a vital resource for both general welfare and fire suppression. This paper will provide an overview of Metropolitan's approach to ensuring reliable deliveries and mitigating potential impacts from a seismic event, focusing specifically on the CRA and a recent vulnerability study that assessed potential impacts to the CRA from a large earthquake on the Southern San Andreas Fault.

COMPREHENSIVE RELIABILITY STRATEGY

Metropolitan has developed a comprehensive approach to system reliability through a collaborative effort with its 26 member agencies. The strategy was first developed as an element of the Integrated Area Study, which aims to maximize the coordination between Metropolitan and its member agencies to meet the region's future water supply needs. System reliability has five principal components:

- Water Supply Reliability – the ability to obtain water to meet member agency demands under all foreseeable hydrologic conditions.
- System Capacity – the ability to convey, treat, and distribute supplies to meet firm demands under peak conditions.

Figure 1: Regional Faults within Metropolitan's Service Area in Southern California



- Infrastructure Reliability – the ability to maintain facilities in a state of readiness to make water deliveries.
- System Flexibility – the ability to respond to short-term changes in water supply, water demands, and water quality; and the ability to meet member agency needs during planned outages.
- Emergency Response – the ability to respond to unplanned outages and restore service quickly.

Metropolitan's strategy to ensure the reliability of its conveyance facilities and distribution system following an earthquake is carried out through actions taken under the Infrastructure Reliability, System Flexibility, and Emergency Response functions. Following are descriptions of these three functions.

Comprehensive Reliability - Infrastructure Reliability Component

Seismic preparedness activities under the Infrastructure Reliability function include Metropolitan's long-term Seismic Upgrade Program and periodic Vulnerability Assessments.

Seismic Upgrade Program. For over 25 years, Metropolitan has maintained a Seismic Upgrade Program to harden its above-ground facilities against potential earthquake damage. Metropolitan's system was constructed over a period of 80 years in conformance with then-current building codes. Over time, building codes have evolved as engineering capabilities and the industry's knowledge of earthquake hazards have advanced. The goal of the Seismic Upgrade Program is to maintain water deliveries immediately following a code-level earthquake.

The Seismic Upgrade Program utilizes a systematic approach to identify and prioritize facilities in need of seismic retrofit. In California, buildings constructed in the 1990's or later are generally considered to have reasonable assurance of withstanding a code-level earthquake without catastrophic structural failure. As a result, the Seismic Upgrade Program focuses on Metropolitan facilities constructed prior to 1990. Facilities are divided into three groups – 1) those related to water delivery, 2) those not related to water delivery but which are essential to Metropolitan's business operation, and 3) those that do not fall within the first two groups. Facilities within the first group receive the highest priority for evaluation.

To date, Metropolitan has invested over $230 million to enhance the seismic performance of its existing facilities, including $135 million at its five regional treatment plants. All facilities related to water delivery have been evaluated, and the identified upgrades have either been completed or are currently underway.

Vulnerability Assessments. Metropolitan conducts vulnerability assessments to identify potential impacts to its ability to deliver water following various postulated hazards including large seismic events. Vulnerability studies can focus on individual facilities (i.e. treatment plants) or assess the system as a whole. The findings of vulnerability studies can lead to new operation and maintenance procedures, new design guidelines, new projects within Metropolitan's Capital Improvement Program, or can provide guidance for emergency response planning. One example of a vulnerability study is the recently completed CRA Seismic Assessment, which will be detailed later in this paper.

Comprehensive Reliability - System Flexibility Component

As Metropolitan has expanded its distribution system over the decades, it has incorporated both flexibility and redundancy to allow for temporary shutdown of facilities and pipelines with minimal impact to its member agencies. This flexibility and redundancy will be vital for Metropolitan to maintain water deliveries following a seismic event.

As stated previously, Metropolitan imports water from multiple areas within California for treatment and distribution into its service area. Water from Northern California can supply all five of Metropolitan's regional water treatment plants and therefore reach the entire distribution system. With recent upgrades to this distribution system, CRA water can now supply most of the service area. These modifications have helped Metropolitan meet member agency needs during the current long-term drought in the American West.

The concept of system flexibility has also been promoted between Metropolitan's member agencies. These agencies are encouraged to develop interconnections between systems, and to ensure that they have adequate local back-up supplies. One of Metropolitan's core strategies is to help member agencies develop these local supplies. As a minimum, member agencies are required to maintain seven days of storage for temporary shutdowns and emergency repairs.

Comprehensive Reliability - Emergency Response Component

Metropolitan's Emergency Response Program focuses on maintaining the capability to execute multiple simultaneous repairs, conducting emergency planning and training events, and maintaining storage of emergency water supplies.

Repair Capabilities. Metropolitan has protocols to inspect and monitor its conveyance facilities and distribution system, and to distribute resources following a major seismic event. The repair response will depend on a number of factors including the extent of damage and repairs needed, the back-up capabilities of member agencies, and the immediate delivery benefits provided by individual repairs. To execute urgent repairs, Metropolitan would first rely on its own construction forces and utilize its existing supply of materials and heavy equipment. If necessary, Metropolitan would then turn to its existing construction contracts. As a standard provision in all of its construction contracts, Metropolitan retains the ability to mobilize contractors to perform emergency work on an as-needed basis. In addition, Metropolitan maintains a list of prequalified contractors for emergency repairs. Lastly, Metropolitan maintains mutual aid and mutual assistance agreements with state and local agencies to share available resources during emergencies.

In addition to its construction forces, Metropolitan owns and operates its own machining, fabrication, and coating shops located centrally within the distribution system. These shops have the ability to respond on short notice to either Metropolitan's or its member agencies' emergency needs. Metropolitan recently invested $40 million to upgrade manufacturing equipment and seismically strengthen and expand this facility, and plans to invest $10 million to purchase additional equipment. The investments in these shops allow Metropolitan to fabricate large-diameter pipe to repair at least two simultaneous pipeline breaks utilizing in-house capabilities.

Emergency Response Planning and Training Events. To prepare for major earthquakes, Metropolitan has developed an Emergency Response Plan which documents the assessment and reporting guidelines following a seismic event, and identifies the structural hierarchy of the response teams and their responsibilities. The Emergency Response Plan specifies the level of seismic event for which emergency response activation is required, based on the magnitude and proximity of an earthquake to conveyance and distribution facilities.

In addition to the Emergency Response Plan, Metropolitan conducts annual emergency response exercises to evaluate the plan's effectiveness, train staff, and identify potential areas for improvement. The exercises can be either table-top, in which a response to an emergency scenario is talked through, or a more elaborate simulated event in which Metropolitan's various emergency operation centers (EOCs) are activated. For these simulated exercises, the EOCs must coordinate amongst each other as damage information is submitted by Damage Assessment Teams. Metropolitan encourages member agencies and State of California representatives to participate in the simulations.

Emergency Storage. Metropolitan has long recognized the potential for a major earthquake to occur on the Southern San Andreas Fault System (SSAFS), which may interrupt deliveries from the CRA. In 2000, Metropolitan completed construction of Diamond Valley Lake (DVL), which is Southern California's largest surface water reservoir. DVL was constructed on the coastal side of the SSAFS and the San Jacinto Fault Zone (SJFZ) in order to supply the region in case CRA deliveries are interrupted. Water stored in DVL can directly supply four out of Metropolitan's five water treatment plants. With the completion of DVL, Metropolitan nearly doubled the available surface water storage in the region. In conjunction with local production and conservation, DVL and other local reservoirs can provide the region with six months of emergency water supply.

COLORADO RIVER AQUEDUCT SEISMIC ASSESSMENT AND MITIGATION

The CRA conveys water from the Colorado River across the California desert to Lake Mathews in Riverside County. As noted above, Metropolitan recognizes the potential for water deliveries from the CRA to be disrupted by a major earthquake on the SSAFS or the SJFZ. During the original design and construction of the CRA in the 1930s, Metropolitan engineers incorporated measures to mitigate potential impacts from surface displacement due to an earthquake on the SSAFS or SJFZ. These measures included: providing 2.3 meters (7.5 feet) of additional head (allowable loss) in the hydraulic profile of the aqueduct as it crosses the SSAFS zone; utilizing inverted siphons or shallow conduits for crossing identified active traces of the fault, in order to make damaged areas more accessible; and utilizing segmented conduit sections rather than typical monolithic construction to reduce potential damage from displacements [2][3]. Recent advancements in earthquake engineering and design, and increased knowledge regarding geology and seismicity within Southern California, have prompted Metropolitan to periodically reassess the seismic vulnerability of the CRA and its related facilities, and the potential impacts to CRA deliveries from a major earthquake.

Seismic Upgrade of CRA Facilities

Upgrades to CRA facilities to date have largely focused on the five aqueduct pumping plants. Upgrades completed at these facilities include seismic strengthening of the pump buildings, the discharge pipelines from the pumping plants, electrical switch houses, and various appurtenant structures. Figure 2 shows the Hinds Pumping Plant's main building after completion of the structural upgrades. Buttresses were added to withstand the out-of-plane seismic loading, and to minimize deflection.

In addition to seismically upgrading the pumping plants, Metropolitan constructed a new outlet tower for the Lake Mathews Reservoir, which is the terminus of the CRA. The original tower was constructed in 1940, and the seismic evaluation found it to be deficient. Figure 3 shows the original Lake Mathews outlet tower and the new outlet tower that was completed in 2003.

Figure 2: Seismic Upgrade of CRA Pumping Plant

Figure 3: Original and New Lake Mathews Outlet Towers

Colorado River Aqueduct Seismic Vulnerability Study

The CRA crosses the SSAFS in an area known as the San Gorgonio Pass. In recent years, there has been a significant increase in knowledge regarding the structure of the SSAFS within the San Gorgonio Pass. As a result, Metropolitan recently conducted new vulnerability studies of the CRA to reassess the risk and nature of a potential rupture of the San Andreas Fault, and to reexamine previous assumptions about damage to the CRA and potential delivery impacts. The recently completed CRA Seismic Vulnerability Study was conducted in two phases. The first phase of the study modeled potential displacements from a rupture of the San Andreas Fault using the United States Geological Survey's Coulomb 3.3 software [4]. The second phase applied the results of the model to the CRA to determine potential damage and service impacts.

Phase 1 - Modeling of the SSAFS within the San Gorgonio Pass. The San Gorgonio Pass area is the most complex portion of the SSAFS and has been the least understood. Outside of the pass, the SSAFS is a northwest trending, right-lateral strike-slip fault. Within the pass, the San Andreas Fault bifurcates into northern and southern branches of discontinuous fault segments as shown in Figure 4. The bifurcation creates a leftward stepover of the fault. The south-eastward movement of the North American Plate and the north-westward movement of the Pacific Plate compress the area within the San Gorgonio Pass, forming a zone of transpression (Figure 5). A rupture of the SSAFS through this zone of transpression can cause broad regional uplift. This uplift is potentially significant because the water flows by gravity through the CRA in a westerly direction downstream of the Hinds Pumping Plant toward Lake Mathews. Consequently, broad regional uplift within the San Gorgonio Pass could have implications on the hydraulic capacity of the CRA. To evaluate the potential horizontal and vertical deformation that may occur from a rupture of the San Andreas Fault and the impact to the CRA, Metropolitan initiated the Colorado River Aqueduct San Gorgonio Pass Seismic Event Vulnerability Study (SEVS) [5]. The study was led by a team of geoscientists experienced in assessing the potential for fault displacements along the SSAFS in the San Gorgonio Pass area, and was presented by GeoPentech, Inc. Using recently available data, estimates for post-seismic event ground deformation were developed following a five-step approach.

Step 1 – Analysis and Integration of Geologic, Seismologic, and Geodetic Data – The SEVS incorporated the most recent information available relating to the seismicity of the area including: geology, tectonics, paleoseismology, seismicity, and geodesy.

Figure 4: CRA Crossing of Southern San Andreas Fault System and San Jacinto Fault Zone

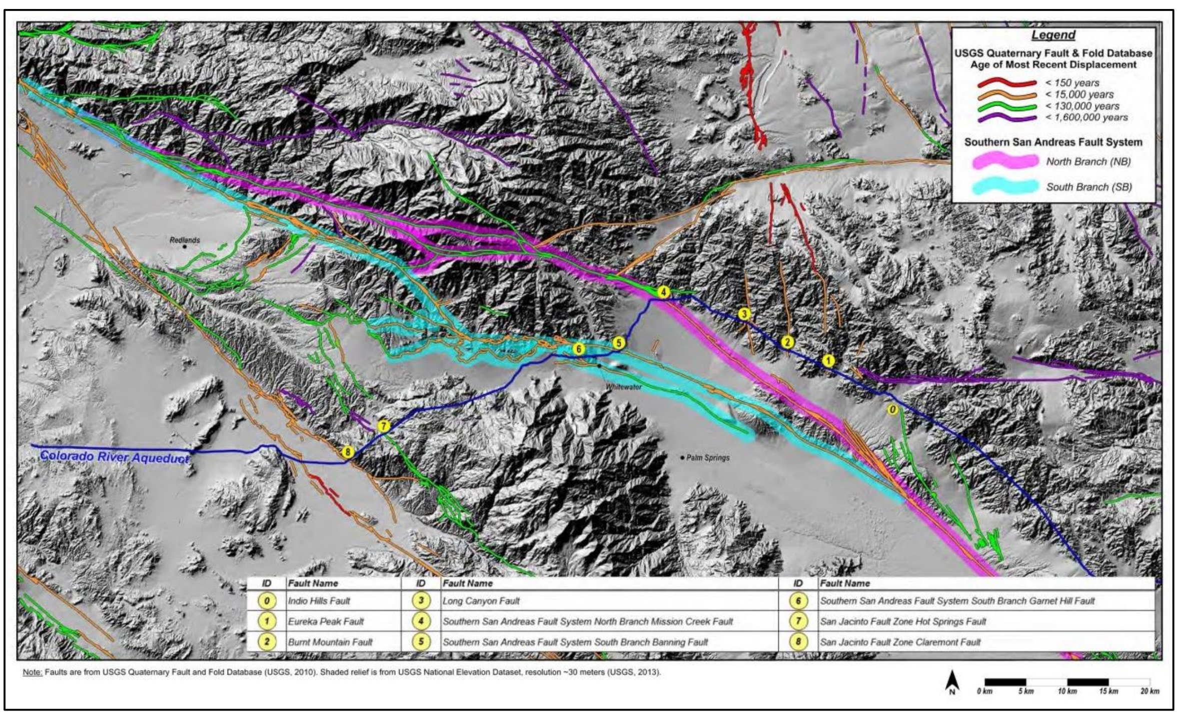
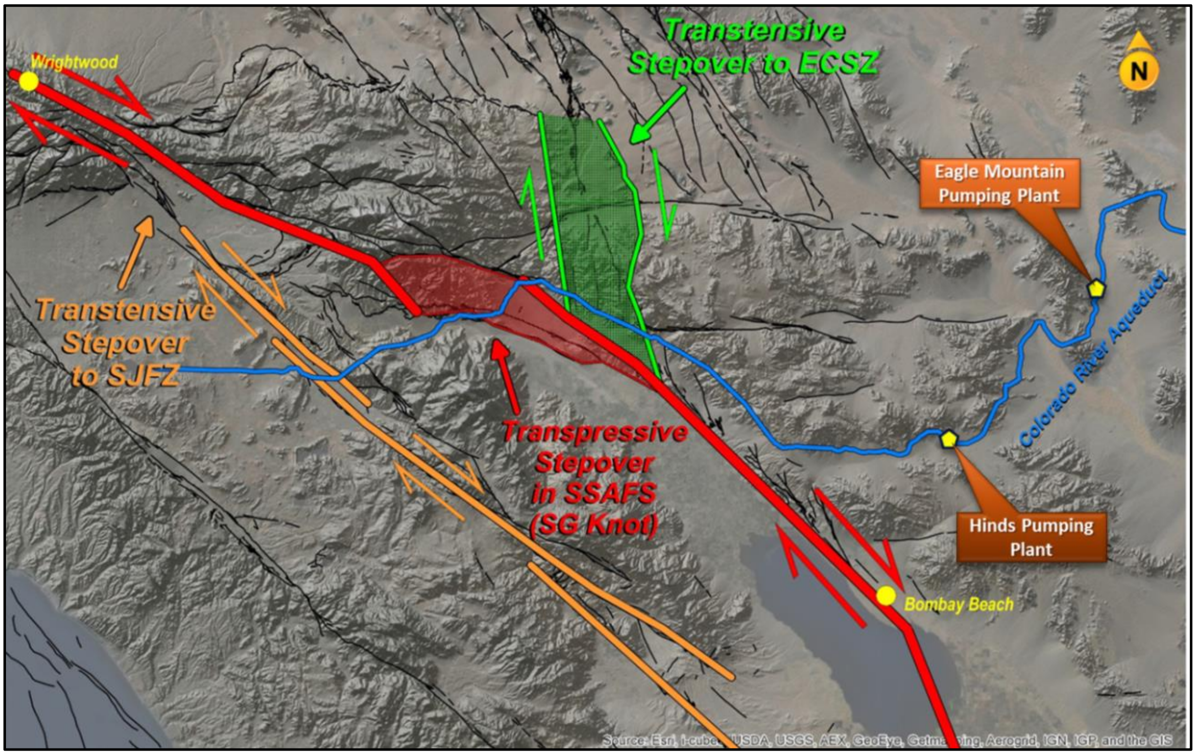


Figure 5: Southern San Andreas Fault System Directional Motion Showing Zone of Transpression



Step 2 – Three Dimension Construction of San Gorgonio Pass Subsurface Geometry **–** The second step in the modeling process was to incorporate the information gathered from Step 1 and develop a three-dimensional (3D) graphical representation of the subsurface geometry of the faults beneath the San Gorgonio Pass area.

Step 3 – Configuration of the Deformation Model **–** Step 3 involved building a model for the Coulomb 3.3 software based on the final 3D graphical representation.

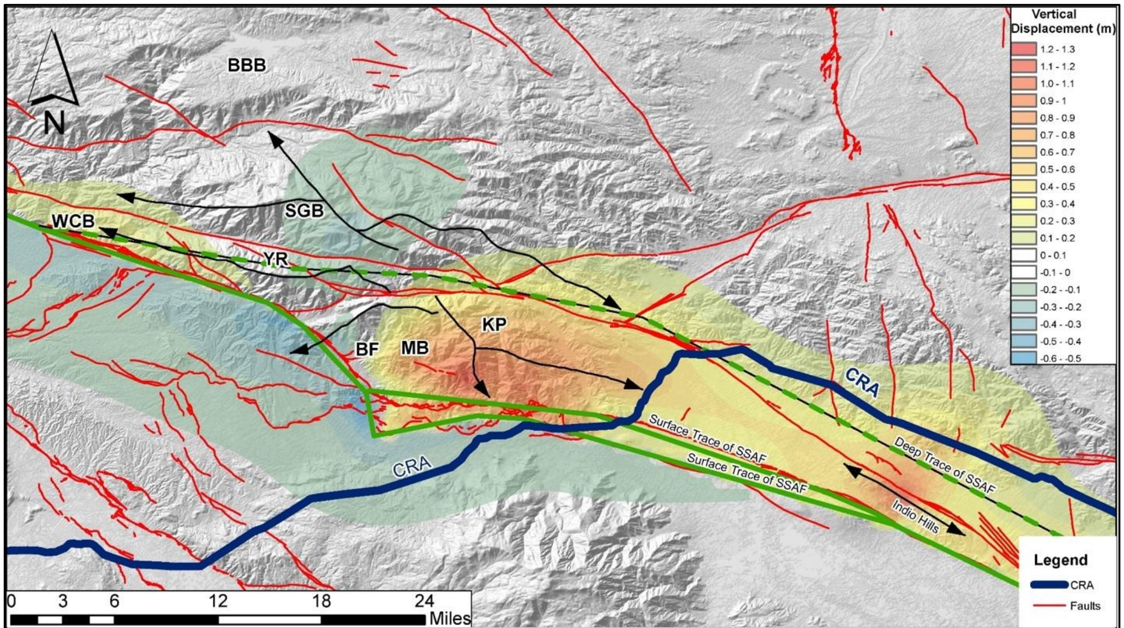
Step 4 – Model Runs for Three Earthquake Scenarios **–** While the focus for this study was to determine impacts to the CRA from the Maximum Considered Earthquake (M_W 7.8) on the SSAFS, three earthquake scenarios were identified in order to bracket the results. The study included the following model scenarios:

- Scenario 1 – Approximately 1 m (3 feet) of slip at and above 12 km (7.5 miles) in depth, tapering to no slip at the surface, representative of a M_W6 to M_W6.5 event with an estimated recurrence of several decades, similar to a North Palm Springs type event.
- Scenario 2 – Approximately 4 m (13.1 feet) of right lateral strike-slip at and above 12 km (7.5 miles) in depth, representative of a M_W7 to M_W7.8 event with an estimated return period of 500 to 1,000 years.
- Scenario 3 - Approximately 8 m (26.2 feet) of right lateral strike-slip at and above 25 km (15.5 miles) in depth, representative of a M_W8.5 event with an estimated return period of greater than 5,000 years.

Scenario 3 was considered improbable by the team of geoscientists due to geologic complexities within the San Gorgonio Pass and magnitude/displacement scaling relationships for 8 m (26.2 feet) of average displacement.

Step 5 – Critical Review and Documentation of Results **–** The results of the model were compared against specific geologic, geomorphic, and paleoseismic data from the San Gorgonio Pass Area. In Figure 6, the results from the Coulomb 3.3 model of vertical deformation for Scenario 2, M_W7-M_W7.8, are superimposed on a map showing geomorphic expressions within the San Gorgonio Pass. The black arrows were taken from a study by Yule and Seih [6] and approximate the broad, regional flexure associated with crustal shortening at and near the stepover. The

Figure 6: Comparison of Coulomb 3.3 Model Results for Scenario 2 and Existing Geomorphology



COMPARISON OF COULOMB 3.3 MODEL 4-METER & 12-KILOMETER (UP TO MW ~7.8) SCENARIO VERTICAL DEFORMATION RESULTS WITH GEOMORPHOLOGY

arrows point down-gradient. There is a strong correlation between the model results and the existing geomorphology. The greatest model uplift coincides with the location of Kitching Peak, which is approximately 1,200 meters (4,000 feet) higher than the eastern arrow tip touching the CRA.

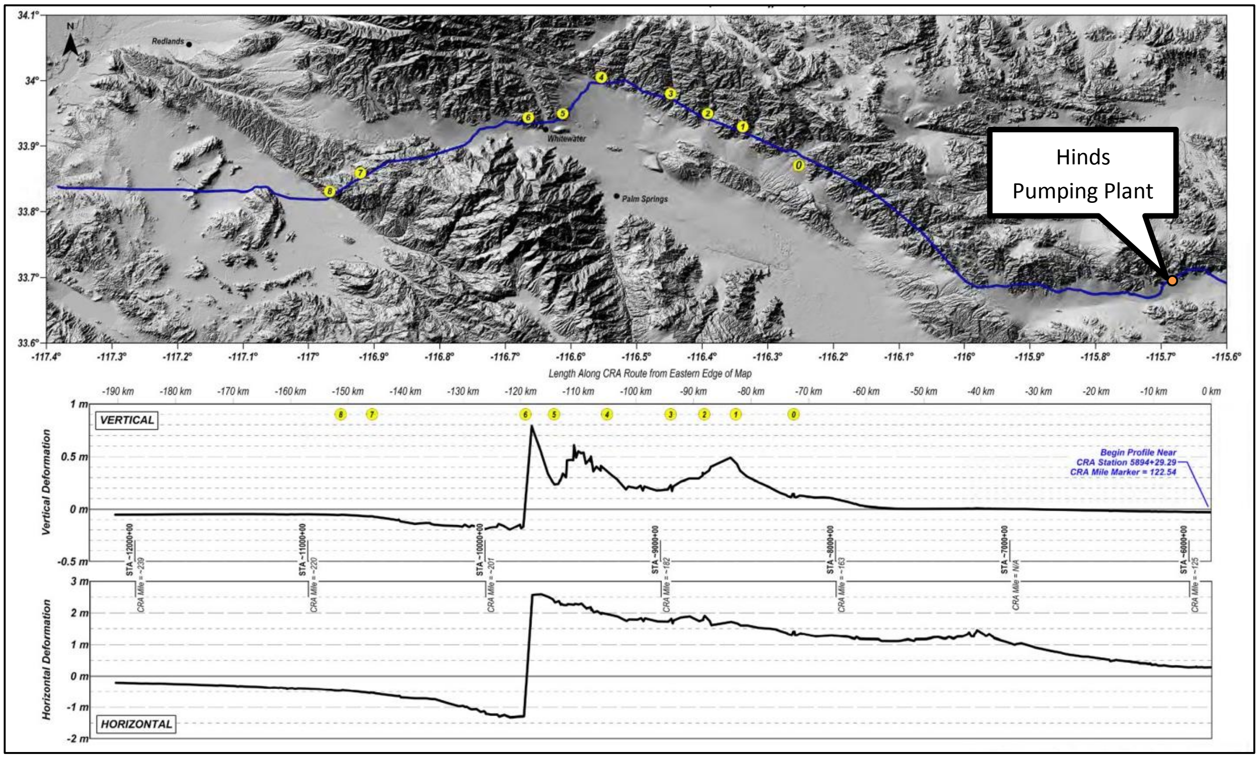
Phase 2 - Application of Coulomb 3.3 Model Results. The second phase of the CRA Seismic Vulnerability Study applied the modeled deformation results to the CRA. Figure 7 shows the change in the horizontal and vertical profiles of the CRA due to the modeled Scenario 2 event, M_W7-$M_W7.8$, on the SSAFS. At the crossing of the Garnett Hills fault and the CRA, the model results identified a 3.75 meter (12 feet) horizontal and 1 meter (3 feet) vertical gross displacement. Focusing specifically on vertical displacement, the CRA experiences uplift over an approximate 60 kilometer (37 mile) distance with three distinct peaks. The highest and most westerly peak is located at the crossing of the CRA and the Garnett Hills Fault, and is 0.8 meters (2.6 feet) above the baseline CRA elevation. This information was used to assess hydraulic impacts to the CRA as well as the potential repair time following the postulated earthquake.

CRA Hydraulic Impact Analysis – The CRA has a design flowrate of 45,450 Liters per second (lps) [1,605 cubic feet per second (cfs)]. The CRA's five pumping plants, all of which are located east of the SSAFS, are capable of lifting the aqueduct's design flowrate a combined height of 493 meters (1,617 feet). As stated previously, water discharged from the Hinds Pumping Plant flows by gravity through the San Gorgonio Pass area to the remainder of Metropolitan's system. Uplift of the CRA would have the effect of reducing the water delivery capa- city of the aqueduct.

Metropolitan conducted the CRA Hydraulic Impact Analysis [7] to determine the extent of flow reduction resulting from the Scenario 2 modeled uplift, which approximates the MCE for the SSAFS. The hydraulic analysis utilized a smoothed version of the vertical displacement profile of the CRA shown in Figure 7 in order to determine the loss in capacity. The original design roughness coefficient was applied to the various aqueduct components (i.e. tunnel, siphon, or covered canal) and the emergency repairs were assumed to maintain the original component cross-sections. The analysis also maintained the original design freeboard, retaining the original intent of non-pressurized free-water-surface flow.

The result of the hydraulic impact analysis indicated that the capacity of the CRA would be reduced to 36,800 lps (1,300 cfs) – an approximate 20% reduction. This result shows that despite the uplift, Metropolitan would be able to

Figure 7: Deformation Profile of Colorado River Aqueduct for Scenario 2 San Andreas Fault Rupture Event (Mw 7 to Mw7.8)

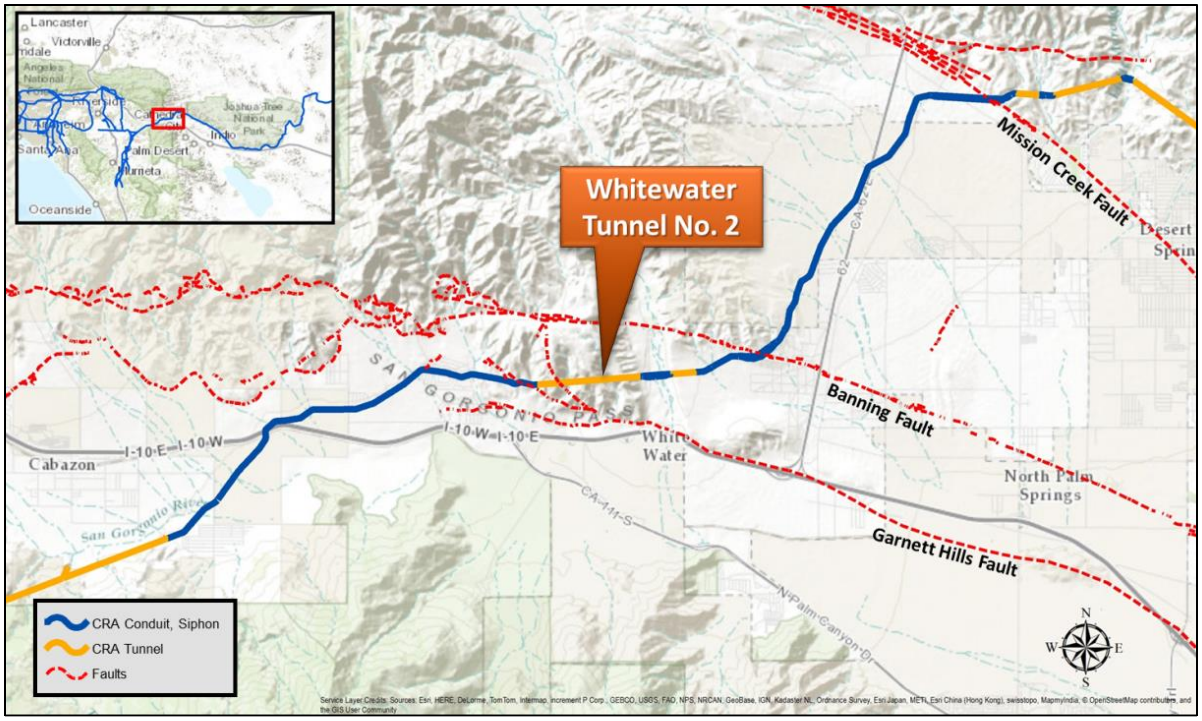


convey significant amounts of water through the CRA following any initial repairs required to re-establish service. Thus, Metropolitan could continue to supply the Southern California region with water from the Colorado River while long-term repairs to restore the original design flow are planned and executed. Long-term repairs would take advantage of the available head in the CRA's hydraulic profile to compensate for uplift resulting from the earthquake.*Estimation of Potential Damage and Repair Times* **–** The next step was to determine the potential damage that could occur to the CRA from the modeled seismic event. Figure 8 shows the location of the CRA relative to various fault segments within the San Gorgonio Pass. The CRA was designed to cross the Mission Creek and Banning Faults perpendicular and in shallow, readily accessible conduits. The CRA parallels the main strand of the Garnett Hills Fault on the hanging-wall side of the fault. The Garnett Hills Fault has one hanging-wall splay fault that crosses downstream of the Whitewater Tunnel No. 2. An additional hanging-wall fault, alternatively mapped as a fold by Yule and Seih [6], crosses through the Whitewater Tunnel No. 2 upstream of its west portal. From the SEVS study, the likely path for a continuous rupture of the SSAFS through the San Gorgonio Pass is the Garnett Hills Fault segment, which is the most recently active strand. However, the Coulomb 3.3 model is not precise enough, and there is insufficient information available, to determine how the displacement would be distributed among the main fault trace and its splay faults.

Given the location of the Garnett Hills Fault's hanging-wall splay or fold within the Whitewater Tunnel No. 2, the specialized nature of tunnel repair, and the access challenges of repairing a tunnel compared to a siphon or conduit, it was assumed for planning purposes that the worst-case scenario would be for the primary fault rupture to occur on the Garnett Hills Fault's hanging-wall splay or fold within the Whitewater Tunnel No. 2. It was also assumed that repair of the Whitewater Tunnel No. 2 would be the critical path to restoring deliveries from the CRA.

Additional research was conducted to determine the type of damage that might occur within a tunnel from different seismic hazards (i.e. shaking, ground failure, fault rupture). Previous studies have shown that tunnels perform well during earthquake shaking when compared to above-ground structures [8][9][10]. Much of the heavy damage to tunnels from earthquake hazards is attributable to heavy shaking in areas of shallow overburden (i.e. near portals) or

Figure 8: CRA Southern San Andreas Fault System Crossings in the San Gorgonio Pass



ground failure (i.e. landslide or liquefaction)[9][11]. In addition to damage that may occur near the portals, the high levels of shaking during the earthquake could result in minor-to-moderate cracking or spalling of the tunnel liner.

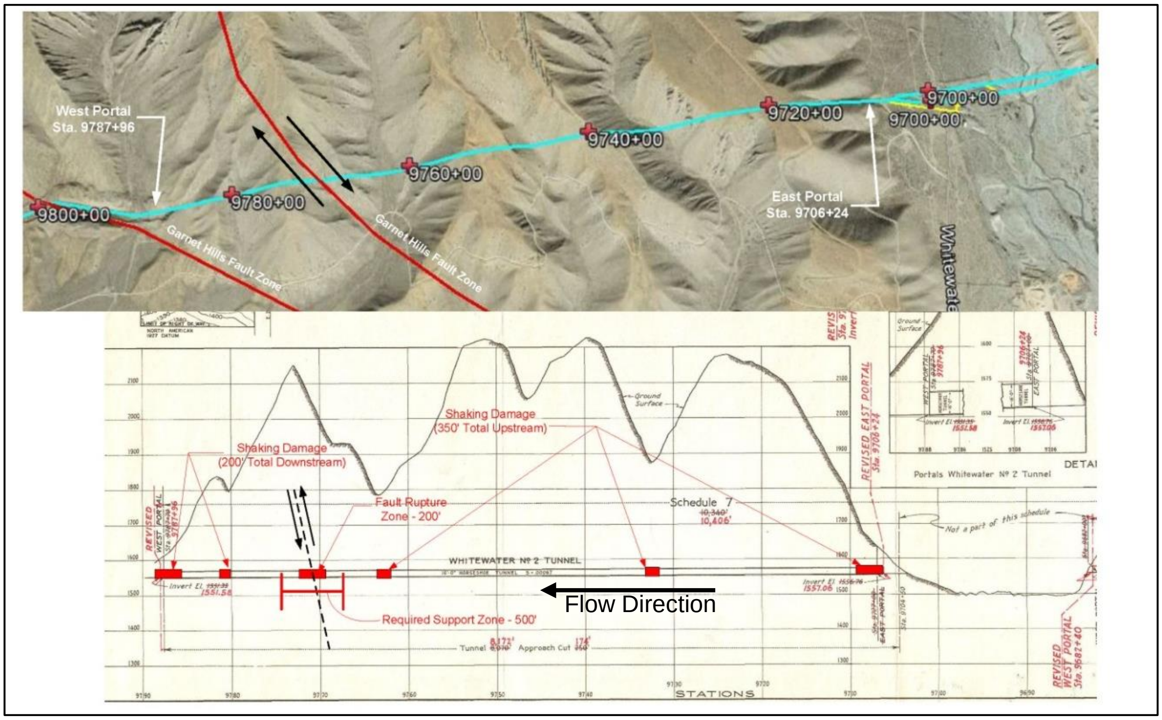
A Tunnel Repair Workshop was conducted [12] to identify realistic repair requirements and to estimate times to re-establish service. The Tunnel Repair Workshop was conducted by a team with expertise in geology, tunnel engineering, tunnel construction and repair, and hydraulics. Workshop participants received a detailed presentation of the Whitewater Tunnel No. 2 construction and geology, and were provided a damage scenario as shown in Figure 9.

The damage scenario assumed the tunnel experienced the full 3.75 meter (12 feet) horizontal and 1 meter (3 feet) vertical displacement on the Garnet Hill Fault from the Coulomb 3.3 model results. The scenario also assumed that displacement at the rupture zone collapsed the tunnel and blocked the flow of water. Additional shaking and ground failure damage was assumed to occur throughout the tunnel with major damage occurring at the portals and the shallower portions of the tunnel. In addition, the sudden blockage would cause a backup at the upstream east portal location that would wash out the access road to the portal.

Two options for repair were identified during the workshop to address the severe damage incurred at the fault rupture zone. Option 1 involved direct mining through the damaged tunnel section (i.e., through the destroyed concrete liner, steel and timber, backfill muck, etc.) to restore the original tunnel. Option 2 would construct a new bypass tunnel around the rupture zone. Due to the uncertainty in mining rate caused by the range of materials encountered and safety issues under Option 1, the team concluded that Option 2 would be the preferred option.

For the damage scenario under Option 2, the tunnel contractors were confident that repairs to the Whitewater Tunnel No. 2 could be completed within a 6-month period. However, they stressed the benefits of pre-planning the repair activities including prequalification of tunnel repair contractors, stockpiling of steel sets for support of damaged tunnel areas to facilitate rapid inspection and repair, and completion of design in advance for a junction structure between the existing tunnel and the new bypass tunnel. The conclusion of the tunnel repair workshop regarding the time to re-establish service was consistent with previous estimates of repair times used for planning purposes.

Figure 9: Whitewater Tunnel No. 2 Rupture Damage Scenario



CONCLUSION

Metropolitan's strategy to ensure reliability of its conveyance facilities and distribution system in the event of a major earthquake includes the hardening of essential facilities; continual reassessment of the system as new research and data become available; conducting emergency response exercises and planning; maintaining the capability to perform emergency repairs; and maintaining stockpiles of key supplies and equipment. For the CRA, Metropolitan has completed seismic upgrades to key structures at its pumping plants and has constructed a new outlet tower for the Lake Mathews Reservoir. These upgrades will enable specific essential CRA facilities to better withstand a major earthquake.

The recently conducted SEVS identified the potential surface deformation that could result from the MCE on the SSAFS, and the potential impact to CRA deliveries. A rupture of the Garnett Hills Fault's splay fault or fold located within the Whitewater Tunnel No. 2 could severely damage the tunnel, and while unlikely, could result in a 3.75 meter (12 feet) horizontal and 1 meter (3 feet) vertical offset within the tunnel. In addition to the localized damage within the tunnel at the fault crossing, the earthquake could cause a regional uplift within the San Gorgonio Pass area and along a 60 kilometer (35 mile) stretch of the CRA that would reduce the flow capacity of the CRA by approximately 20%.

With adequate pre-event planning, localized damage to the CRA could be repaired within six months. While the initial repairs are underway, Metropolitan would continue to supply the Southern California region with water from emergency supplies that it holds in local reservoirs such as Diamond Valley Lake. Following completion of the initial localized repairs to the CRA, Metropolitan could continue to supply a significant amount of water to the region from the CRA while long-term repairs to restore the aqueduct's original design flow are planned and executed.

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