REPORT

SEISMIC RESILIENCE WATER SUPPLY TASK FORCE

MARCH 30, 2016 AQUEDUCT WORKSHOP AND FIVE-YEAR ACTION PLAN

The Metropolitan Water District of Southern California
700 N. Alameda Street, Los Angeles, California 90012

Report No. 1536
June 2017

Prepared By:
This document was prepared by the Seismic Resilience Water Supply Task Force (SRWSTF) and technical writing assistance was provided by Ray DeWinter and Tiffany White.

Additional Copies or Changes*:*
This document is located on the SRWSTF SharePoint site and is available from the SRWSTF members.

SRWSTF Members

Clark, David (Metropolitan)	LeCocq, Phil (DWR)
Davis, Craig (LADWP)	Rennie, Dave (DWR)
Grahek, Mike (LADWP)	Rojas, Mike (Metropolitan)

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EXECUTIVE SUMMARY

On March 30, 2016, the Seismic Resilience Water Supply Task Force (SRWSTF) held an Aqueduct Workshop at The Metropolitan Water District of Southern California (Metropolitan) Headquarters in Los Angeles, California. The purpose of this Workshop was to discuss potential damages to Southern California's imported water aqueducts from a major seismic event on the San Andreas Fault (SAF).

For this Workshop, the Great Southern California ShakeOut Scenario (ShakeOut) of a M 7.8 earthquake, developed by the U.S. Geological Survey (USGS) and many partners, was assumed for all damage assessments. The Workshop included representatives from Metropolitan, the Los Angeles Department of Water and Power (LADWP) and the California Department of Water Resources (DWR). The Workshop format allowed for a candid exchange of information and ideas between staff from the three agencies along with LADWP's Seismic Resilience and Sustainability Program's Expert Panel.

The results of this collaborative workshop are presented in this report. The findings and recommendations are significant for two reasons. First, they clearly provide justification for the three regional water agencies to continue working together to improve the seismic resilience of the region's imported water systems. Second, the Workshop helped build a meaningful consensus regarding specific future actions to better prepare the region for large seismic events on the SAF.

Participants were asked to consider preparation for, and response to, the ShakeOut Scenario from a regional perspective. Specifically, participants were asked, "If all aqueducts were owned and operated by a single agency, then what steps should be taken now to mitigate potential damage and what would the priority of repairs be following a major seismic event to most rapidly restore imported water deliveries to the region?" This focus on actions that would best serve the region, led to productive discussions and practical recommendations for the three agencies to improve the resilience of imported water supplies.

The assembled team concluded that for a M 7.8 ShakeOut Scenario event on the southern portion of the SAF, the recovery times would exceed historic planning assumptions:

- Restoration of full aqueduct capacities could take more than six months
- Restoration of partial aqueduct flows could take at least two months

When considering this specific scenario from a regional perspective, the participants concluded that residents within Metropolitan's service area would be best served if the three agencies:

- Implement recently identified mitigation projects on the Colorado River Aqueduct (CRA) and Los Angeles Aqueduct (LAA)
- Prioritize known vulnerabilities on the CRA, LAA and the State Water Project (SWP)
- Execute an agreement to allow for a coordinated response to emergency events
- Share resources when responding to emergency events
- Focus initial repair efforts on the SWP's West Branch and the CRA*

(*This is based on a ShakeOut-type event; it is recognized DWR will also have a priority to serve other customers on the East Branch.)

LADWP's Resilience Program's Expert Panel noted the significance of the nation's largest municipal utility, largest water wholesaler, and largest state-owned water agency joining together to address a major hazard for the first time and encouraged the SRWSTF to continue working together long into the future. The assembled team agreed that Southern California could become better prepared for seismic events and that the SRWSTF should continue to facilitate coordinated vulnerability assessments, evaluate mitigation options, and develop agreements that allow coordinated emergency responses to major seismic events. It was clear that common issues could be studied more efficiently together and there was a consensus for the SRWSTF to continue to maintain the momentum achieved through this Workshop. Although the challenge this region faces in achieving a greater level of seismic resilience is significant, the consensus was that it would be achievable through the continued, dedicated efforts of the SRWSTF.

The long-term SRWSTF strategy developed after the Workshop involves continuing bi-monthly meetings and initiating a repeating 5-year cycle of planning, executing, and reporting of collaborative activities and accomplishments. This approach will ensure effective management of long range actions and stability of the SRWSTF. The first three cycles are summarized below. This Aqueduct Workshop report initiates the first 5-year cycle.

Cycle 1 (March 2017)	Document progress achieved during 2016 Set goals for April 2017 – March 2022
Cycle 2 (March 2022)	Document progress achieved during 2017-2021 Set goals for April 2022 – March 2027
Cycle 3 (March 2027)	Document progress achieved during 2022-2026 Set goals for April 2027 – March 2032

Each successive 5-year plan will include documenting progress achieved during the previous cycle, setting common goals for the task force, and communicating related agency-specific goals. This strategy will maintain open communication between agencies, assure action is taken to resolve issues identified at the 2016 workshop, facilitate the coordination of emergency response efforts, and help identify and resolve other seismic resilience issues in a collaborative manner.

INTRODUCTION

This report documents the March 30, 2016 Aqueduct Workshop held at The Metropolitan Water District of Southern California (Metropolitan) Headquarters in Los Angeles, California and the resulting 5-year action plan developed by the Seismic Resilience Water Supply Task Force (SRWSTF). The structure of the SRWSTF and members are provided in Appendix 1 and the Workshop goals and objectives are presented in Appendix 2.

The purpose of the Workshop was to discuss potential aqueduct damages, restoration timelines, and regional priorities for the Great Southern California ShakeOut (ShakeOut) Scenario M 7.8 earthquake on the Southern San Andreas Fault (SAF) System that would impact the Colorado River Aqueduct (CRA), the State Water Project (SWP), and the Los Angeles Aqueduct (LAA) systems. The 5-year action plan sets the course for how the SRWSTF will continue working to increase the region's seismic resilience of its imported water systems.

The Workshop was moderated by Mr. Michael Thomas (Metropolitan), and the agenda was designed to provide an effective and flexible forum for the exchange of ideas between staff from Metropolitan, the Los Angeles Department of Water and Power (LADWP), and the California Department of Water Resources (DWR). The Workshop agenda is provided in Appendix 3 and a list of the Workshop attendees and their affiliations is provided in Appendix 4 at the end of this report. The presentations from the Workshop are contained in Appendix 5.

This report contains summaries of the presentations and discussions in order to briefly capture the broad content of the talks and resulting discussions. It also includes the presentation slides, documents shared in the Workshop, and documents developed to capture the key workshop findings and recommendations. This report also includes a 5-year action plan to guide SRWSTF activities through March 2022. The implementation of a long-term strategy for SRWSTF activities had been a key recommendation of Workshop participants.

WORKSHOP OBJECTIVES

The Workshop objectives were to establish consensus on:

- Base timeline for restoration of partial aqueduct flows
- Timeline for restoration of full aqueduct capacities
- Regional priorities for aqueduct repairs
- Key issues to be investigated further
- Next steps for the SRWSTF

BACKGROUND

In August 2015, Metropolitan, LADWP, and DWR formed the SRWSTF for the purpose of collaborating on studies and mitigation measures aimed at improving the reliability of imported water supplies to Southern California. Specific task force goals included:

- Revisiting historical assumptions regarding potential aqueduct outages
- Establishing a common understanding about individual agency aqueduct vulnerability assessments, projected damage scenarios, and planning assumptions
- Discussing ideas for improving the resilience of Southern California's imported water supplies through multi-agency cooperation

The structure of the SRWSTF and members are provided in Appendix 1.

OPENING STATEMENTS

Following the introductions, Mr. Michael Thomas (Metropolitan) explained that the goal of this Workshop/project was to allow Metropolitan, LADWP, and DWR to share information on each agency's best understanding of their respective aqueduct performance when subjected to a San Andreas Fault earthquake. This information would then be used as a basis of common understanding for improving the resilience of Southern California's imported water supply. The focus was on the ShakeOut Scenario and it was desired to re-visit historical assumptions about how to respond to this type of event. It was understood that the agencies' initial priority was to restore customer deliveries, but the focus of the Workshop was on the aqueduct supplies.

Mr. Thomas then reviewed the agenda. He indicated the first part of the workshop would consist of presentations providing background information for the scenario damage, and the remainder of the day would entail group brainstorming. The morning session would be focused on descriptions of the regional water system; overview of the seismic impacts; agency-specific aqueduct damage assumptions; and post event recovery times. The afternoon discussions would focus on how the agencies could better prepare for and respond to a major seismic event that would damage one or more of the regional aqueduct systems.

Mr. Thomas closed his introduction by reminding the group that as a ground rule, the validity or details of the ShakeOut Scenario and that of the agency-projected damage and response times were not to be debated; the group should focus on how collaboration could help reduce either the amount of damage or the amount of time to restore partial and/or full aqueduct flow. He also noted that his role as moderator would be to keep the discussions moving forward and task-oriented. Appendix 6 identifies fixed assumptions used as a basis to direct discussion for this workshop.

REGIONAL WATER SYSTEM

Mr. Jack Safely (Metropolitan) provided an overview of Southern California's water systems. Metropolitan provides wholesale water service to 26 member agencies in a service area that covers six counties. This region contains about 19 million residents and has a $1 trillion economy. Retail water demand is about 4 million acre-feet per year and the demand is expected to grow to about 4.5 million acre-feet per year by 2040.

The region imports water (via the CRA, the SWP, and LAA) and obtains water via local supplies (groundwater, saltwater desalination, brackish groundwater desalination, and wastewater recycling). Metropolitan provides about 50% of the water supply and the remaining 50% comes from local supplies

During 2014 and 2015, Metropolitan significantly expanded its use of Colorado River water due to limited SWP supplies. This was possible due to the flexibility of Metropolitan's water system. Metropolitan's future focus will be to help expand local supplies, primarily groundwater and recycled water.

Metropolitan reserves 626,000 acre-feet of water for a catastrophic imported water supply interruption. This is stored in a number of reservoirs, including Diamond Valley Lake (DVL). For the ShakeOut Scenario study, it was assumed the storage need would be 600,000 acre-feet; retail demands would be reduced by 25% through extraordinary conservation; and imported water supply would return to normal after six months. It was noted that storage in Castaic and Pyramid lakes have implications on power agreements held by LADWP.

OVERVIEW OF SEISMIC EVENT IMPACTS

Dr. Craig Davis (LADWP) and Dr. Kenneth Hudnut (USGS) provided an overview of the impacts associated with "The Great Southern California ShakeOut Scenario."[1]

Defining Ground Motions

USGS looked at the 1906 and 1857 M 7.8 SAF earthquakes and developed a scenario for a future M 7.8 on the southern SAF called the ShakeOut Scenario. In the Coachella Valley, there is a 150 year recurrence interval for major events, but the last large event there was in 1680, more than 300 years ago. The latest work led by Dr. Kate Scharer (USGS) near Gorman shows perhaps as little as 100 year average recurrence, but time between major earthquakes can even be as short as 45 years. There has been increased paleoseismic trenching work by USGS, California Geologic Survey and Southern California Earthquake Center scientists since USGS increased the funding for this work in 2007. For ShakeOut, they modeled known information and geometry with similar earthquake ground motions observed from around the world. USGS looked at what was thought to be the most likely great and damaging SAF event and then

1 https://pubs.usgs.gov/of/2008/1150/; https://pubs.usgs.gov/circ/1324/; http://www.shakeout.org/california/scenario/; https://www.usgs.gov/media/videos/preparedness-now

simulated the ground motions for that event, thereby creating a realistic and scientifically plausible scenario.

They used a M 7.8 instead of a M 8.1, because a M 8.1 event is too rare. A “Wall-to-Wall” Bombay Beach (Salton Sea) to Parkfield full fault shift is also possible and would be greater than M 7.8, and that would be a ‘worst case’ scenario, whereas ShakeOut does not rupture that entire section of the fault. The current probability of a M 7.0 or greater earthquake in the Coachella section is higher than for any other part of the SAF and the current slip rate is 25-35 mm/year.

Over the fault area there is a “Big Bend” compression zone that induces vertical movement (as with the 1971 Sylmar and 1994 Northridge events). This compression and uplift of the Transverse Ranges has big implications for water planning due to prevalence of gravity fed systems. Surface rupture can occur in earthquakes of M 6.0 or greater, as with the 2014 Southern Napa earthquake; an earthquake that is at least a M 6.7 is likely to cause extensive damage if near an urban area. On the SAF there is a 59% probability of this occurring, and on Hayward-Rodgers Creek Fault in Northern California, a 39% probability. Surface faulting can be especially serious for lifeline infrastructure, as well as the potential for shaking damage to critical facilities.

The scale and scope of the ShakeOut Scenario was originally intended to be close to the economic impact from Hurricane Katrina. In the ShakeOut Scenario, the SAF rupture is up to 9 meters near Coachella and 3-4 meters near Los Angeles (all the way to Lake Hughes). The Trans-Alaska Pipeline was designed for, and survived, fault rupture from a M 7.9 earthquake in 2002. Many lifelines, however, were not originally designed with large amounts of fault rupture in mind.

The USGS used a single scenario. However, Ken Hudnut and the other Resilience Expert Panel members, Prof. Tom O’Rourke and Charles Scawthorn, hope that the agencies (i.e., Metropolitan, LADWP, and DWR) will consider using a more sophisticated Probabilistic Seismic Hazard Analysis (PSHA) assessment, or a series of deterministic scenarios that approximate a PSHA, rather than a single-event scenario type of Deterministic Seismic Hazard Analysis (DSHA) assessment. A probabilistic approach to ground motions and surface faulting will certainly provide a better understanding for planning and design.

Prior to developing/presenting the ShakeOut Scenario, USGS referred to a great SAF event as “The Big One,” without providing details. The ShakeOut Scenario was later created to provide important details, and in order to provide the public and decision-makers with a scientifically plausible event that they could more easily envision occurring and understand and use. The Workshop’s focus was on aqueduct systems and ShakeOut Scenario interdependencies.

Disaster vs. Catastrophe

For Hurricane Katrina, the emergency response was not sufficient to stop economic decline. This is compared to the 1994 Northridge earthquake, in which economic impacts recovered within years and is categorized as a disaster. The Hurricane Katrina recovery has taken decades and is classified as a catastrophe. For the ShakeOut Scenario the interruption of water delivery is the biggest source of business interruption. High fire danger as a result of an earthquake could result in “super conflagrations,” especially if water pressure and supply is insufficient to fight fires. The impacts from water and fire could result in a Southern California catastrophe if unmitigated in advance of a SAF event.

Lifeline System Dependencies

The ShakeOut Scenario interrupts all lifelines including communications, electric power, water, wastewater, gas and liquid fuels, and transportations systems. The majority of these services are lost the first day throughout Southern California. Telecommunication services are restored within two weeks of the event. Other system restorations come within days to months following the ShakeOut. The Cajon Pass, which lies along the SAF, is a major corridor with many lifelines. Regarding service restoration times, it may be necessary to stage repairs so that some groups can complete repairs on their lifelines before other groups are allowed to come in and make repairs. Restoration of other lifeline systems has an impact on water service restoration, including the LADWP, DWR, and Metropolitan supply systems.

AQUEDUCT SYSTEM PRESENTATIONS

Each agency was asked to present the following information on its aqueduct systems:

1. Overview of the system and its operation
2. Assumed damage for The ShakeOut Scenario
3. Estimated duration to restore partial and full aqueduct flows
4. Planned or in-progress mitigation projects

COLORADO RIVER AQUEDUCT

Greg de Lamare presented for Metropolitan. The CRA has a design capacity of 1.2 million acre-feet/year and delivers water from Lake Havasu near the California/Nevada border to its terminus point, Lake Mathews in Riverside County. Water is conveyed through a series of five pumping plants. After the fifth pumping plant (Hinds Pumping Plant) water flows by gravity through the San Gorgonio Pass to Lake Mathews. The first deliveries were in 1941. Annual deliveries depend on multiple factors, including available supplies from the Colorado River system and the State Water Project, with an average of 0.89 million acre-feet/year over the past 13 years.

Completed Seismic Upgrades

Metropolitan has performed a significant number of seismic upgrade projects on the CRA's key facilities. The primary goals were to minimize damage, maintain deliveries, and protect occupants. For example, Metropolitan has upgraded each of the five pumping plants and outlet piping (e.g., adding buttresses to the building walls) and constructed a new outlet tower at Lake Mathews in 2003. All five of the pumping plants are expected to remain operational following the ShakeOut Scenario.

In addition to the seismic upgrades to key CRA facilities, one of the most significant steps Metropolitan has taken to mitigate the impact of a major earthquake on the SAF was the construction of Diamond Valley Lake (DVL) in the 1990s. DVL nearly doubled the available surface storage capacity on the west side of the

SAF and, together with local production and other regional reservoirs, provides the region with up to six months of emergency supplies.

Assumed Damage

For the ShakeOut Scenario, the San Gorgonio Pass is an area of major concern, as the CRA crosses the SAF in this area. Within this area, there is a left transpressive stepover in the SAF system. This stepover is a complex region of discontinuous faults with both horizontal and vertical thrust components. A M 7.8 rupture through this area would not only result in an offset of the CRA at the fault crossing, but could also result in uplift over a broad region. Together with a team of experts, Metropolitan modeled potential surface deformation from a M 7.8 earthquake through the San Gorgonio Pass and found that this area could experience a gradual uplift over a distance of 35 miles, with a maximum uplift of approximately 3 feet in the Whitewater vicinity, which is in the gravity flow portion of the aqueduct, downstream of the last pumping plant. Despite this uplift, a detailed hydraulics analysis concluded that after initial repairs are completed, there would be a less than 20-percent reduction in the capacity of the CRA.

In addition to vertical uplift, approximately 96 miles of the CRA would be subjected to strong ground shaking levels between 0.25 and 0.75g. Within this area, 54 miles of tunnels that are constructed primarily in hard bedrock are expected to perform well, with only minor damage. The 42 miles of cut-and-cover conduit and siphons will experience some damage requiring as many as 20 repairs, which can be completed within two to four months with multiple crews working on repairs.

Within the San Gorgonio pass, three segments of the SAF cross the CRA. During the original design of the CRA, the designers identified these faults and designed the CRA to cross the faults at right angles to minimize damage and in easily accessible cut-and-cover siphons. Of the three fault segments that cross the CRA in the San Gorgonio Pass, the Garnet Hills Fault is considered the most active strand. The main strand of the Garnet Hills Fault crosses the CRA in a cut-and-cover conduit; however, a splay of the Garnet Hill Fault crosses the CRA's Whitewater Tunnel No 2. Although the most probable scenario would be a rupture through the main trace of the Garnett Hills Fault, which crosses the CRA in a conduit section, for planning purposes, Metropolitan assumed a worst-case scenario in which the splay that crosses Whitewater Tunnel No. 2 ruptures with the full modeled displacement of 3 feet of vertical uplift and 12 feet of horizontal movement and severely damages Whitewater Tunnel No. 2.

Estimated Recovery Durations

For this worst-case damage scenario, a team of outside experts estimated it would take six months to restore the tunnel section to partial capacity (i.e., roughly 80%), with one month required to mobilize equipment and crews and five months to excavate a bypass tunnel around the damaged section with a roadheader. However, it may also be possible to reduce the repair time to less than six months by stockpiling materials, improving access at the west portal and pre-designing a bypass tunnel.

- Recovery projections to repair damage and restore partial capacity (80%) after the ShakeOut Scenario are summarized below. Note that at 80% capacity, the CRA can still deliver more than the average deliveries of water from 2003 to 2016.

- Worst Case – Fault Displacement Through Whitewater Tunnel No. 2: This failure would require a bypass tunnel around the rupture area through Whitewater Tunnel No. 2 and repairs to isolated portions of conduits, siphons, and tunnels. The duration of repairs was estimated to be up to six months.
- More Probable Case – Fault Displacement through a Conduit Section: This failure would require extensive repairs to conduit sections at rupture area and repairs to isolated portions of conduits, siphons, and tunnels. The duration of repair was estimated to be from two to four months.

Next Steps

Seek Board authorization for recommended CRA Whitewater Tunnel seismic mitigation measures to assure restoration of partial CRA deliveries within six months. This will include stockpiling key materials (e.g., steel sets), improving access at the west portal by constructing a new access structure, strengthening shallow tunnel sections near the portal, and pre-designing a bypass tunnel to circumvent the area damaged from fault rupture through the tunnel. Other planned CRA assessments include an evaluation of non-structural elements at the pumping plants and consideration of potential mitigation measures at power system substations.

STATE WATER PROJECT

Mr. David Rennie presented for DWR. The SWP, built, operated, and managed by the DWR, is the largest state-built, multipurpose, user-financed water project in the country. It was designed and built to deliver water, control flooding, generate power, provide recreational opportunities, and enhance habitat for fish and wildlife. SWP water irrigates about 750,000 acres of farmland, mainly in the southern San Joaquin Valley. Approximately 25 million of California's estimated 38 million residents benefit from SWP water.

The SWP has approximately 5.8 million acre-feet of storage (Lake Oroville and San Luis Reservoirs account for approximately 77% of the total), 31 dams, 20 reservoirs, 29 pumping and generating plants, and approximately 705 miles of aqueducts and pipelines. In the past decade, the SWP has conveyed an annual average of 2.9 million acre-feet to 29 agencies and districts that have long-term contracts with DWR for the delivery of SWP water. In Southern California, the California Aqueduct can convey approximately 3,000 cfs peak flow.

The energy needed to operate the SWP, the largest single user of electrical power in California, comes from a combination of its own hydroelectric generating plants and power purchased from and exchanged with other utilities. The project's eight hydroelectric power plants, including four pumping-generating plants, produce enough electricity in a normal year to supply about two-thirds of the SWP's necessary operating power.

Water conveyed by the California Aqueduct is delivered to Southern California, which is home to roughly two-thirds of California's population. Before it can be delivered, the water must first cross the Tehachapi Mountains. Fourteen 80,000-horsepower pumps at Edmonston Pumping Plant, situated at the foot of the mountains, raise the water 1,926 feet—the highest single lift of any pumping plant in the world. The water enters 8.5 miles of tunnels and siphons as it flows into Antelope Valley, where the California Aqueduct divides into two branches: the East Branch and the West Branch.

The East Branch

The East Branch carries water through Alamo Powerplant, Pearblossom Pumping Plant, and Mojave Siphon Powerplant into Silverwood Lake in the San Bernardino Mountains. From Silverwood Lake, water flows through the San Bernardino Tunnel to Devil Canyon Powerplant. Water continues down the East Branch through the Santa Ana Pipeline and terminates in Lake Perris, the southernmost SWP reservoir.

The 33-mile East Branch Extension links parts of service areas for San Bernardino Valley Municipal Water District and San Gorgonio Pass Water Agency to the California Aqueduct. The East Branch Extension carries water from Devil Canyon Powerplant Afterbay to Cherry Valley, bringing water to Yucaipa, Calimesa, Beaumont, Banning, and other communities.

Almost the entire East Branch parallels the fault and could be subjected to large seismic forces. Power plants in the SWP system were designed as peaking plants for low cost power, and have excess conveyance capacity to meet annual deliveries (capacity of up to 3,000 cfs, while actual deliveries are one-third to one-half of that).

The West Branch

Water in the West Branch flows through Oso Pumping Plant, Quail Lake, and then from the Peace Valley Pipeline through Warne Powerplant into Pyramid Lake in Los Angeles County. From there it flows through the Angeles Tunnel, Castaic Powerplant, Elderberry Forebay, and into Castaic Lake, terminus of the West Branch. Castaic Powerplant is operated by the Los Angeles Department of Water and Power.

In the specific ShakeOut Scenario, the fault break stops short of where the West Branch is, so it would be subjected to reduced seismic forces than for the East Branch.

The ShakeOut Scenario and the SWP

For the ShakeOut Scenario, the focus was on the portion of the SWP/California Aqueduct located south of Bakersfield (i.e., roughly the southern 200 miles of the aqueduct, which includes the East Branch and the West Branch). This portion of the aqueduct crosses the SAF in several places, including Devil Canyon. Devil Canyon is a distribution hub where several pipelines servicing local areas begin.

DWR performed seismic damage evaluations in five study areas in the portion of the aqueduct from Bakersfield to the South:

1. Study Area A - Buena Vista to Edmonston

   There are four pumping plants between Bakersfield and the Tehachapi Mountains that are in strong shaking areas. In the section located between Buena Vista and Edmonston, the pumping plants are founded on bedrock and are expected to perform well during the ShakeOut Scenario event based on a study done with Cal Poly. There are, however, questions regarding the electrical and mechanical components. Also, it is expected there would need to be repairs made to breaks on canal sections that are built on alluvium.

2. Study Area B – Edmonston to Bifurcation

   This area of the aqueduct crosses Garlock fault at shallow depth/surface, though the reach has tunnels. This is in keeping with the general philosophy used when designing the aqueduct, which was that fault crossings should be at surface or shallow depth for easier repair to aid in recovery following an earthquake event.

3. Study Area C – West Branch

   The West Branch branches off of the Tehachapi segment and goes to Pyramid Lake and Castaic Lake; it crosses the SAF at Quail Lake. There is one pumping plant, one generating plant, and three dams. An event such as the ShakeOut Scenario could potentially sever the constructed facilities on West Branch due to ground motion shaking. However, after Oso Pumping Plant, water flows by gravity into all subsequent facilities and there is the possibility of utilizing the natural drainages and flow paths to continue delivery during an emergency. It is believed that the West Branch could be repaired in 0 to 6 or 6 to 12 months, depending on the extent of the damage. Oso Pumping Plant is likely to remain operable, with minimal damage. The biggest question is the Peace Valley Pipeline, as it is Prestressed Concrete Cylinder Pipe (PCCP) and not as resilient as other pipelines, but it has redundancy at half capacity through Gorman Creek which can also deliver water from Quail Lake to Pyramid Lake should the Peace Valley Pipeline fail; if the fault ruptures through this area, there would be severe damage.

The aqueduct flows through an LADWP Power Plant at Castaic. Additional coordination with LADWP is needed to clarify bypass capabilities at the power plant and operation options during an incident to provide water into Castaic Lake. As a result, DWR will need to work with LADWP to resolve this issue.

4. Study Area D – East Branch to Devil Canyon Power Plant and East Branch Extension

This is the most challenging area. This portion the California Aqueduct and the SAF mostly run parallel to each other. Although it is believed that the aqueduct canal structure will perform well, there are about 80 miles of canals within three miles of the fault. The embankments are not anticipated to be the biggest issue, but there are 31 siphons (12-20 feet diameter) that are not easily repaired if they rupture due to availability of materials, and there are 100 drainage culverts that pass water under the canal and potential issues with seismic induced landslides and liquefaction.

The bifurcation to Pearblossom flows by gravity. Pearblossom is about three miles from the fault and the electrical and mechanical systems (or equipment) at Pearblossom are the most vulnerable. There have been some seismic improvements made to switch yards, but overall, electrical and mechanical problems are unclear. Regarding electrical problems, failure of an electrical system could spark a fire, and past fires suggest five to six years to restore. Currently DWR is assuming no catastrophic failures for this scenario.

Detailed estimates of repair are very difficult. There may be about 3 to 3.5 feet of horizontal displacement at each SAF crossing near Palmdale. The starting point estimate is at least one major break per pool (a pool is the canal section between radial gate check structures which are located approximately three to six miles apart in the East Branch). The SAF also crosses the aqueduct at Devil Canyon Power Plant, through the 2nd afterbay. If this plant floods, damage and repair time may be significant and at this point extremely difficult to estimate. DWR also expects severe damage in the area near the fault zone (i.e., within about 15 miles of the fault), including a possible fault rupture across penstocks, afterbays, etc. There is about 1,200 feet of head going into the power plant, which is an additional concern. Seismically-induced landslides are a concern due to the steep terrain, and there may be liquefaction issues.

5. Study Area E – Santa Ana Pipeline to Perris

The greatest concern is not water delivery, but rather, the impact of pipe breaks on the surrounding area. The PCCP pipeline is not expected to perform well and could impact developed areas. In general, the return-to-service estimates that were prepared assume no catastrophic damage to pumping plants (fire, flood, tilted units, crane operability, etc.).

Findings, Assumptions, and Concluding Remarks

About 80 miles of the California Aqueduct is located within three miles of the SAF, which poses significant risk for damage in a major event. However, most East Branch conveyance features are located above ground or at shallow depth to allow for relatively easy repair resulting from damage from the SAF. The West Branch has comparatively few facilities and a much shorter length of aqueduct within three miles of the SAF as compared to the East Branch. While damage on the West Branch may be substantial, the exposure risk is significantly less than on the East Branch. Preliminary evaluations suggest that partial flows may be restored on the West Branch within 6-12 months. The level of uncertainty regarding potential damage and repair scenarios for the East Branch is considerably higher given the extensive length of aqueduct and higher number of facilities within close proximity to the SAF. Preliminary evaluations suggest that repairs to restore partial flows along the East Branch may exceed 12-24 months.

Seismic preparedness. DWR expects damage, and therefore has Emergency Action Plans (EAPs) and has significant resources. DWR has 420 staff located south of Bakersfield and 700 staff located north of Bakersfield (with O&M centers near Grapevine and Pearblossom). In an emergency, DWR could bring down some of the staff stationed in the north to make repairs. Currently, DWR's emergency response applies to local emergencies only and does not yet include region-wide emergencies.

State Contract Act – In the event of an emergency, the State Contract Act has a mechanism to quickly award contracts. This facilitates rapid mobilization of a contractor to make repairs.

LOS ANGELES AQUEDUCT

Dr. Craig Davis presented for LADWP. The Los Angeles Aqueduct System consists of the First and Second Los Angeles Aqueducts (FLAA and SLAA, respectively). They have a combined flow of 700 cfs. All flow is by gravity from the Mono Basin to Los Angeles.

The FLAA was completed in 1913 to bring water to Los Angeles from the Owens River. In 1940, it was extended into the Mono Basin. The SLAA was placed in service in 1970 and starts at the south end of North Haiwee Reservoir, near the southern end of the Owens Valley. The SLAA was built with a separate conduit between North Haiwee Reservoir and Elizabeth Tunnel. At Elizabeth Tunnel, the FLAA and SLAA are combined and flow in a single conduit for several miles south to just before Power Plant 2, where the SLAA branches off in a separate conduit and flows to Los Angeles. The Elizabeth Tunnel is a 5-mile long horseshoe-shaped concrete lined tunnel that crosses the SAF.

A high level analysis was performed using the ShakeOut Scenario event for the FLAA and SLAA. In the vicinity of the Los Angeles Aqueducts, the ShakeOut Scenario shows unusually high peak ground velocity (pgv) values and low peak ground acceleration (pga) values compared to areas further south. This is something LADWP would like to follow up on with the USGS.

ShakeOut Specifics

The FLAA and SLAA were evaluated within the 0.2g shaking contour. Peak ground motion acceleration ranged from 0.2g to 0.5g and peak ground velocities ranged from 70 cm/s to 246 cm/s. Evaluations assumed that the SAF ruptured 11.5 ft. across the Elizabeth Tunnel. Liquefaction occurs in the Antelope and Santa Clarita Valleys. However, the ground water is relatively low in many of those areas and the liquefaction potential should be reassessed; nonetheless, permanent ground deformations were evaluated in these areas. Landslides were assumed to occur along the aqueducts south of the SAF and were assessed based on LADWP expectation.

Damage Overview

Over 100 total damage locations were identified, varying from minor to severe. There would be an immediate loss of the entire Los Angeles Aqueduct system flow, with flow from the Owens Valley halted with the tunnel damaged by the rupture. Flow from Bouquet Canyon Reservoir would also be halted due to damage to the inlet/outlet and penstock.

Elizabeth Tunnel: The two aqueducts combine at Fairmont and go through Elizabeth Tunnel. There is potential for two large collapse areas and 11.5 feet of offset. The vertical movement is unknown, but there is over 50 feet of head pressure through the tunnel, so vertical deformations are not expected to disrupt the flow.

FLAA: The FLAA could be subjected to lateral spreading of up to 10 feet and differential settling of up to 24 inches in the Mojave and Antelope Valley Divisions. Some box conduits might not be structurally supported at the top. Fairmont Reservoir No. 2 is expected to perform well, as is Bouquet Reservoir, which was built to provide supply south of the SAF (ocean side of fault). However, Bouquet Reservoir cannot be used immediately after the event because of potential damage to conduits and tunnels, and landslides could damage the Bouquet inlet-outlet line. North and south of the SAF the FLAA has concrete siphons, and partially and fully buried riveted steel pipe, which may be severely damaged in some locations.

- ***The San Francisquito Power Plant No. 1 and No. 2:*** Power Plant No. 1 is expected to sustain significant damage to penstocks, surge tank, and building. Severe damage may also result from erosion due to penstock damage. There is no bypass of aqueduct flow around the power plant, so the damage will result in halting all flow from FLAA and SLAA until repairs are made or an emergency bypass is constructed. Additionally, Power Plant No. 2, penstocks, surge chamber, and Drinkwater Reservoir are expected to be severely damaged, eliminating flow from FLAA, but flow can resume in the SLAA just north of this location. Pipeline damage in Bee Canyon is also anticipated.
- ***Siphons and Channels:*** The Soledad, Elsmere, and Whitney siphons were damaged in the 1994 Northridge Earthquake. On the Van Norman Complex there were many examples of failures in channels, taking about 8 months to repair. These are expected to perform similarly in the ShakeOut Scenario.

The SLAA: The SLAA is primarily welded steel pipe and is expected to perform better than the FLAA. A large area in the Antelope Valley is predicted to liquefy in the ShakeOut Scenario, resulting in settlement up to 12 inches and lateral spread of 25 inches, which in turn will result in severe damage. This would be similar to failures on the Granada Trunk Line failure on Balboa Blvd. that resulted from 24 inches of lateral movement from the 1994 Northridge earthquake. There are a few other locations of pipeline damage anticipated on the SLAA in the Santa Clarita Valley and San Francisco area from ground movements and substructure performance.

Restoration Timeline

The Los Angeles Aqueduct will lose all flow immediately after the event for about 8 months. At 8 months, about 200 cfs flow from Bouquet Reservoir could be restored for two months, at which time the reservoir capacity will be depleted. There would be no further flow for the next eight months, before resuming full 700 cfs capacity through FLAA and SLAA once Elizabeth Tunnel is repaired. Specific restoration criteria for Bouquet Reservoir and for the FLAA/SLAA are summarized below:

- ***Bouquet Reservoir Water.*** The critical items are repairing the Bouquet Inlet/Outlet lines and eroded slopes and installing a bypass around Power Plant No. 1. It was estimated the repairs to the SLAA south of the SAF and the cascades and channels on the Van Norman Complex will take less than 8 months.
- ***FLAA/SLAA.*** The Elizabeth Tunnel restorations are critical for restoring the flow from Owens Valley and are estimated to take 18 months. The FLAA and SLAA north of Elizabeth Tunnel are expected to take less than 18 months.

The above doesn't account for finding additional damaged locations as flow is restored. The restoration process will consist of repairing known damage locations, filling conduit, confirming repairs work, and then looking for additional leaks/breaks needing repair. Finding additional leaks/breaks will require that the same drain-repair-fill process be repeated until all damage locations are located and repaired.

Ongoing Work

Current evaluations and improvements to dams. The LADWP maintains a continuous dam and reservoir safety program that incorporates earthquake evaluations and mitigations. Current evaluations and improvements include the following:

1. Terminal Hill experienced significant repeated damage in the 1971 San Fernando and 1994 Northridge Earthquakes. Mitigation to prevent damage at Terminal Hill is complete.
2. An Elizabeth Tunnel seismic enhancement project is in progress, which will allow some flow to pass through a small diameter HDPE pipe in events having fault rupture of up to about 8 to 10 feet, but would not mitigate any flow for large movements like those from the ShakeOut Scenario. Investigations are being initiated to characterize the SAF for maximum movements across the Elizabeth Tunnel, which are anticipated to lead to identifying possible mitigation alternatives for maximum fault movement.
3. Currently the Bouquet Dams, North and South Haiwee Dams, and Tinnemaha Dams have active earthquake improvements being studied or implemented.

Many other faults could have significant earthquakes (San Gabriel, Garlock, Sierra Nevada, and Owens Valley) along the FLAA and SLAA length. These need to be considered for an entire aqueduct improvement program.

In response to a ShakeOut Scenario event, the LADWP would receive support from crews in the Owens Valley and through contracts with East Bay Municipal Utility District (EBMUD), Las Vegas Valley Water District (LVVWD), Metropolitan, and DWR. Emergency response plans are continually maintained to aid in this response. LADWP also has a large fleet of equipment and stockpiled emergency materials. The LADWP is currently implementing plans to reduce reliance on imported supplies through improved conservation, increased reclaimed water use, and storm water capture.

Next Steps

1. Prepare scenario emergency response and restoration plan accounting for known vulnerabilities
2. Determine mitigations to undertake, and modify the Emergency Response and Restoration Plan as improvements are completed
3. Reassess ground motion and liquefaction hazards. Also factor in how long before people flee Los Angeles

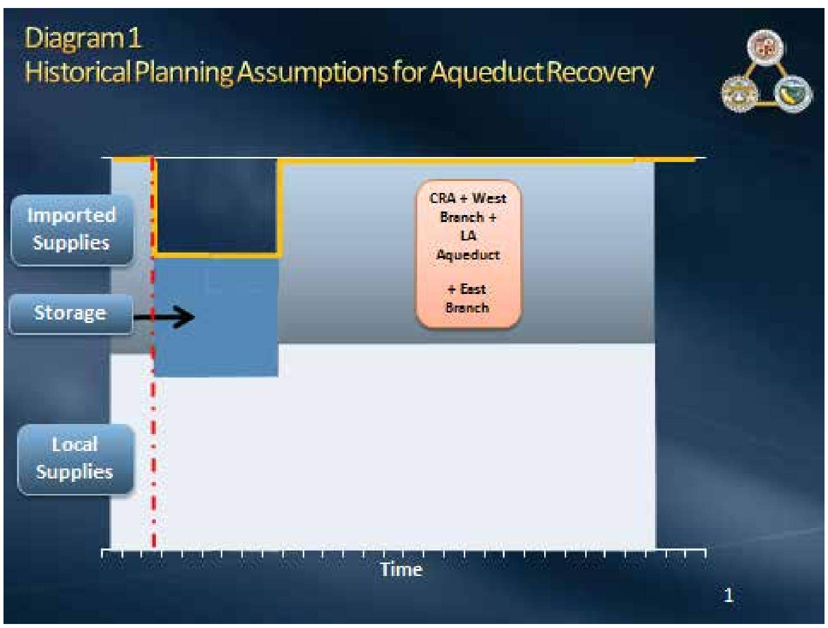
POST-EVENT WATER SUPPLY DISCUSSION

Mr. Michael Rojas (Metropolitan) discussed three potential scenarios regarding the recovery for aqueduct flows following the ShakeOut Scenario based on the input from each agency. Three diagrams were used to illustrate: 1) Metropolitan's historical planning assumptions; 2) Hypothetical staggered recovery of aqueduct flows; and 3) Accommodating partial aqueduct flows with emergency allocation. Each diagram is discussed below and indicates total aqueduct flows on the vertical axis and time on the horizontal axis.

Diagram 1 – Metropolitan's historical planning assumptions

The first diagram illustrates Metropolitan's historical assumptions regarding the recovery of imported water deliveries following a major seismic event and will be described in phases.

Pre-Event Phase: Prior to the event, retail water demand in the Southern California area of approximately 4 MAF/year is met by two sources, imported water and local water (2 MAF/year of imported water and 2 MAF/year of local supplies). In addition, Metropolitan emergency storage reserves of 600,000 AF exist in a number of reservoirs.



Post Event Phase: When the event occurs, imported supplies to Southern California are assumed to go to zero-flow immediately and retail water demand in the Southern California area is reduced immediately by 25%. Locally produced supplies are assumed to have 100% availability at this time, except the LAA, which is considered a local supply by Metropolitan planning. The LAA reduction in local supply is shown in the diagram. During this assumed 6-month post event phase (during which repairs are being made to all imported water aqueducts), Metropolitan reserve storage supplies are delivered to supplement Local Supplies. Local Supplies plus storage reserves meet 75% of normal demand level.

Post Recovery Phase: Within 6 months, repairs are completed on CRA, LAA, and SWP aqueducts and delivery of imported supplies resumes and the emergency allocation is lifted. At this time, there is no further need to rely upon emergency storage reserves to meet full demands.

Diagram 2 – Hypothetical staggered recovery of aqueduct flows

This diagram does not specify times associated with any potentially extended aqueduct repairs. Its purpose is to demonstrate how emergency storage reserves could become depleted if aqueduct repairs extended beyond historical assumptions and to stimulate discussions regarding how aqueduct recoveries could be accelerated through collaboration. In this hypothetical case, the aqueduct recoveries are staggered in the following order: the CRA, the West Branch of the SWP, the LAA, and then the east Branch of the SWP.

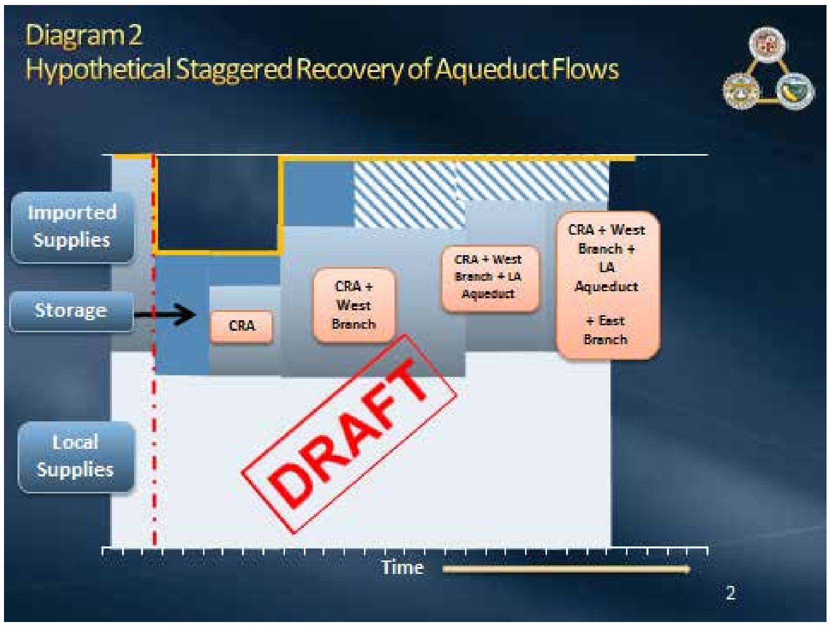
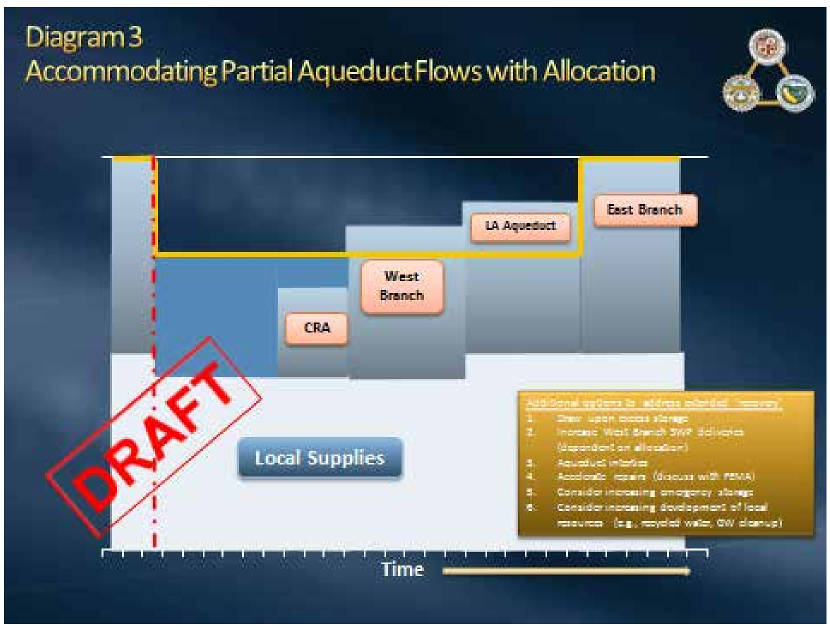


Diagram 3 – Accommodating partial aqueduct flows

This diagram also does not specify times associated with any potentially extending aqueduct repairs. Its purpose is to demonstrate how extended aqueduct recoveries could be accommodated by continued use of the emergency allocation. In this hypothetical case, the aqueduct recoveries are staggered in the same manner as diagram 2 (CRA, West Branch of the SWP, the LAA, and East Branch of the SWP).

It was shown that even long duration repairs could be accommodated by extending the emergency allocation. Other options for accommodating an extended recovery of aqueduct flows were also offered to spur later discussions. These included drawing upon excess storage, increasing West Branch deliveries, implementing aqueduct interties, accelerating repairs, increasing the amount of dedicated storage, and increasing the development of local resources. It was recognized that many of these concepts would require further investigation beyond the workshop.



QUESTION AND ANSWER PERIOD

Mr. Thomas then opened the floor to questions regarding the information covered in the previous presentations and an amount of general comments.

Question #1:

- ***How long would it take to get an accurate vertical displacement map from USGS following a large earthquake?***

Answer (Ken Hudnut - USGS):

There could be damage to telemetry systems, and we would be reliant on cell system. It may take several days to gather the data from the monitoring stations (depending on the ability to access the data), and then several more days to process the data and to generate a model. Therefore, the total time could be about a week. USGS should, however, be able to provide a rough map (with errors) based on data from the surrounding area within a couple of days. Furthermore, USGS may be able to access the earthquake monitoring stations via helicopter and have a final map prepared in maybe a couple of days.

After Northridge we had to go and retrieve data manually. In a case like this, it could be a week to get good maps. Knowing how much shaking was at critical facilities would give a much quicker picture of situation. Suggestion: put instruments and ensure good telemetry at key facilities?

Question #2:

- ***How long would it take to get post-earthquake LiDAR data from USGS?***
- ***How did we perform after Napa earthquake?***

Answer (Ken Hudnut - USGS):

The best-case scenario would be about 1 month for data that could be used to design with (although this was not firm as the area needs to be flown before as well as after).

For Napa, we worked with DWR as rapidly as we could. Would love to be able to do this much faster than was achieved for the Napa earthquake. There was <20cm movement so it was 'in the noise.' There is a December 6, 2014 report on pre and post event LIDAR. Rapid response airborne LIDAR could be done within a month. Initial estimate could be done within a few days but with unknowns/errors. Seismic stations will be used to produce initial general data.

Question #3: LADWP asked if the updated grid files for ShakeOut Scenario are accurate.

Craig Davis said that they had a version that was different than the one that can be downloaded today. The older version had a higher velocity over greater area with lower accelerations. Metropolitan has 1g, LADWP has <0.5g. We may also want info on other scenarios.

Answer (Ken Hudnut - USGS):

We are learning how earthquakes happen and our models are changing based on coherence and previous earthquakes. We should get reasonable ground shaking estimates at critical facilities that have seismic instrumentation and good vertical displacements from locations that have GPS instrumentation. Some critical facilities have such instrumentation already, but many others do not.

Question #4:

- ***Is there any data available (or are there any case studies) that indicates how electrical and mechanical equipment will perform during an earthquake?***
- ***Can we get better info from experts?***

Answer (Tom O'Rourke and others):

Yes, there is data on performance of large equipment from the Tibet earthquakes, 2011 Tohoku earthquake, Chile earthquake, etc. The nuclear power community has a large database of such information. Reports are also available from Electric Power Research Institute (EPRI) and these can be acquired through LADWP Power. It is important to note that Electrical equipment, transformers, will have a long lead time (1 year) for delivery.

An individual then asked, "How interchangeable is electrical equipment?"

230 kV transformers are in demand and there are spares but not many. There is not enough stock because SCE would also need quite a few in the Shakeout Scenario. Moving them is not trivial ether. The Department of health and safely has a spare transformer program, but it is small.

Tom O'Rourke (LADWP): what are the voltages are we looking at? Your problem is the transformers. It could be a year.

Sukhbir Singh (DWR): to minimize damage, we will install local seismic equipment in those plants. We have super transformers that can be used in all their four plants.

Question #5:

- ***Have the agencies looked at where/if we can get the pipe and/or materials necessary to make repairs following such an event?***

Answer:

Metropolitan does stock some steel plate for large pipeline emergency repairs but specific studies have not been performed by the agencies for this specific event. Appendix 7 summarizes Metropolitan's emergency resource matrix.

Question #6:

- ***For the CRA, the assumption of six months, one month to mobilize, 5 to fix (tunnels), is that optimistic? With aftershocks it may be more.***

Answer (Greg de Lamare - Metropolitan):

The estimate included mobilization and repair, all in six months. It also considered aftershocks which could slow progress. The 6 month estimate included stabilization efforts and waiting 1 month for mobilization, provides some time for aftershocks.

The assessing team included contractors who concluded not to attempt to fix the tunnel but to abandon and build a new portion around the damaged section.

Question #7:

- ***Do we understand the ShakeOut well enough?***

Answer:

Craig Davis (LADWP): We need to learn more about what this means. Understanding the uncertainty of the physics, what is that range of ground motion and how does that affect the damage projections.

Rob Barry (DWR): We understand the ShakeOut Scenario pretty well, but there is always more information, not just for this scenario. The one we face will not be the one we are talking about today. Working with USGS will help us get there.

Dr. Charles Scawthorn (LADWP): The cumulative impact of aftershocks is something that we are not yet planning for.

Craig Davis (LADWP): Aftershocks and after slip there could be something else we need to look at.

Jack Safely (Metropolitan): We don't have to know everything, but we will learn more going forward.

Michael Thomas (Metropolitan): We need to leverage our assets.

Question #8:

- ***Money hasn't been mentioned. Do our agencies have repair policies in place?***

Answer:

Tom O'Rourke (LADWP): After Northridge earthquake…we had damaged modeled by noon, the next day the state received hundreds of millions in aid.

Ken Hudnut (USGS): FEMA and CALOES are currently reviewing and revising the southern California Catastrophic Earthquake Response Plan to include additional earthquake scenarios. Each of these would have different implications for the import water system. There needs to be follow up after this meeting.

General Comments

Rob Barry (DWR): A coordinated post-earthquake response may be more inefficient based on bureaucracies involved.

John Wallace (Metropolitan): Coordination is a must to share contractors and construction teams.

Michael Thomas (Metropolitan): Contractors will be a premium. If we want to most effectively use contractors between us, maybe CRA isn't as important as getting the West Branch of the SWP fixed.

Craig Davis (LADWP): We should operate as one unit with our response.

Unknown: Is this the first time all our agencies would come together to do something? Yes. If you are not cooperating for resources, would you be competing? Yes

Lilly Shraibati (Metropolitan): At some point we will be competing for all those resources, we need to figure out priorities to get the best bang for our buck.

Craig Davis (LADWP): We have the three largest water agencies coming together, and we would have a lot of influence if we are working together.

Tim Gamble (Metropolitan): We should bring on the fact that vendors, contractors and more will be overtaxed when something like this happens. We should be looking at how to establish emergency contractors and suppliers.

Joe Resong (LADWP): Mutual aid agreements.

Ian Whyte (Metropolitan): Mutual aid/assistance: we have numerous things in place. The three agencies coming in to accomplish the common good would carry a lot of weight with the state and the federal government.

Charles Scawthorn (LADWP): Does California have MOUs with Arizona, Oregon, and Nevada?

Ian Whyte (Metropolitan): Can't go outside the state without agreement.

Rob Barry (DWR): Should we establish a committee to meet with FEMA on this topic?

Blaine Laumbach (DWR): Different systems with different vulnerabilities.

Dale Cox (USGS): Restoration of water services should be highest priority after a disaster. Priorities: Life safety, property, everything else. Water is in the front of the line.

Cameron Poya (DWR): The most effective way to restore imported water supply is to prioritize repairs to CRW, state water project west branch.

Tom O'Rourke (LADWP): We need more info about ShakeOut Scenario, there is more detail about where liquefaction would be…more accuracy and precision and information. Operators frequently don't live close to the operating structures, may not have access.

John Wallace (Metropolitan): Can have competitive bids, but need to look outside your service area.

Ron Rodriguez (Metropolitan): Workers might be getting bonus for getting jobs done within certain time, very expensive.

After clarifying these issues, Mr. Thomas moved into the creativity session.

CREATIVITY SESSION

Mr. Thomas closed the session with a group activity to build a consensus on items that were agreed upon and steps that could be taken to better prepare the region.

This exercise led to the following two lists:

"What do we Agree Upon?"

1. We all need to better understand our seismic vulnerabilities better than we do today
2. We can improve preparation for an event like the ShakeOut scenario (and other similar events)
3. The assumption that all flow would be restored within six months has been challenged
    - All imported water will be interrupted for at least two months
    - The actual recovery of the water supply post event will vary by scenario
    - Restoration of full aqueduct flows will take more than six months
4. The largest municipal utility, largest wholesaler, and largest state owned water provider coming together to proactively address a major hazard is unprecedented and the SRWSTF should continue
5. We as a group should have a plan in place to deal with the federal government response
    - Resumption of imported water supply and in-basin water services
    - Bring in CAL OES, then FEMA
6. Each agency should evaluate which staff should receive SEMS/NIMS training
7. We need a plan for coordinating contractor use and resource use
    - If agencies do not cooperate, they will be competing for resources
    - Water is required for life safety (including firefighting) so it should jump to the front of the list
    - We need to work with power folks – pumping plants need power
8. We will need to look out of the region for all resources
9. Common issues can be studied jointly and it is important to continue the momentum of the SRWSTF
10. In planning for the ShakeOut Scenario, the priority for the region should be restoring the West Branch and the CRA as quickly as possible (the West Branch can supply the greatest area)
11. We need to better understand the full range of hazards associated with earthquakes (aftershocks, fault rupture, fires, etc.)
12. Some imported water is better than none
13. Power is a critical codependence
14. We need to revisit our scenario resource planning for a major outage (storage, local supplies, conservation, recycling)

"What can we do to be in better shape 5 years from now?"

1. Make an assessment of the response capabilities of our agencies, determine what the needs will be and identify the gaps
2. Identify vulnerabilities in order of priority and armor them accordingly or develop contingency plans
3. Join forces and share resources for repairs to vulnerable areas
4. Plan and conduct joint emergency response exercises
5. Develop canned repairs for common failures and key 'critical' failures
6. Evaluate how to procure assets (emergency power, materials, contracts, equipment, fuel, etc.)
7. Develop a database of available resources and investigate sharing opportunities (craft, consultants)
8. Share knowledge on approaches to vulnerability assessments and seismic upgrades
9. Establish leadership structure for unified response, who fills what role
10. Increase system flexibility through potential interconnects (between SLAA and East Branch @ Fairmont; between FLAA and East Branch Pool 44 or Tehachapi afterbay; and/or pump-in options on East Branch)
11. Consider applicability of American Lifelines Alliance Water system reliability guidelines to aqueducts
12. Share emergency response plans and consider funding methods in response to an event and plan for it
13. Plan for personnel unavailability
14. Prepare a 3-agency MOU for coordinated emergency response
15. Cooperate, share, and discuss perspectives and information on the survivability of large equipment

These two lists were combined into a refined workshop findings document (Appendix 8) that was used in management briefings. After the workshop, some of the next steps identified in this document were implemented, including building executive management support and obtaining information on seismic performance of large mechanical and electrical equipment. Appendix 9 contains information used for an SRWSTF oversight committee briefing held on May 4, 2016. Within this briefing meeting, the Oversight Committee communicated support for the findings and results of the workshop. Appendix 10 contains information obtained during a conference call with San Diego Gas and Electric initiated to learn more about their equipment performance in a recent earthquake. This conference call was held on May 23, 2016.

FIVE-YEAR PLAN

Over the past twelve months, the SRWSTF documented the workshop, briefed management on key issues, exchanged information on individual agency aqueduct assessments, initiated research on follow-up items and reached a consensus on an approach to improve the resilience of the region's imported water supplies. The agreed upon long-term SRWSTF strategy involves continuing bi-monthly meetings and initiating a repeating 5-year cycle of planning, executing, and reporting of collaborative activities and accomplishments (see below). This approach will ensure effective management of long range actions and continuity of the SRWSTF. This Aqueduct Workshop report will initiate the first 5-year cycle.

Cycle 1 (March 2017)	Document progress achieved during 2016 Set goals for April 2017 – March 2022
Cycle 2 (March 2022)	Document progress achieved during 2017-2021 Set goals for April 2022 – March 2027
Cycle 3 (March 2027)	Document progress achieved during 2022-2026 Set goals for April 2027 – March 2032

Each successive five year plan will include documenting progress achieved, setting common goals for the task force and communicating agency-specific goals. This will help maintain open communication between agencies, assure action is taken to resolve issues, coordinate the agencies' emergency response efforts, and facilitate the collaborative resolution of issues identified in the future.

Planned accomplishments for 2017-2022 are provided on the following page.

Key SRWSTF accomplishments planned for 2017-2021 include*:

Year 1 (April 2017 – March 2018)

1. Execute an MOU between DWR, LADWP, and Metropolitan for coordinating emergency responses
2. Determine the applicability of lessons learned from seismic events in Japan, Chile and New Zealand
3. Compare DWR/LADWP/Metropolitan approaches to seismic assessments at the Pearblossom Plant
4. Discuss vulnerability assessments of aqueduct power systems with Southern California Edison (SCE)
5. Inspect an SDG&E facility to learn about mitigation measures employed to increase power system resilience

Year 2 (April 2018 – March 2019)

1. Conduct workshop to explore potential aqueduct interties
2. Establish a leadership structure for a coordinated response to major events
3. Finalize a 3-agency database of available emergency response resources
4. Conduct a 3-agency table top emergency exercise
5. Develop a ShakeOut Scenario Response and Restoration Plan

Year 3 (April 2019 – March 2020)

1. Finalize a procedure for procuring and coordinating contracts for common efforts (power, materials, fuel, equipment, out of state specialty contractors)
2. Share progress on internal vulnerability assessments and mitigation projects since 2016
3. Reach a consensus on ‘higher probability’ events to investigate
4. Conduct a 3-agency functional emergency exercise
5. Re-assess regional system flexibility (all three systems together)

Year 4 (April 2020 – March 2021)

1. Conduct a second aqueduct workshop that focuses on ‘higher probability’ events
2. Conduct a second multi-agency table top emergency exercise that includes energy utilities (DWR, LADWP, Metropolitan, SCE, PG&E, and So. Cal. Gas Co.)
3. Assess emergency response capabilities and identify gaps
4. Initiate project work on an aqueduct intertie (should a promising one be identified)

Year 5 (April 2021 – March 2022)

1. Conduct a second 3-agency functional emergency exercise that includes energy utilities (DWR, LADWP, Metropolitan, SCE, and So. Cal. Gas Co.)
2. Report on 2017-2021 accomplishments and finalize 5-year action plan for April 2022-March 2027

*This is merely a list of high level collaborative activities which does not include agency specific actions.

APPENDICES

The appendices include:

Appendix 1	SRWSTF Functions and Responsibilities
Appendix 2	Goals and Objectives
Appendix 3	Workshop Agenda
Appendix 4	List of Attendees
Appendix 5	Workshop Presentations
Appendix 6	Fixed Assumptions
Appendix 7	Metropolitan's Emergency Resource Mix
Appendix 8	Aqueduct Workshop Findings
Appendix 9	Oversight Committee briefing materials
Appendix 10	Conference Call Notes on "Seismic Performance of Large Equipment"

Appendix 1

SRWSTF Functions and Responsibilities

Seismic Resilience Water Supply Task Force

Functions and Responsibilities

Management Oversight Committee

Members:
DWR: Jeanne Kuttel, David Duval
MWD: Gordon Johnson, Jim Green
DWP: James Yannotta, Susan Rowghani

Seismic Resilience Team

Members:
DWR: Dave Rennie, Phil LeCocq
MWD: David Clark, Mike Rojas
DWP: Craig Davis, Mike Grahek

Public Relations

Scope: Coordinate multi-agency press release (as-needed)
Members:
DWR: Doug Carlson
MWD: Armando Acuna
DWP: Joe Ramallo, Amanda Parsons
Mayor's Office: Vicki Curry

Working Groups (WG's)

Aqueduct Assessments and Mitigation

Scope: Assess aqueduct vulnerabilities and identify potential system improvements with regional seismic resiliency benefits. Identify pro-active measures to reduce infrastructure repair durations. Recommendations should consider MCE and other more probable scenarios.

Members:
DWR: Dave Rennie; Phil LeCocq
MWD: Greg De Lamare
DWP: Craig Davis

Non-aqueduct Assessments and Mitigation

Scope: Assess water system components impacting overall seismic resiliency of imported water supplies and investigate emerging technology to improve seismic resiliency.

Members:
DWR: Dave Rennie; Phil LeCocq
MWD: Greg de Lamare; R. Hernandez
DWP: Craig Davis; Mike Grahek

Emergency Response

Scope: Prepare for a coordinated multi-agency response to emergency events involving one or more aqueducts. Conduct occasional table top and functional joint agency emergency exercises. Perform periodic operational intertie exercises.

Members:
DWR: Bill Croyle
MWD: Ian Whyte
DWP: Patrick Horton, Mike Grahek

June 5, 2017

Appendix 2

Goals and Objectives

2016 AQUEDUCT WORKSHOP

Seismic Resilience Water Supply Task Force

GOALS AND OBJECTIVES

1. OVERALL TASK FORCE GOALS:

- Revisit historical assumptions regarding potential aqueduct outages
- Establish a common understanding about each agency's aqueduct vulnerability assessments, projected damage scenarios and planning assumptions
- Discuss ideas for improving the resiliency of Southern California's imported water supplies through multi-agency cooperation

2. SPECIFIC WORKSHOP OBJECTIVES:

For the "Great California ShakeOut" 7.8M event:

Establish consensus on:

- Base timeline for restoration of partial aqueduct flows
- Timeline for restoration of full aqueduct capacities
- Regional priorities for aqueduct repairs

Identify:

- Options to accelerate the restoration of partial aqueduct flows acting as one agency
- Key issues to be investigated further (beyond the workshop)
- Next steps

The Great Southern California ShakeOut

***Scenarios of lesser damage can be considered after the workshop**

Updated 6/6/2017

Appendix 3

Workshop Agenda

2016 AQUEDUCT WORKSHOP

Seismic Resilience Water Supply Task Force

AGENDA

8:00 a.m.	**1. Introductions/Overview** – Purpose – Objectives, Approach	**D. Clark/M. Thomas**
8:15 a.m.	**2. Description of Regional Water System** – Local and Imported Resources – System Management	**J. Safely**
8:30 a.m.	**3. Overview of Seismic Event Impacts** – Assumptions	**C. Davis/K. Hudnut**
9:00 a.m.	**BREAK**	
	4. Aqueduct Damage Assumptions	
9:15 a.m.	– MWD	**G. deLamare**
9:45 a.m.	– DWR	**D. Rennie/P. LeCocq**
10:15 a.m.	– LADWP	**C. Davis**
11:00 a.m.	– Q&A	
11:15 a.m.	**5. Baseline Post-Event Water Supply**	**M. Rojas**
11:30 a.m.	**LUNCH**	
12:30 p.m.	**6. Key Priorities and Issues**	**L. Shraibati/M. Thomas**
1:00 p.m.	**7. Aqueduct Repair Timeline Refinement**	**M. Thomas**
1:30 p.m.	**8. Creativity Session—Improving the Regional Response**	**M. Thomas**
3:00 p.m.	**BREAK**	
3:15 p.m.	**9. Next Steps**	

Updated 6/6/2017

Appendix 4

List of Attendees

Black & Veatch
Arne Nervik
Department of Water Resource
Rob Barry
Dave Brown
Kenneth Carroll
Blaine Laumbach
Philip LeCocq
Frank Llamas
Doug McElvain
Steve Nicols
Cameron Poya
Dave Rennie
Sukhbir Singh
Don Walker
Jamal Zumot
GeoPentech
Tom Freeman
Alexandra Sarmiento
Los Angeles Department of Water and Power
Abebaw Anbessan
Craig Davis
Michael Grahek
Chris Heron
Patrick Horton
Jianping Hu
Kevin Mass
Tom O'Rourke
Adam Perez
Joe Resong
Susan Rowghani
Charles Scawthorn
Francesco Tatone
Jeff Tyson

Metropolitan Water District
Mohsen Beikae
Robb Bell
Glen Boyd
David Clark
Greg de Lamare
Tim Gamble
Steve Heathcoat
Chris Hill
Gordon Johnson
Rebecca Kimitch
Laura Lamdin
Howard Lum
Keith Male
Albert Rodriguez
Ron Rodriquez
Mike Rojas
Jack Safely
John Shamma
Rick Shpall
Lilly Shraibati
Michael Thomas
John Wallace
Paul Weston
Ian White
Office of Mayor Eric Garcetti
Marissa Aho
Private Contractor
Gregg Korbin
Bill Martin
Jim Seal
Al Wattson
USGS
Dale Cox
Ken Hudnut

Appendix 5

Workshop Presentations

SEISMIC RESILIENCE WATER SUPPLY TASK FORCE

Aqueduct Workshop
March 30, 2016

Colorado River Aqueduct (CRA)
Los Angeles Aqueduct (LAA)
California Aqueduct, East and West Branches

Agenda

- Introductions/Overview
- Southern California Water Systems
- Overview of Seismic Event Impacts

Break

- Aqueduct Damage and Recovery (by Agency)
- Post-Event Water Supply Recovery

Lunch

- Feedback on Key Issues
- Creativity Session

Break

- Next steps

Background

- Resilience by Design
  - Issued by Los Angeles Mayor Eric Garcetti
  - Recognized significance (and vulnerability) of water
  - Recommended LADWP/DWR/MWD Task Force
- Catalyst for formalizing ongoing collaboration

Task Force Goals

- Revisit historical assumptions about aqueduct outages
- Establish a common understanding about each agency's vulnerability assessments
- Discuss ideas for improving the resiliency of imported water supplies through multi-agency cooperation

Aqueduct Workshop Objectives

"Great California ShakeOut Scenario"

- Establish consensus on:
  - Base timeline for restoration of partial aqueduct flows
  - Timeline for restoration of full aqueduct capacities
  - Regional priorities for aqueduct repairs
- Identify:
  - Options to accelerate initial repairs acting as one agency
  - Key issues to be investigated further
  - Next steps

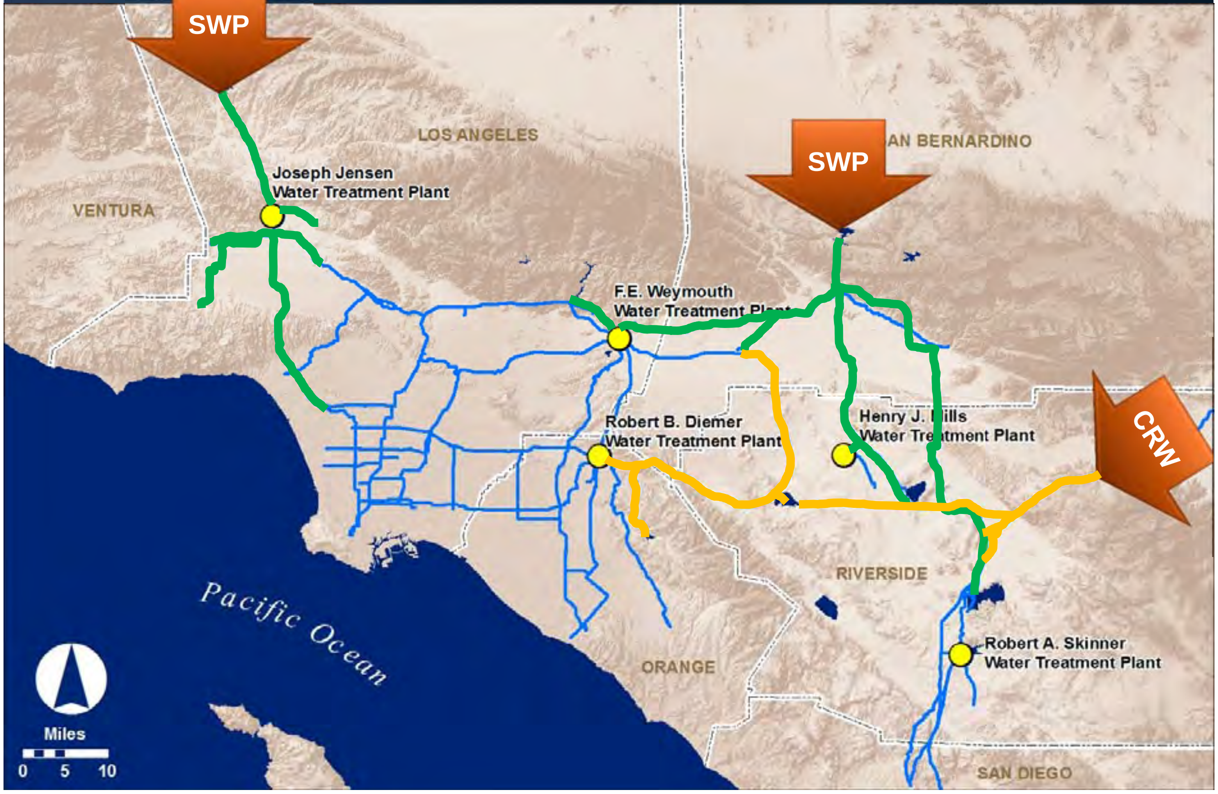
Sources of Water for Southern California

Metropolitan's Service Area

- 6 County region
  - 5,200 square miles
  - ~19 million residents
  - $1 trillion economy
  - 26 Member Agencies
- Retail Demand
  - ~ 4 million acre-feet
- Water Supply
  - ~50% Local water
  - ~50% Imported water

SWP Demand Areas

CRW Demand Areas

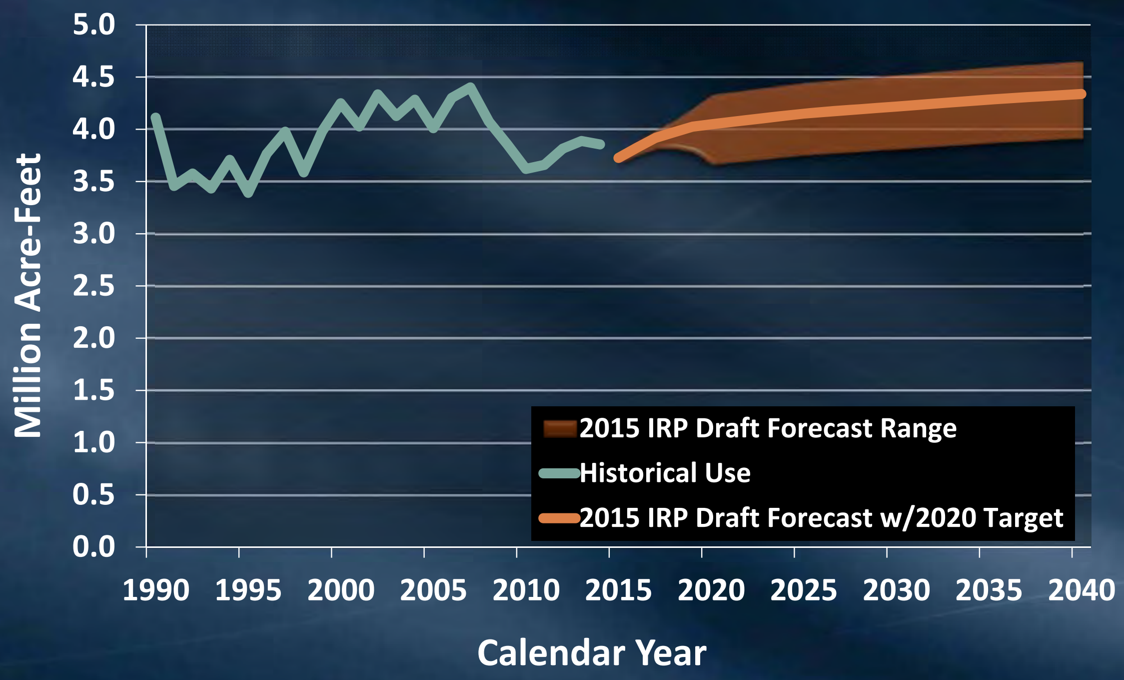


Blended Area

2015 Operation

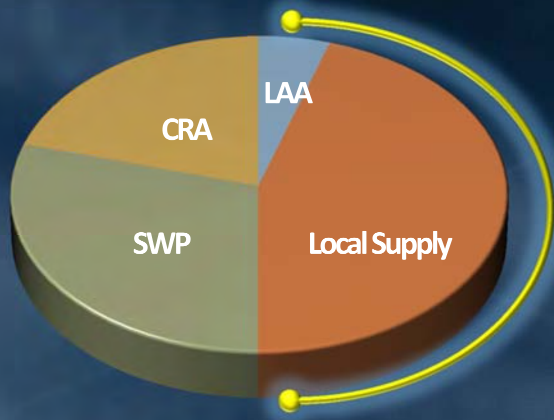
Total Service Area Demands

Demand with Conservation and WUE Target



Typical Water Supply

Average 2005-2015



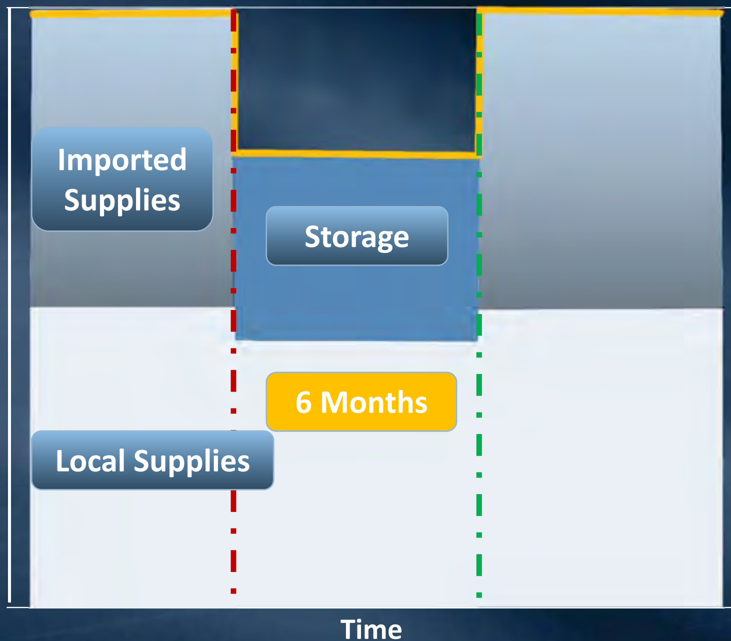
Current – 50% Local

Approximately equal amounts of imported and local resources

Emergency Storage

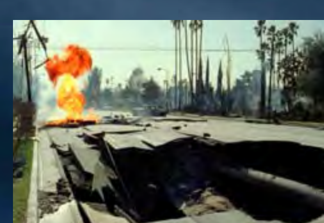
- Metropolitan reserves 626,000 AF of local storage for Catastrophic Supply Interruptions
  - DVL, Lake Mathews, and Lake Perris (Eastern portion)
  - Pyramid Lake and Castaic Lake (Western Portion)
- LAA, SWP, and CRA supplies are unavailable for 6 months
- Non-firm supplies suspended
- Firm Supplies under a 25% cutback

Historical Assumption Regarding Recovery of Imported Supplies



Overview of Seismic Impacts

Switch to Ken Hudnut's File



Morning Break

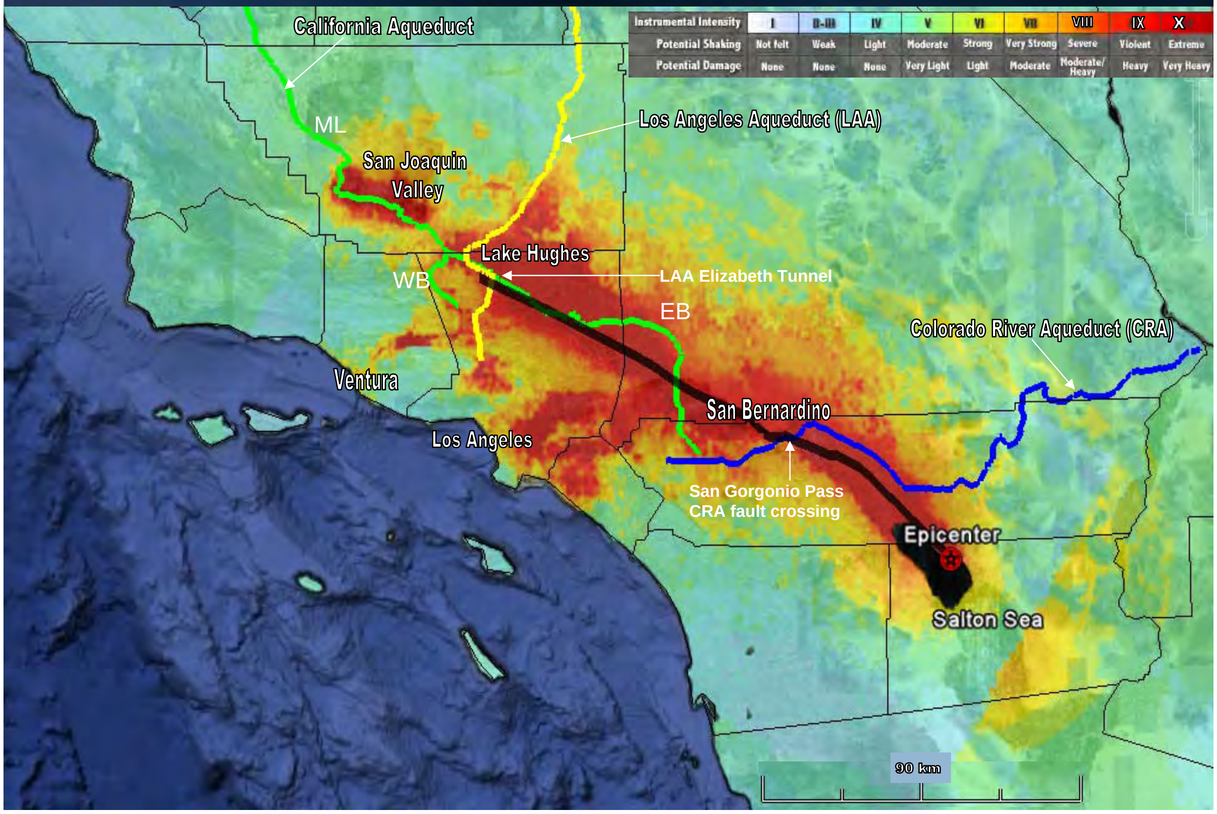


Agency Presentations

- Overview of Agency system
  - Define boundaries
  - Capacity
- Seismic Preparedness
  - Agency approach
  - Emergency Response Capabilities
- Aqueduct Vulnerability Assessments
  - Damage and Recovery Projections
- Conclusions / Key Issues



Great California ShakeOut



SEISMIC RESILIENCE WATER SUPPLY TASK FORCE

Colorado River Aqueduct

Aqueduct Workshop
March 30, 2016

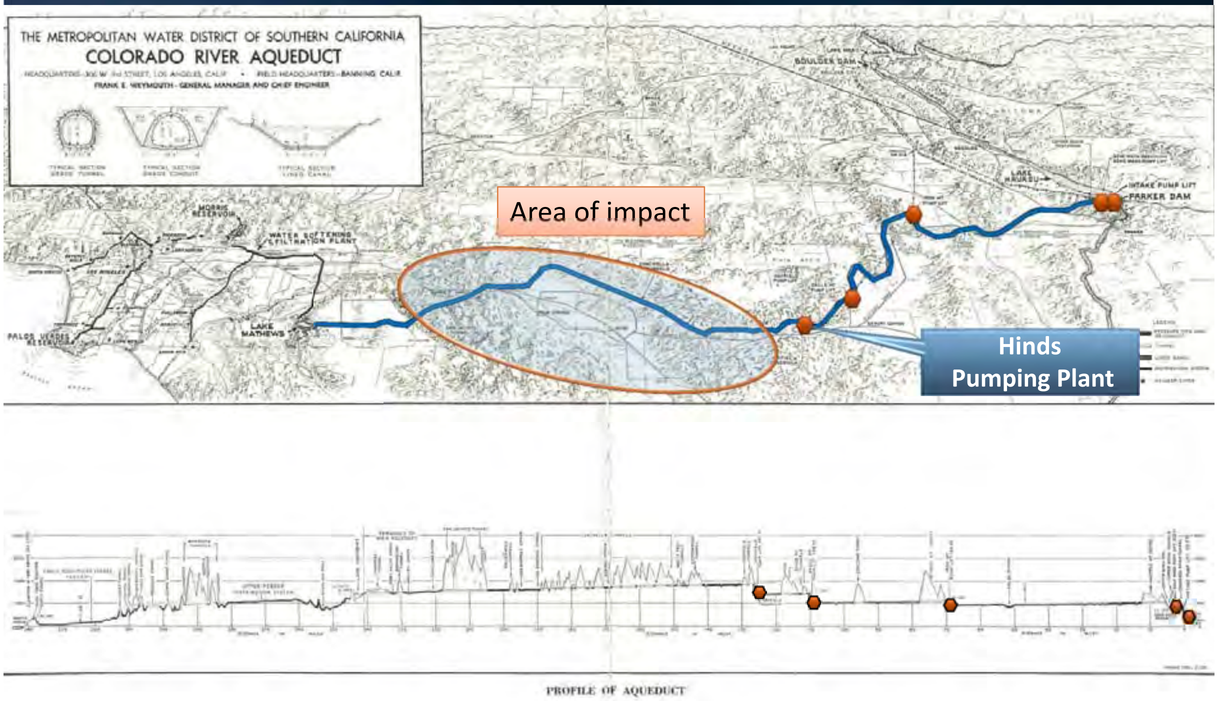
Outline

- CRA Overview
  - System overview & boundary of impacted areas
  - Capacity and actual deliveries
- Seismic Preparedness
  - Metropolitan's approach to reliability
  - Emergency response capabilities
- CRA Vulnerability Assessments
  - Approach and Projected Damage
  - Recovery Projections
    - Partial Capacity
    - Full Capacity
- Conclusions and Next Steps

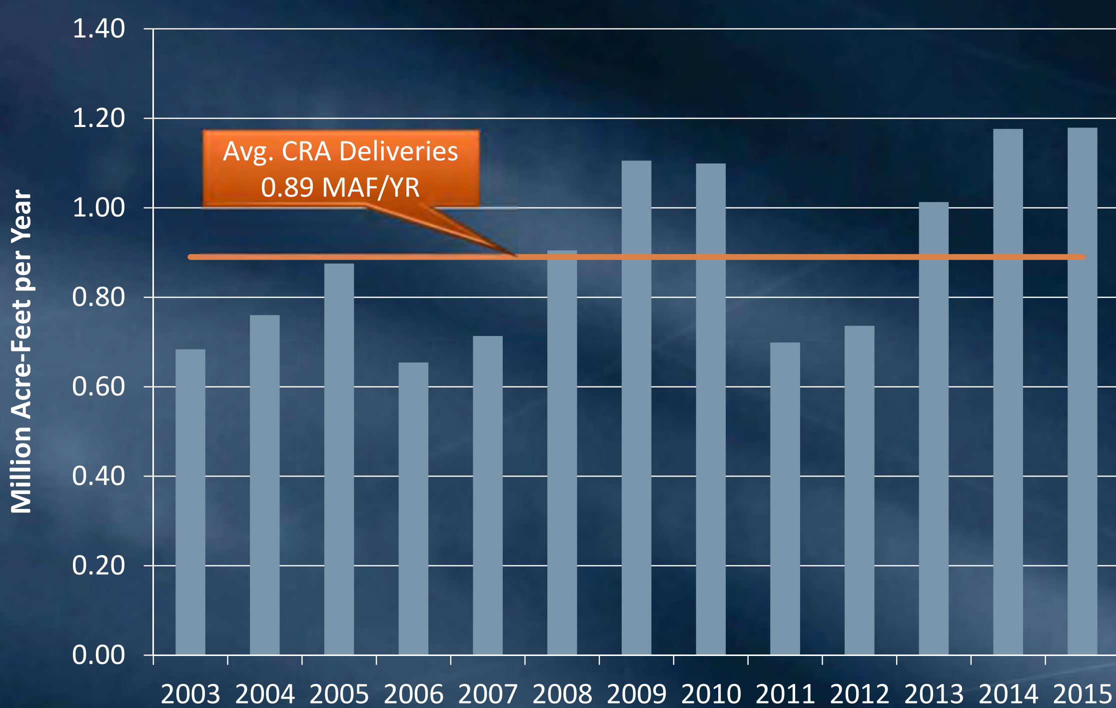
CRA Overview

- 1.2 Million Acre-Ft per year
- Lake Havasu to Lake Mathews
- 242 miles long
  - 63 miles of canals
  - 55 miles of conduits
  - 28 miles of siphons
  - 92 miles of tunnels
- 5 pump stations
- 5 reservoirs

CRA Overview

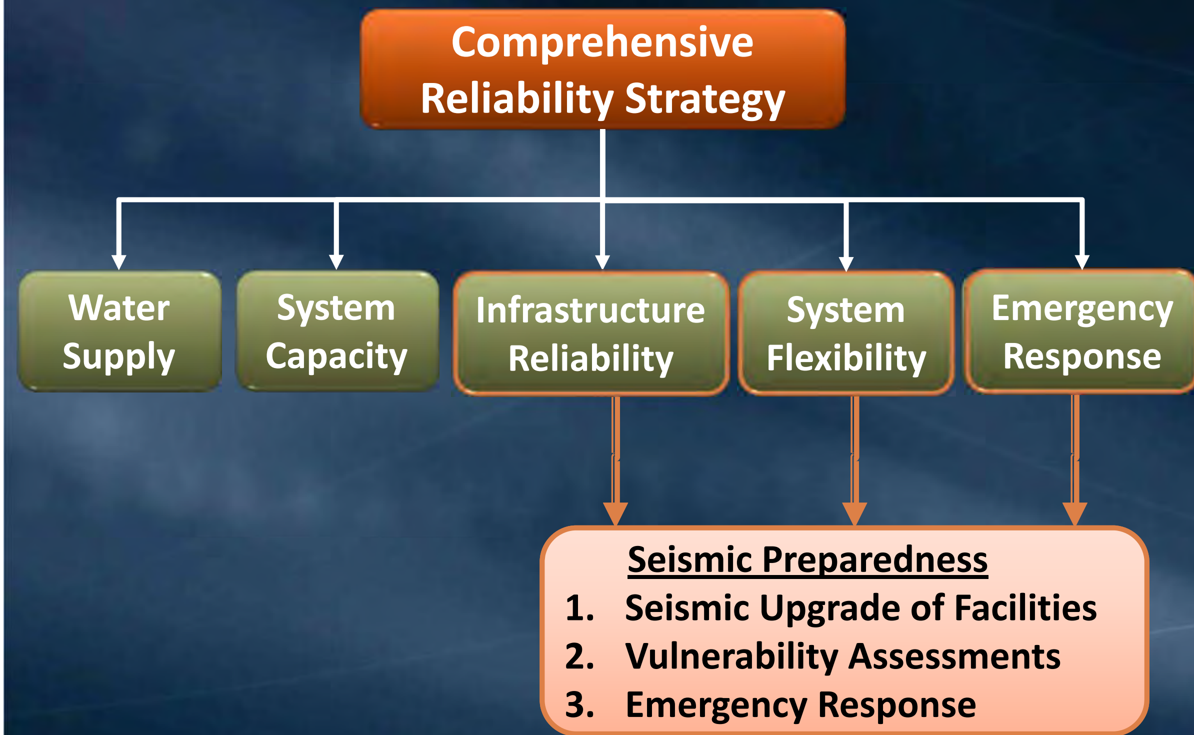


CRA Overview



2003-2015 Actual Deliveries

Seismic Preparedness



Seismic Preparedness

Goals

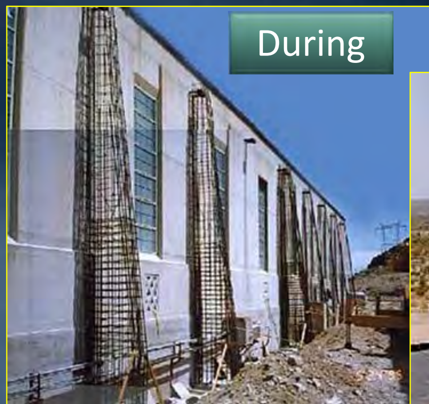
- Maintain continuous deliveries
- Minimize damage to facilities
- Protect building occupants

Approach

- Strengthen individual facilities
- Provide regional storage, & support local development
- Increase distribution system flexibility & redundancy
- Maintain robust emergency response & repair capabilities

Seismic Preparedness

CRA Seismic Upgrade (Pumping Plants)



Steps

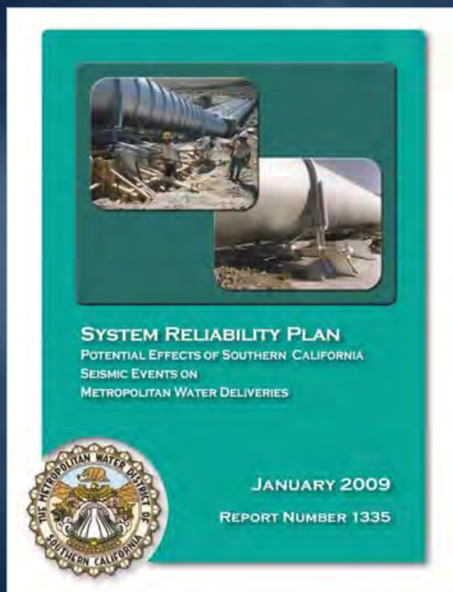
- Evaluations to identify potential deficiencies
- Upgrade to meet latest codes (if needed)
- Periodically reassess

Seismic Preparedness

CRA Seismic Upgrade (Lake Mathews Outlet Tower)

Seismic Preparedness

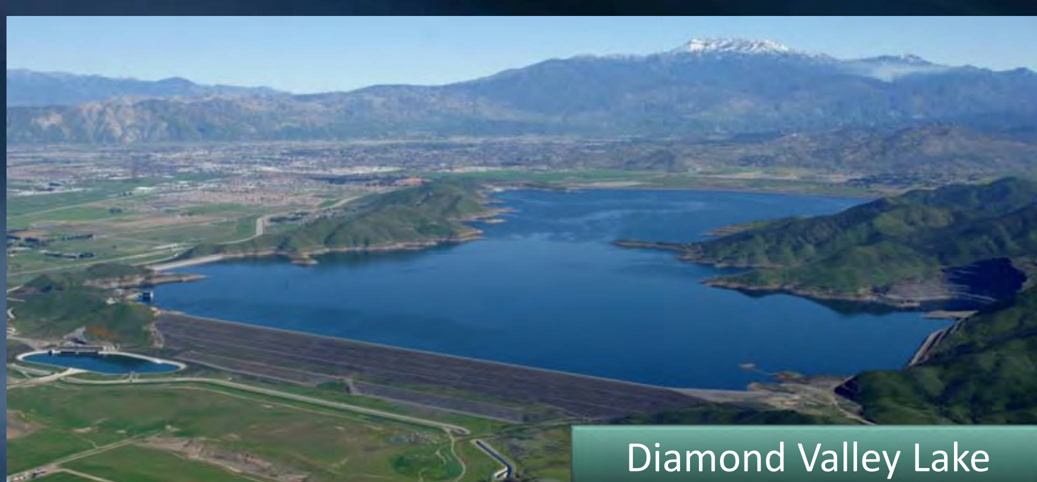
Vulnerability Assessments



- Evaluate impacts on regional water deliveries
- <u>Steps</u>
  - Determine potential damage
  - Estimate outage durations
  - Identify mitigation strategies

Seismic Preparedness

Vulnerability Assessments led to Enhanced Emergency Storage

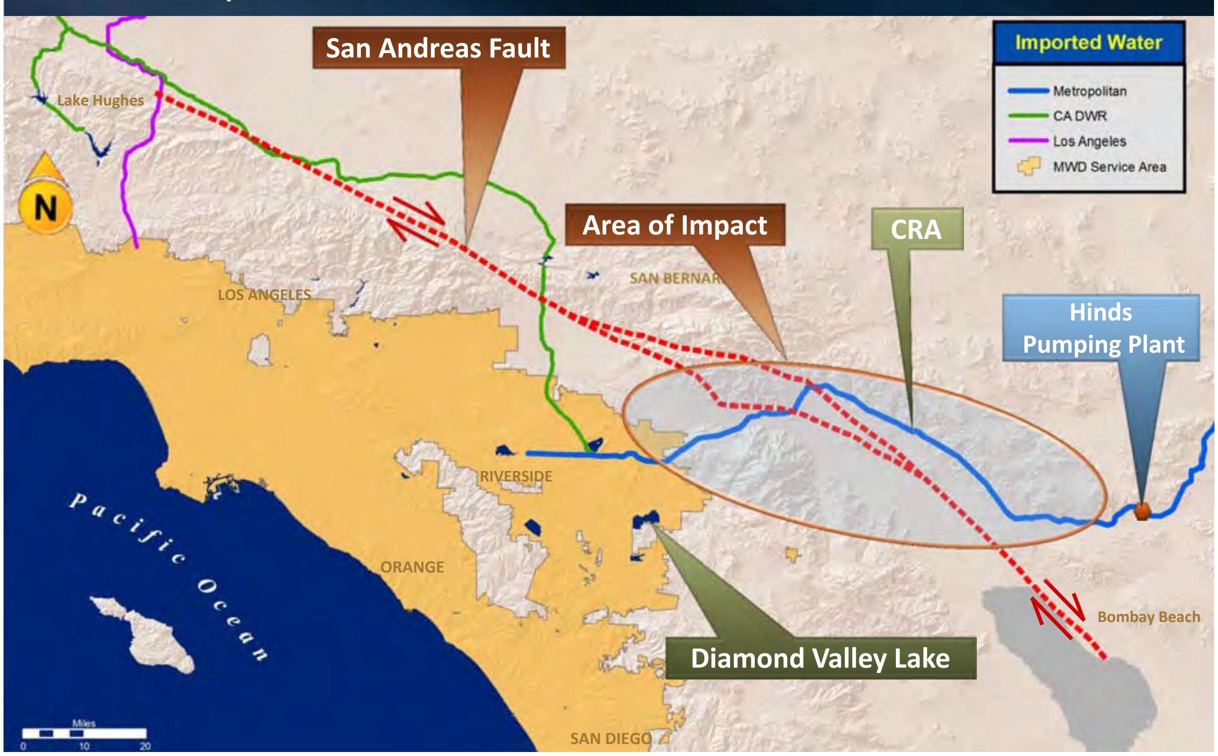


- Constructed on coastal side of major faults
- 800,000 acre-ft capacity
- Can supply wide region

Seismic Preparedness
Emergency Response Capabilities

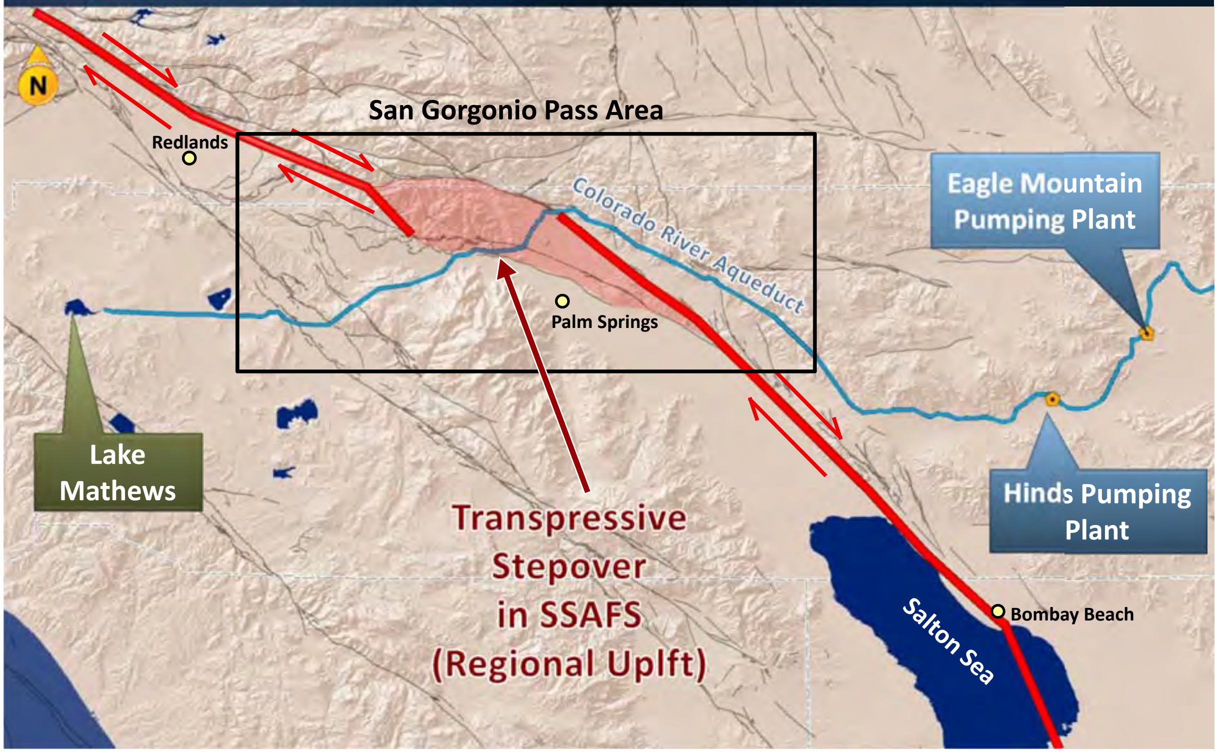
- Key Goal
  - In-house capability to repair 2 simultaneous pipeline breaks
  - *(Ref. MWD summary document)*
- Planning and Training
  - Mutual aid agreements
  - Emergency interconnections
  - Annual exercises

CRA Vulnerability Assessment
Area of Impact for M 7.8 'ShakeOut' Scenario



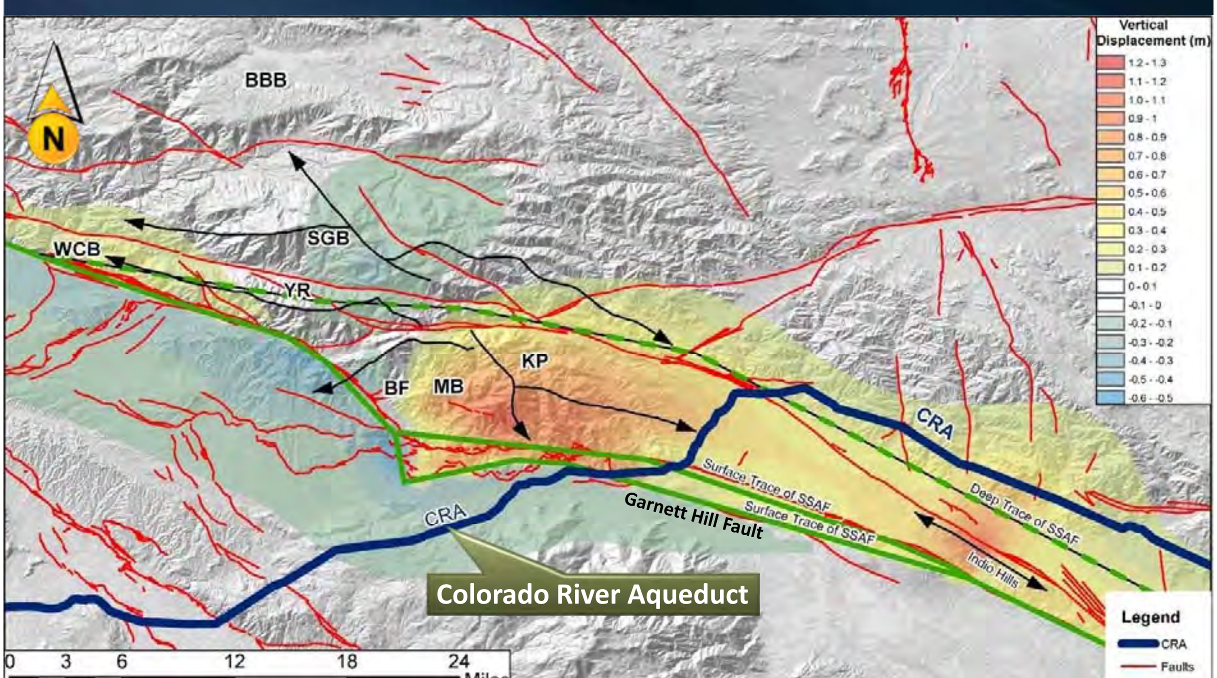
CRA Vulnerability Assessment

Complexity of San Andreas Fault at the San Gorgonio Pass Region



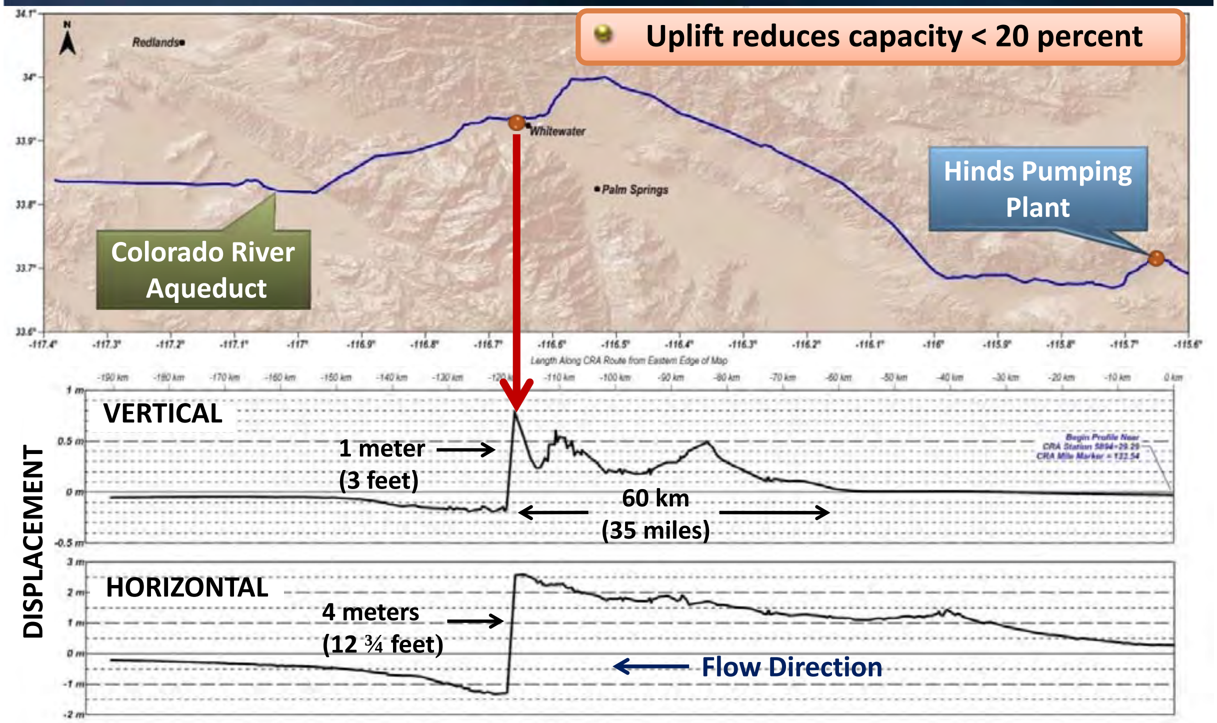
CRA Vulnerability Assessment

Model Results: Uplift in San Gorgonio Pass for M7.8 'ShakeOut'



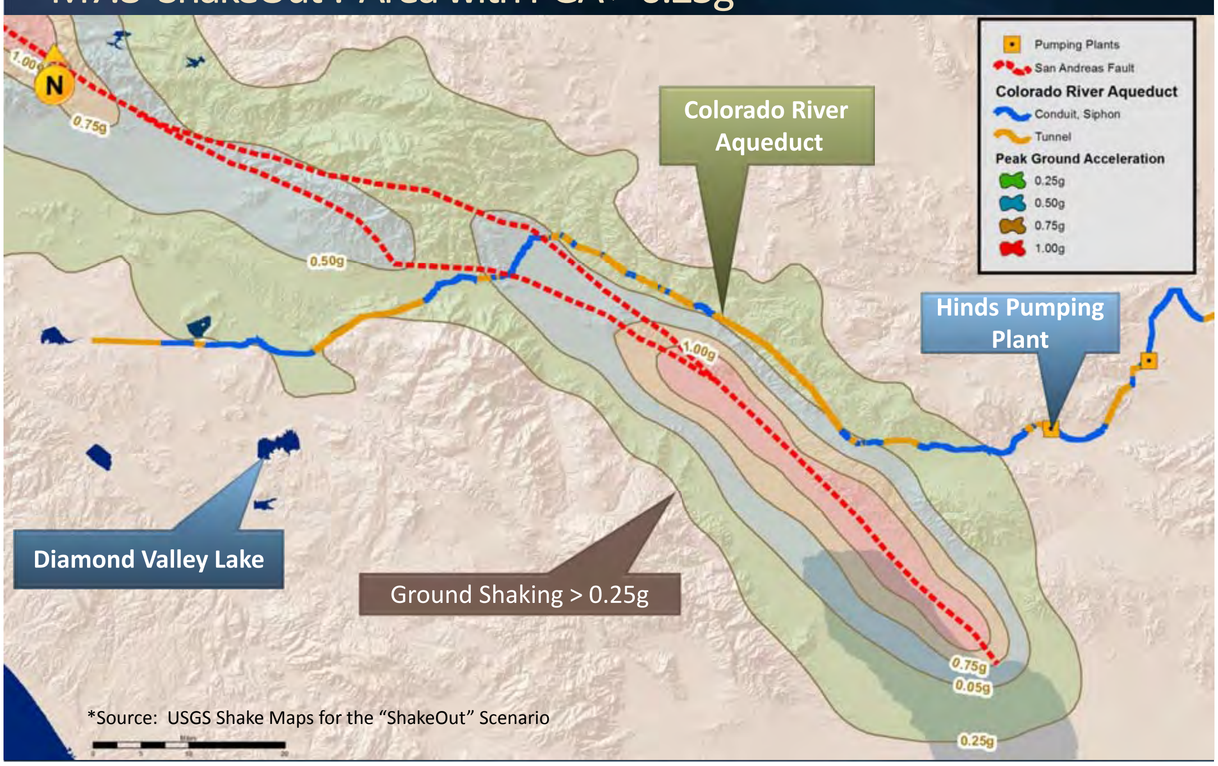
CRA Vulnerability Assessment

Model Results: CRA Displacement for M7.8 'Shakeout'



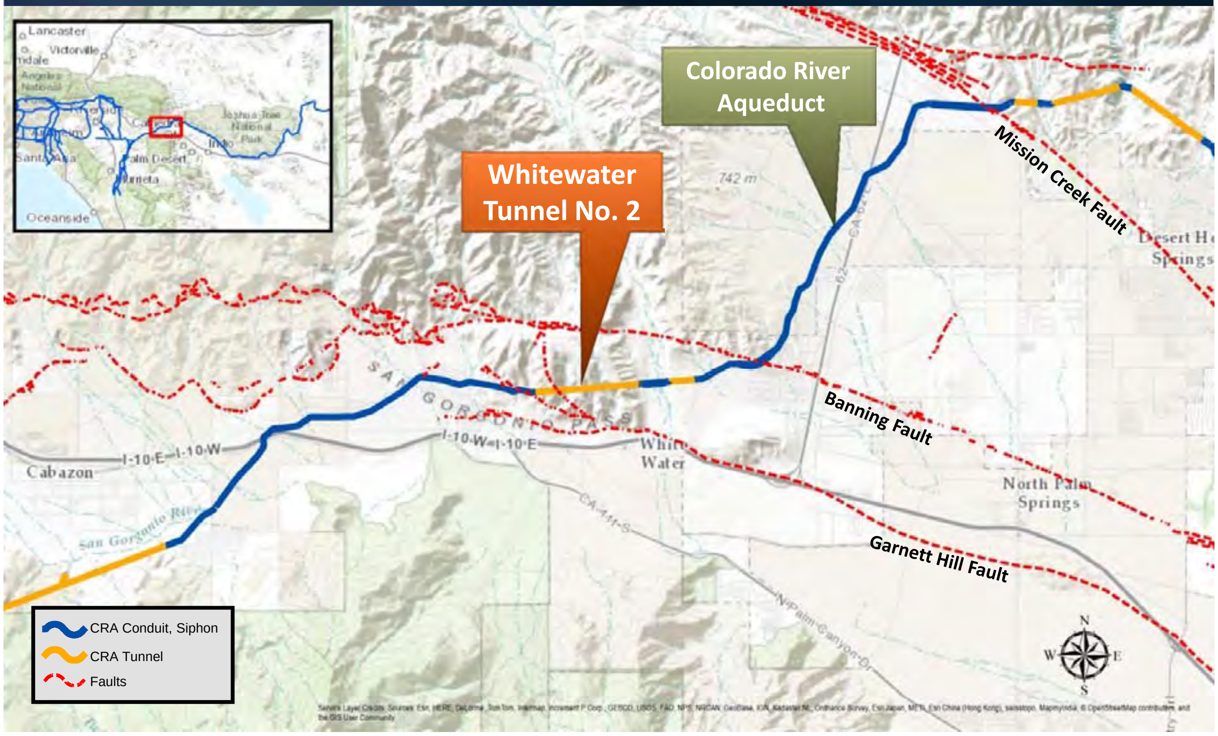
CRA Vulnerability Assessment

M7.8 'ShakeOut': Area with PGA > 0.25g*



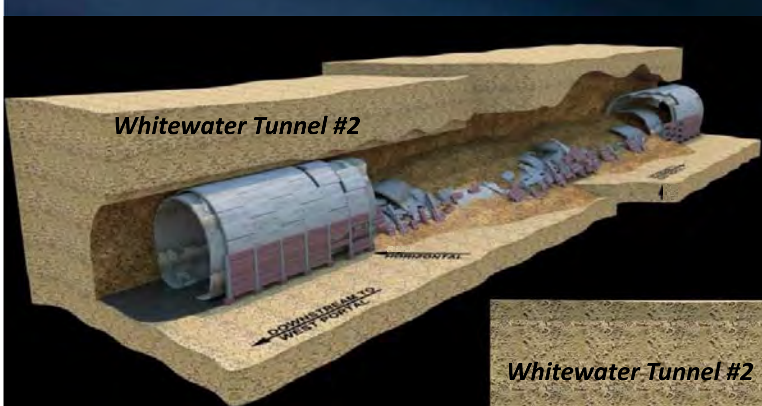
CRA Vulnerability Assessment

M7.8 'ShakeOut': Worst-Case Scenario - Rupture through a Tunnel



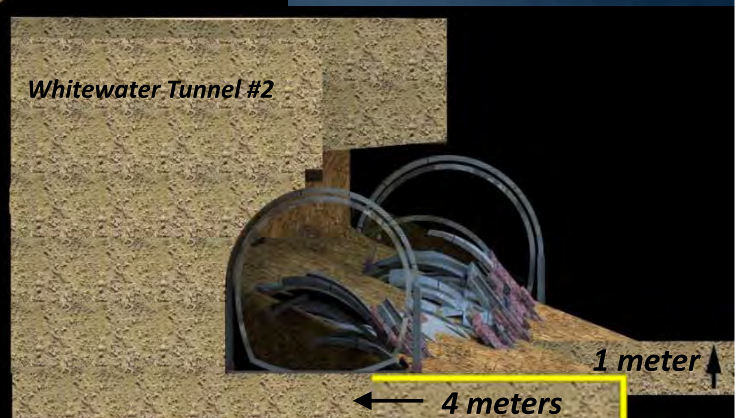
CRA Vulnerability Assessment

Projected Damage – Worst Case Scenario for M7.8 "Shakeout"



Tunnel Impacts

- Partial collapse
- Shaking damage (cracks, spalling) both upstream and downstream



Conduit and Siphons

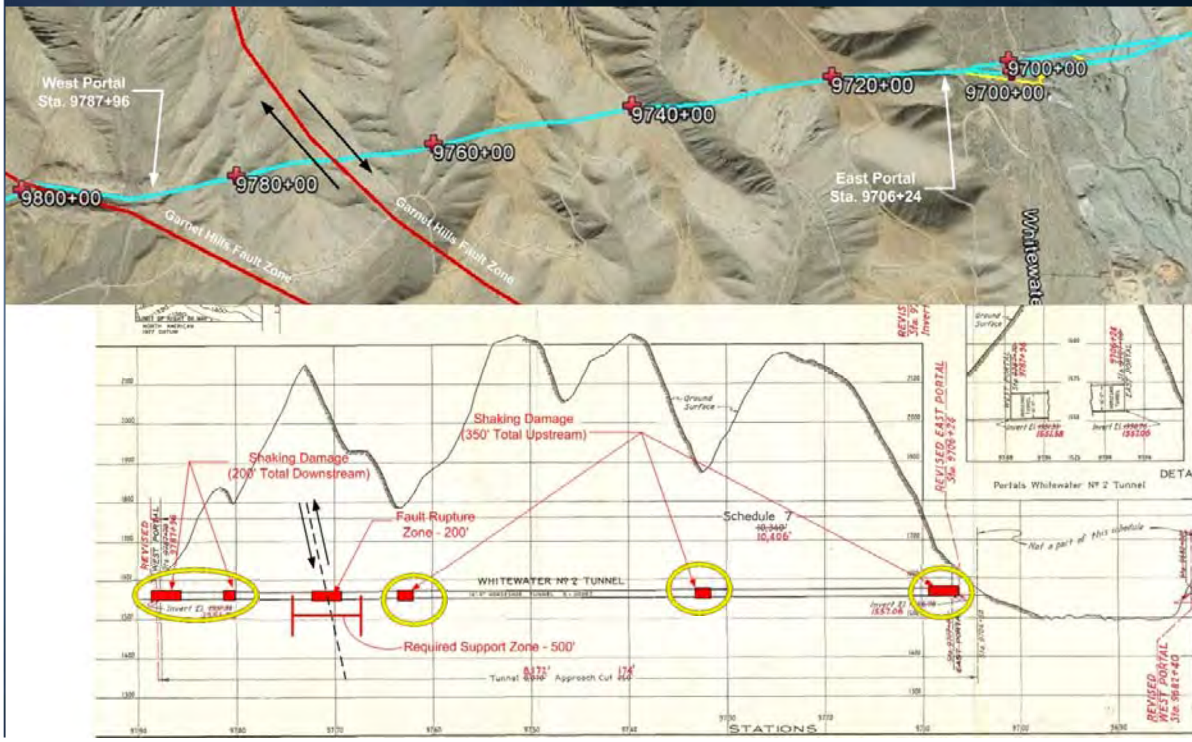
- Multiple damaged areas

Vertical uplift

- Reduces capacity by 20%

CRA Vulnerability Assessment

Projected Damage for Rupture through Whitewater Tunnel #2



CRA Vulnerability Assessment

Recovery Projections – Restoration of Partial Capacity

- Worst case scenario for rupture through Whitewater Tunnel #2 evaluated by MWD staff and consultants in a workshop that included:
  - Geotechnical engineers
  - Tunnel contractors
  - Geologists
  - Metropolitan staff

CRA Vulnerability Assessment

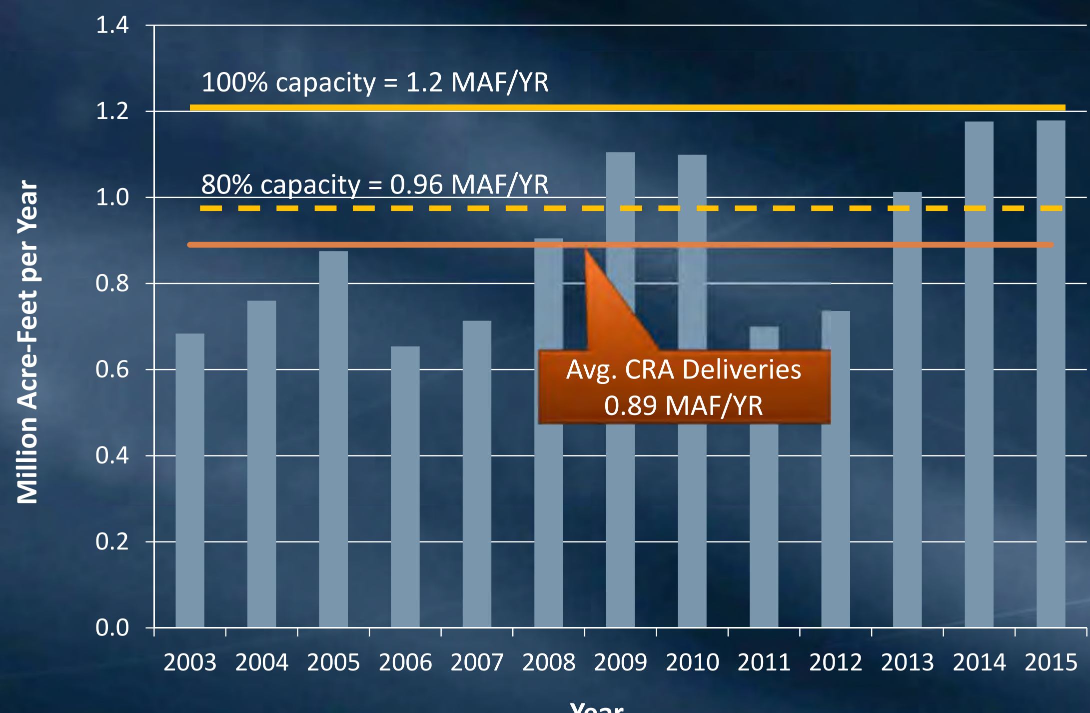
Recovery Projections – Restoration of Partial Capacity

- Worst Case – Displacement at Tunnel
  - Requires: Bypass tunnel around rupture area and repairs to isolated portions of tunnel, conduit, and siphons
  - Estimated duration: Up to 6 months
- More Probable Case – Displacement at Conduit Section
  - Requires: Extensive repairs to conduit section at rupture area, and repairs to isolated portions of conduit, tunnel and siphons
  - Estimated duration: From 2-4 months

Note: CRA pump stations and canal sections are outside of area with high levels of shaking for event and are expected to remain operational

CRA Vulnerability Assessment

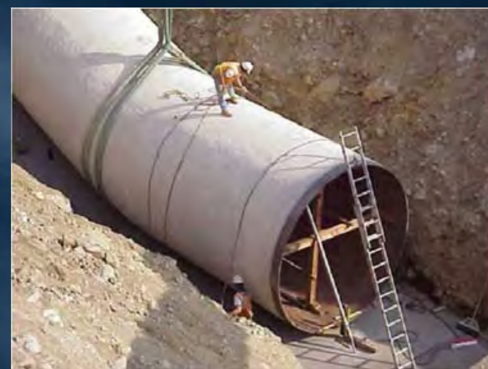
Recovery Projections – Restoration of Full Capacity



CRA Vulnerability Assessment

Recovery Projections – Restoration of Full Capacity

- Worst Case – 35 miles of uplift
  - Requires: 35 miles of 8-ft diameter pipe and a new 200-300 cfs pump station
  - Estimated duration: 36 to 60 months
- Duration will be impacted by
  - Extent of uplift
  - Regional priority and available water supply



Note: The impact of the regional uplift is independent of whether the fault rupture occurs within or outside of a tunnel.

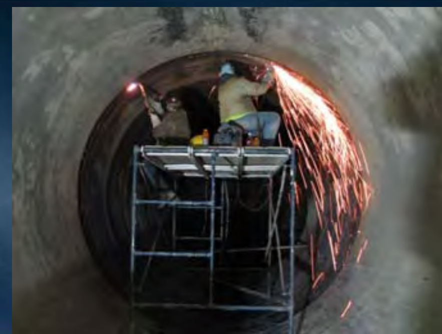
Conclusions

- Metropolitan recognizes potential for deliveries to be disrupted by a large earthquake on the Southern San Andreas Fault System
  - Structural upgrades made at key facilities
  - Emergency storage created on coastal side of fault
  - Emergency response capabilities are continuously evaluated & improved
- ShakeOut Scenario
  - 6-month duration for initial repairs of worst case scenario is consistent with previous estimates (and pre-planning efforts will reduce outage duration)
  - Recovery for the probable scenario is 2-4 months (and will be optimized)
  - Duration to restore full capacity will depend upon specific event and priority of repairs (e.g., 36 to 60 months)

Next Steps

Further Enhancing Seismic Resilience

- CRA Tunnel projects
  - Pre-design repair elements
  - Maintain list of qualified tunnel contractors
  - Stockpile key materials
- Conduct in-basin tunnel study
- Lining PCCP pipe with steel cans and provisions for seismic faults will increase seismic resilience
- Update Metropolitan's System Reliability Study
  - May lead to enhancing distribution system flexibility
- Support Seismic Resilient Water Supply Task Force



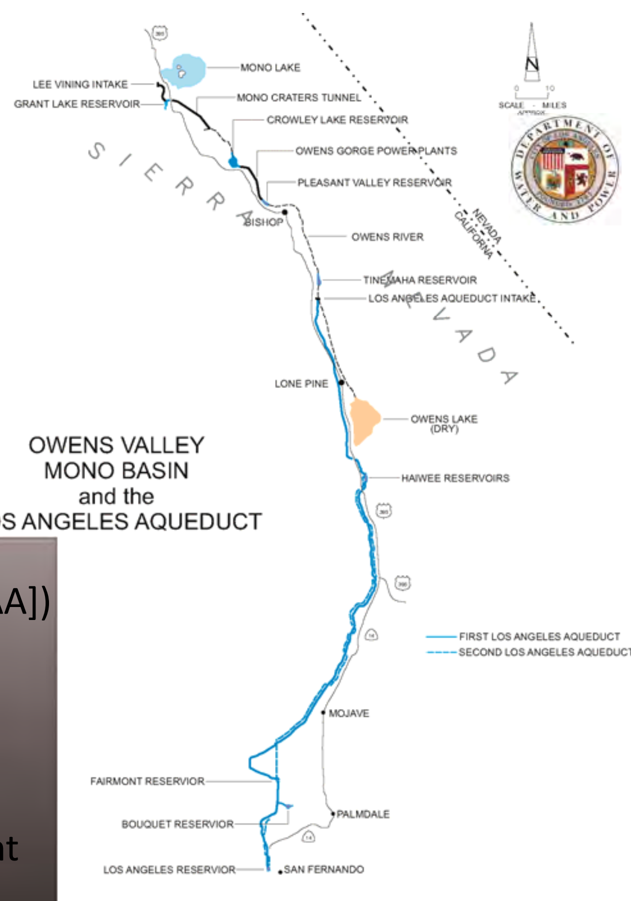
SEISMIC RESILIENCE WATER SUPPLY TASK FORCE

Los Angeles Aqueduct

Aqueduct Workshop
March 30, 2016

Los Angeles Aqueducts

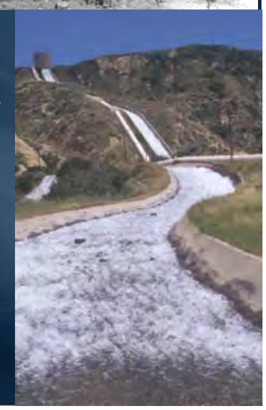
- 1913 – Owens Valley Aqueduct (First Los Angeles Aqueduct [FLAA])
- 1940 –Mono Basin Extension
- 1970 – Second Los Angeles Aqueduct [SLAA]
- Extends from Mono Basin to Los Angeles Aqueduct Filtration Plant



LA Aqueduct

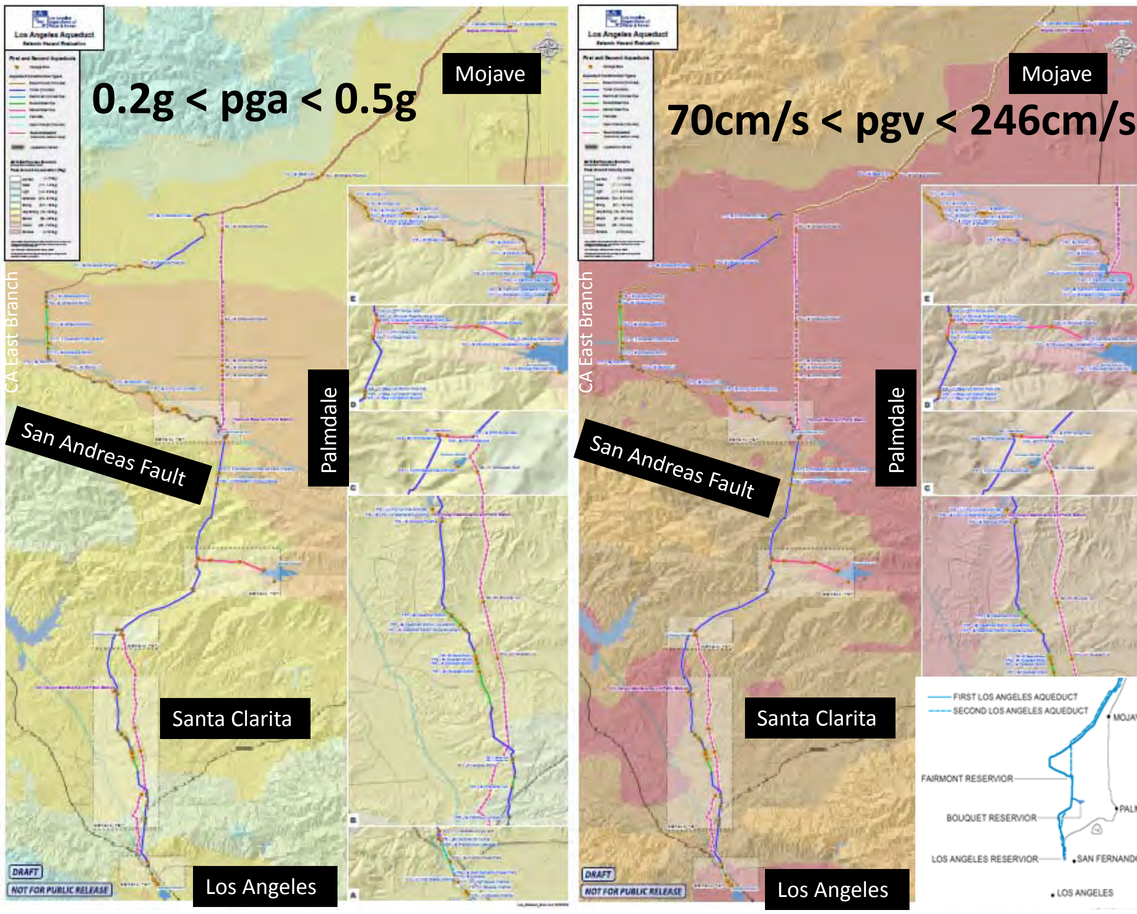
- 1913 - Owens Valley Aqueduct, 485 cfs capacity
- 233 miles, gravity flow to Los Angeles
  - 12 miles pipeline (concrete and riveted steel)
  - 52 miles tunnels
  - 61 miles open channel (37 lined, 24 unlined)
  - 98 miles covered conduit
  - 8 reservoirs
  - 6 power plants

- 1970 - Second LA Aqueduct, 290 cfs capacity
  - 137 miles long, gravity flow from N. Haiwee Res. to LA
  - 69 miles welded steel pipe
  - 64 miles concrete conduits
  - 4 miles other
- 37% water supply to LA (5-yr average)



LAA Assessment of ShakeOut Scenario

- Used USGS defined hazard parameters for ShakeOut Scenario (except landslides)
- Assessment boundary defined by ~0.2g pga contour
- 0.2g < pga < 0.5g [seems low across entire area]
- 70cm/s < pgv < 246cm/s [seems high across entire area]
- 11.5 foot rupture length on San Andreas Fault at crossing
- Liquefaction in large areas in Antelope Valley, Santa Clarita, and LA [seems conservative]
- Landslides assessed based on LADWP expectation



LAA Assessment of ShakeOut Scenario

- Performed High-Level Rapid assessment of FLAA and SLAA to an anticipated ShakeOut Scenario event
- Over 100 total damage locations, from minor to serious
- Estimated damage from ShakeOut hazard parameters
- Identified expected repairs, resources, temporary and permanent repair durations, and priority
- Highlight: **ALL FLOW IMMEDIATELY LOST FROM LAA**

Critical Factors for Restoring LAA Flow

Flow from Owens Valley is halted

- Elizabeth Tunnel dammed up by SAF rupture
- Damage to FLAA and SLAA north of SAF

Flow from Bouquet Canyon Reservoir is halted

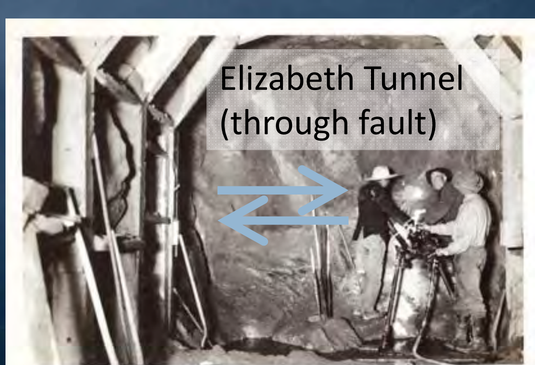
- Damage to Bouquet Canyon Reservoir Inlet/Outlet line
- Damage to Power Plant 1 and Penstocks
- Damage to FLAA and SLAA south of SAF

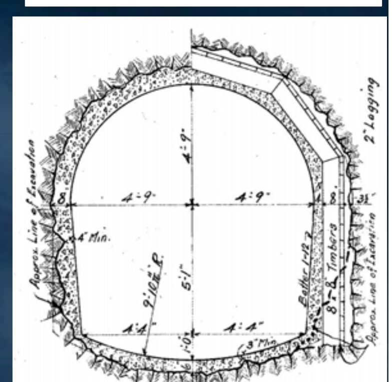
These will be reviewed with more detail in following slides

LAA ShakeOut Damage

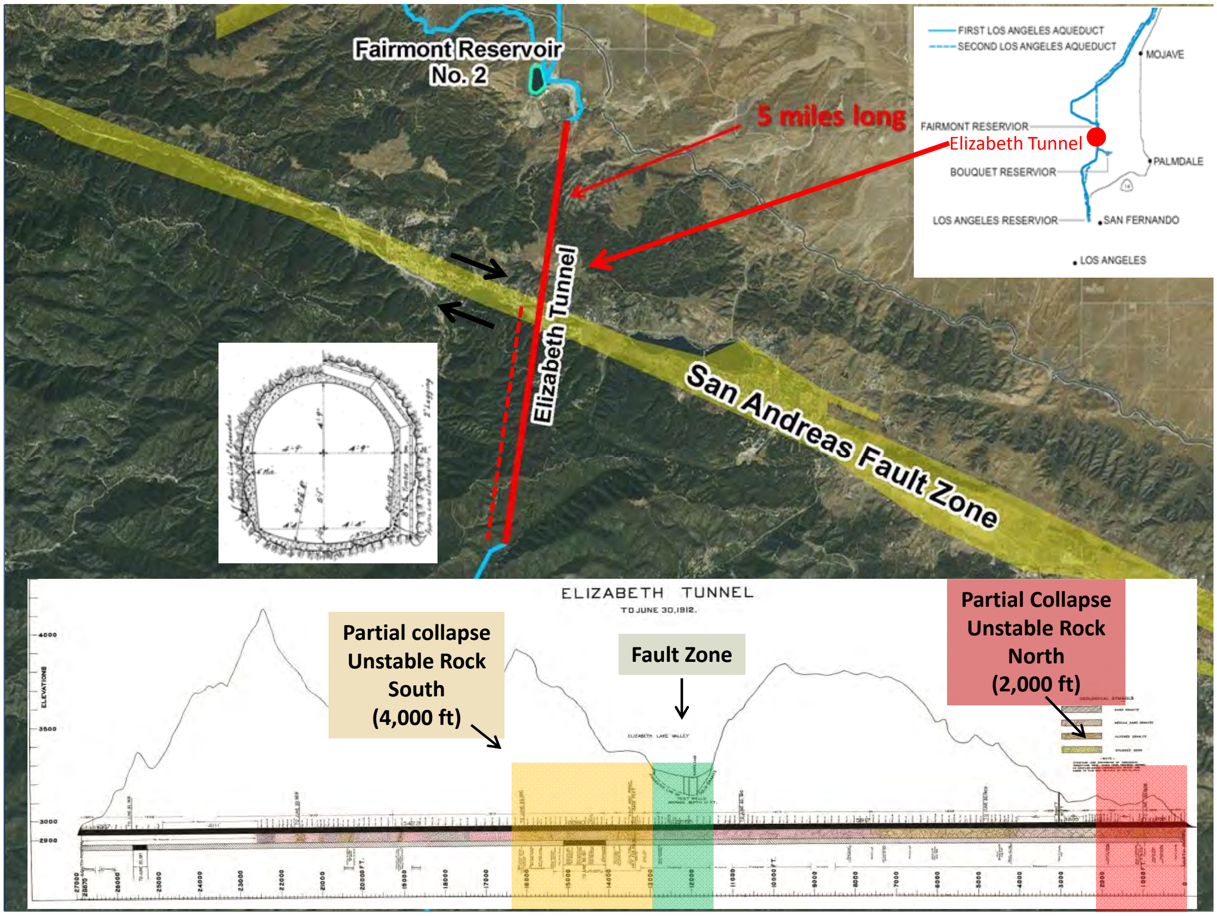
Elizabeth Tunnel

- 1 conduit for both FLAA and SLAA
- 5 miles long
- Horseshoe shaped tunnel
  - 11.5 foot fault offset
  - Collapse at 2 locations in tunnel





Tunnel Cross Section

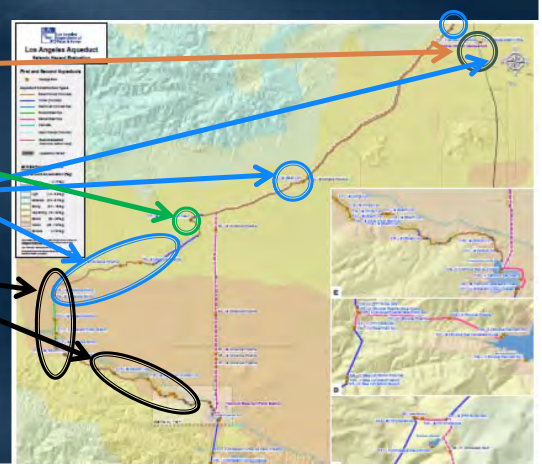


FLAA ShakeOut Damage

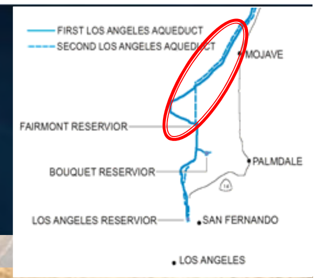
Mojave and Antelope Divisions

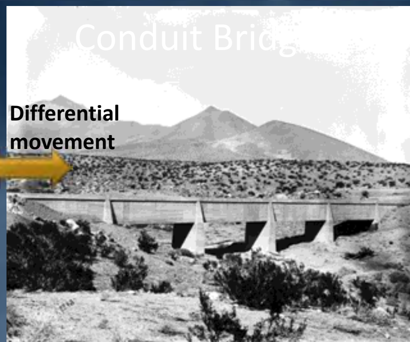
FLAA Mojave and Antelope Valley Divisions

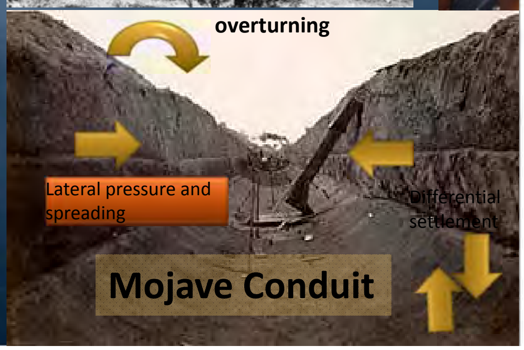
- FLAA
  - Buildings
  - Bridge abutment
  - Differential Settlement
  - Liquefaction
- Fairmont Reservoir No 2
  - Expect to perform well

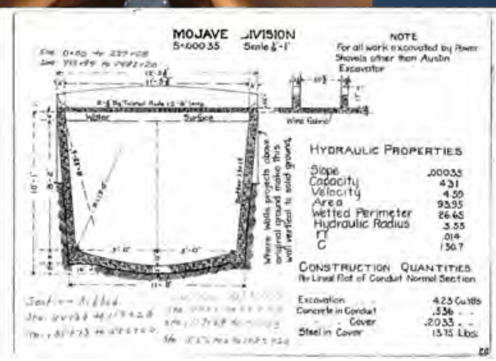


FLAA Mojave and Antelope Division Conduits





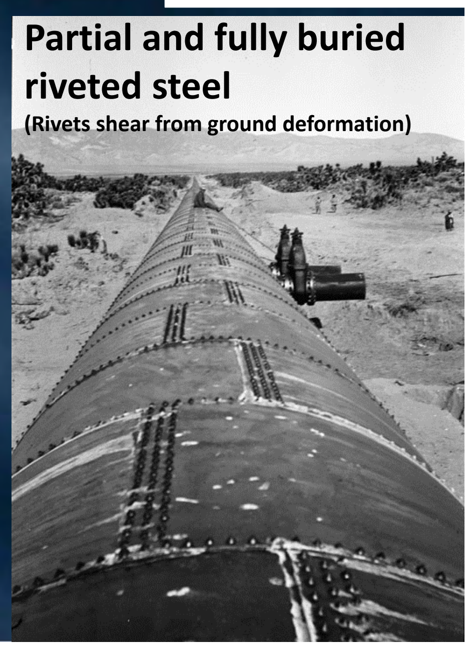




FLAA Mojave and Antelope Division Conduits

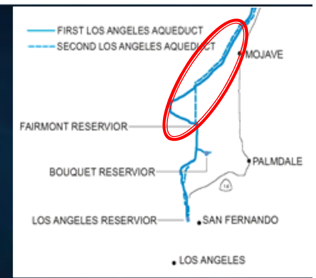
Conduits subject to liquefaction

- Differential settlement up to 24”
- Lateral spreading up to 120”



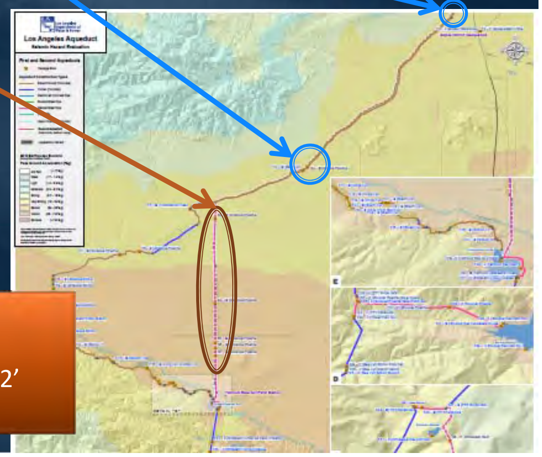
SLAA ShakeOut Damage

Mojave and Antelope Divisions



SLAA Mojave and Antelope Valley Divisions

- Differential settlement
- Liquefaction
  - Settlement up to 12”
  - Lateral Spread up to 25”
- Welded Steel Pipe



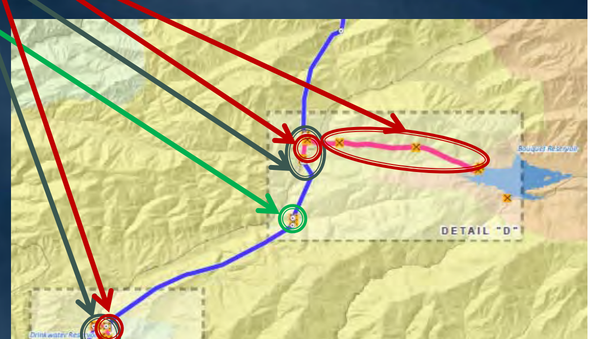
Granada Trunk Line compression failure in Balboa Blvd. from 2’ ground movement

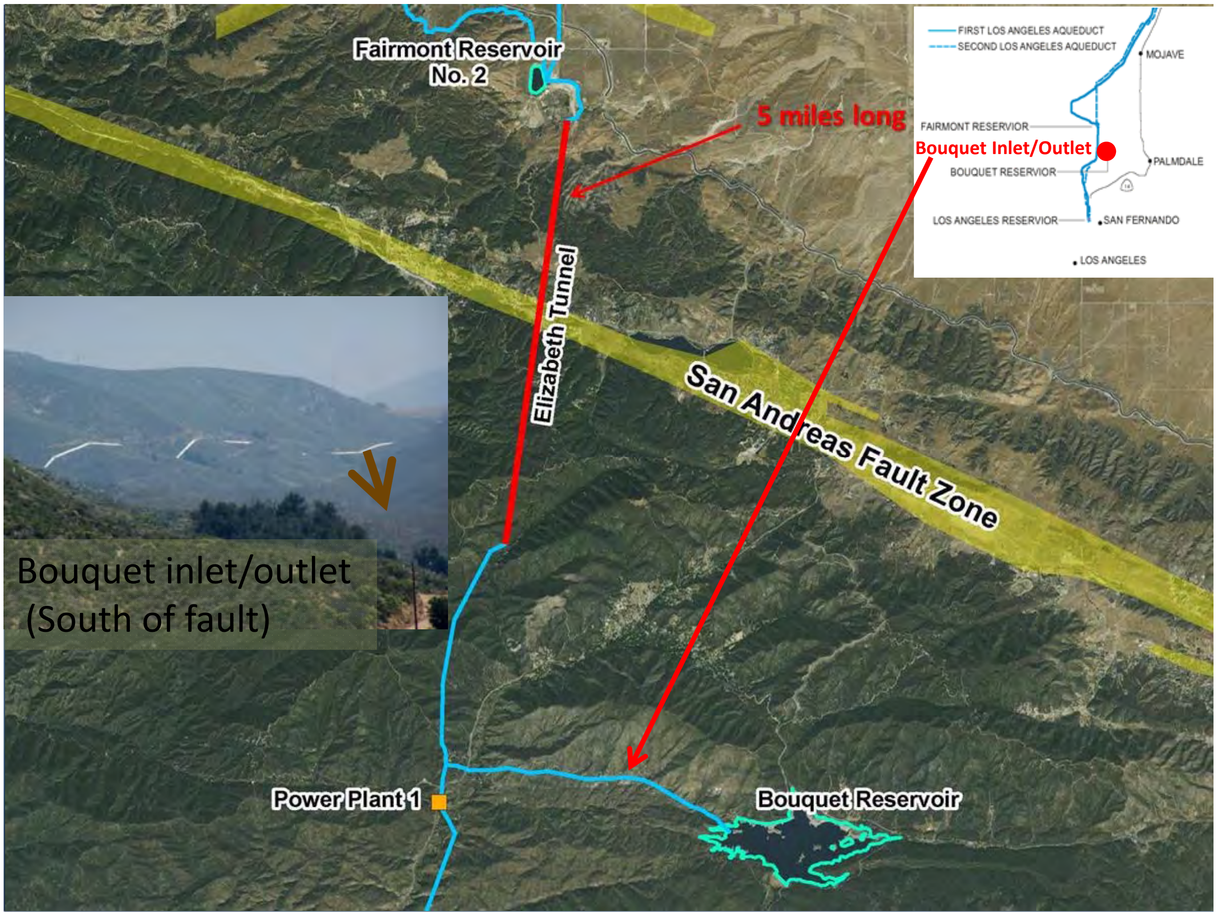
FLAA ShakeOut Damage

San Francisquito and Bouquet Divisions

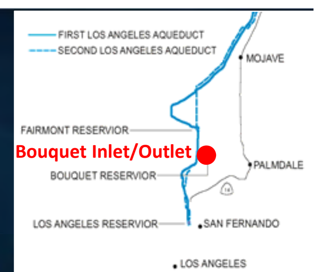
FLAA San Francisquito and Bouquet Divisions

- FLAA
  - Buildings and surge tanks
  - Landslides
  - Pipe supports and movement
- Bouquet Reservoir
  - Expect to perform well
- Drinkwater Reservoir
  - Expected to create concerns, but remain safe





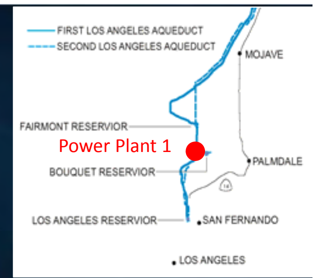
FLAA Bouquet Inlet/Outlet



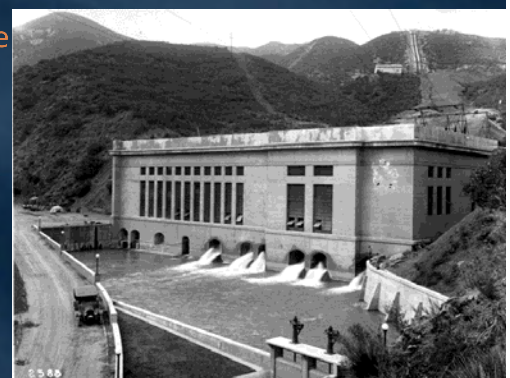
- Bouquet Canyon Reservoir Inlet/Outlet Pipe
  - Landslides
  - Pipe damage at a few locations
  - Severe erosion of slope, removing foundations
  - Access road blockage

Example erosion from pipe failure

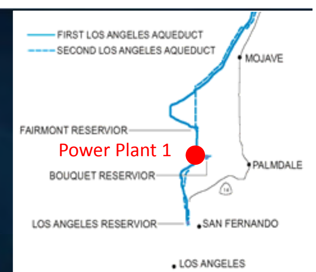
FLAA San Francisquito Division



- San Francisquito Power Plant 1
  - Surge tank damage
  - Penstocks damaged from slope movement
    - Severe erosion and flood powerhouse
  - Building damage, powerhouse potentially unusable

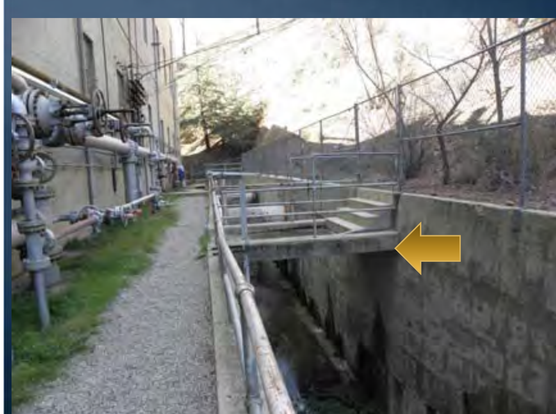


FLAA San Francisquito Division

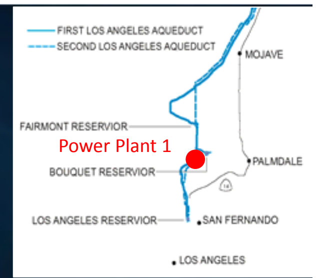


San Francisquito Power Plant 1

- Penstocks buried in large mass of (loose?) fill
- Fill retained by large wall at toe
- High potential for movement, potential wall failure



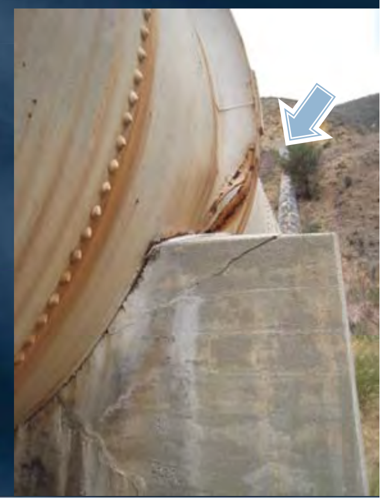
FLAA San Francisquito Division



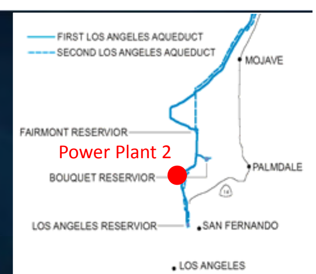
Bee Canyon Siphon (riveted steel pipe)

- Riveted Steel Pipe on Supports
- Soil surcharge
- Ring girder support leg buckling
- Rock fall, potential damage

Buckled and split

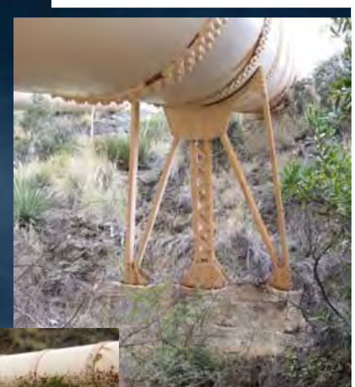


FLAA San Francisquito Division



San Francisquito Power Plant 2 & Drinkwater Reservoir

- Landslides and tunnel tailings debris flow
- Penstocks damaged from slope movement
  - Severe erosion and flood powerhouse
- Building damage, powerhouse potentially unusable
- Surge Chamber Damage
- Access road blockage
- Drinkwater Reservoir and Dam
  - Settlement, cracking
  - Large seepage increase



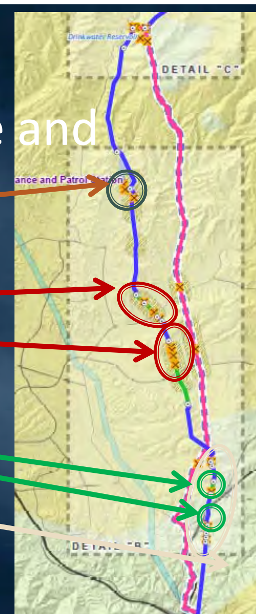
PP2 Penstocks and supports

Landslide
Power Plant 2 & Drinkwater Reservoir

FLAA ShakeOut Damage
Saugus Division

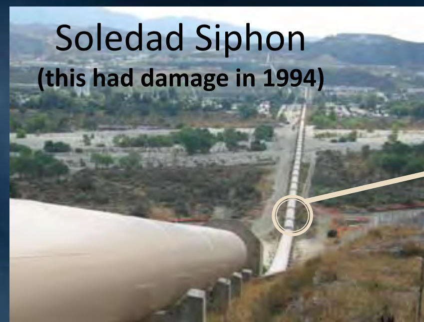
FLAA Saugus Division (Tunnel, concrete and steel pipe)

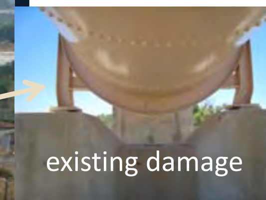
- Buildings
- Liquefaction
- Landslides
- Conduit damage and failures



FLAA ShakeOut Damage

Saugus Division





Elsmere Concrete Siphon

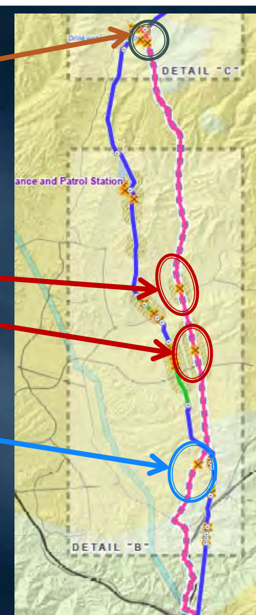
Whitney Concrete Siphon

SLAA ShakeOut Damage

Saugus Division

SLAA Saugus Division (Tunnel, welded steel pipe)

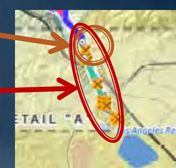
- Large vault
- Liquefaction
- Conduit damage
  and failures



FLAA & SLAA ShakeOut Damage
Cascades and Van Norman Complex

SLAA Saugus Division (Tunnel, cascades, steel pipe, channels, power plants)

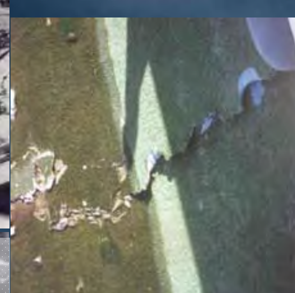
- Potential mechanical problems at power plants
- Liquefaction



FLAA & SLAA ShakeOut Damage
Cascades and Van Norman Complex

- Historic liquefaction damage in 1971 and 1994
- Damage to penstocks in 1971 and 1994

Tailrace, 1971, repeated in 1994



Bypass Channel, 1994 Northridge Earthquake

High Speed Channel, 1994 Northridge Earthquake

Channel failure, differential ground movement & erosion, 1971 San Fernando Earthquake

Channel dike failure, internal erosion (delayed), 1994 Northridge Earthquake

ShakeOut Scenario Repair and Restoration

Critical Restoration Criteria

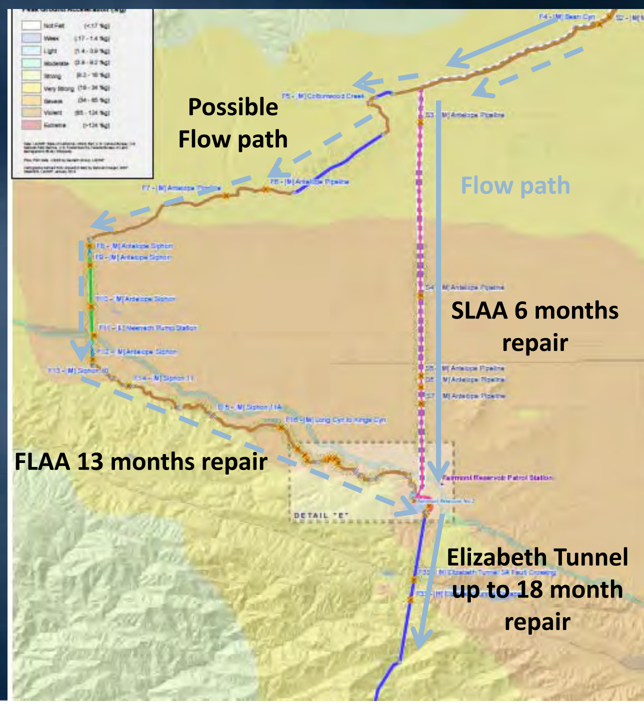
- Bouquet Reservoir water flow restoration
  - Bouquet inlet/outlet (up to 8 months)
  - Power Plants 1 and 2, and conduits operating in between
    - PP1 200 cfs bypass regulating pressure
  - FLAA and/or SLAA below PP2 (note SLAA can bypass PP2)
    - SLAA easiest to restore (<8 months)
    - Cascades and Van Norman Complex (<8 months)
- Owens Valley water flow restoration
  - Elizabeth Tunnel (up to 18 months)
  - FLAA and/or SLAA conduits north of SLAA (<18 months)

Post-Earthquake Operating Scenario Bouquet Canyon Reservoir to LA

PRELIMINARY

Post-Earthquake Operating Scenario Elizabeth Tunnel and North

PRELIMINARY



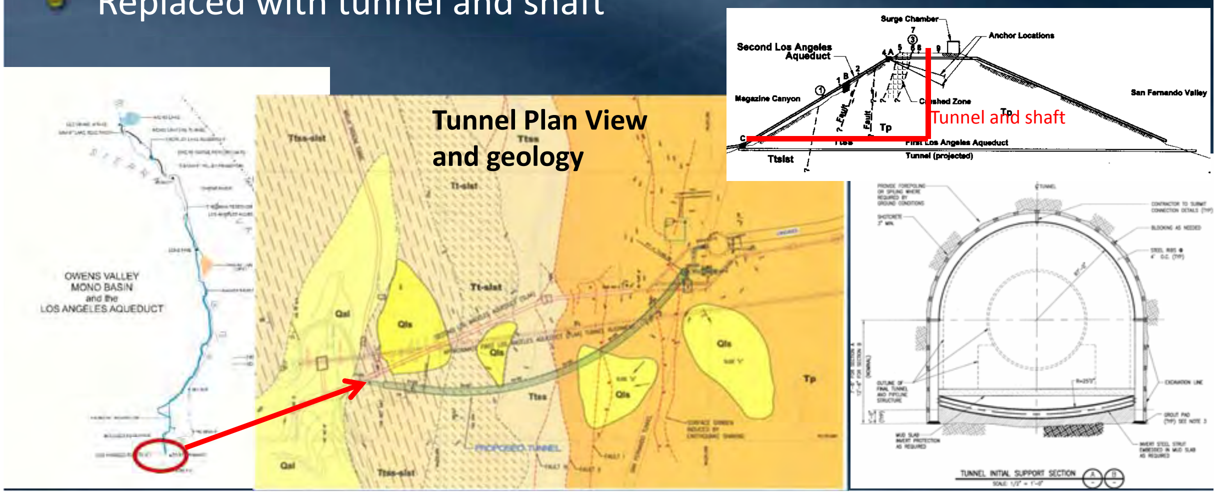
LAA Seismic Resilience Program

In addition to ShakeOut Scenario assessment, LADWP is undertaking additional LAA actions, examples include:

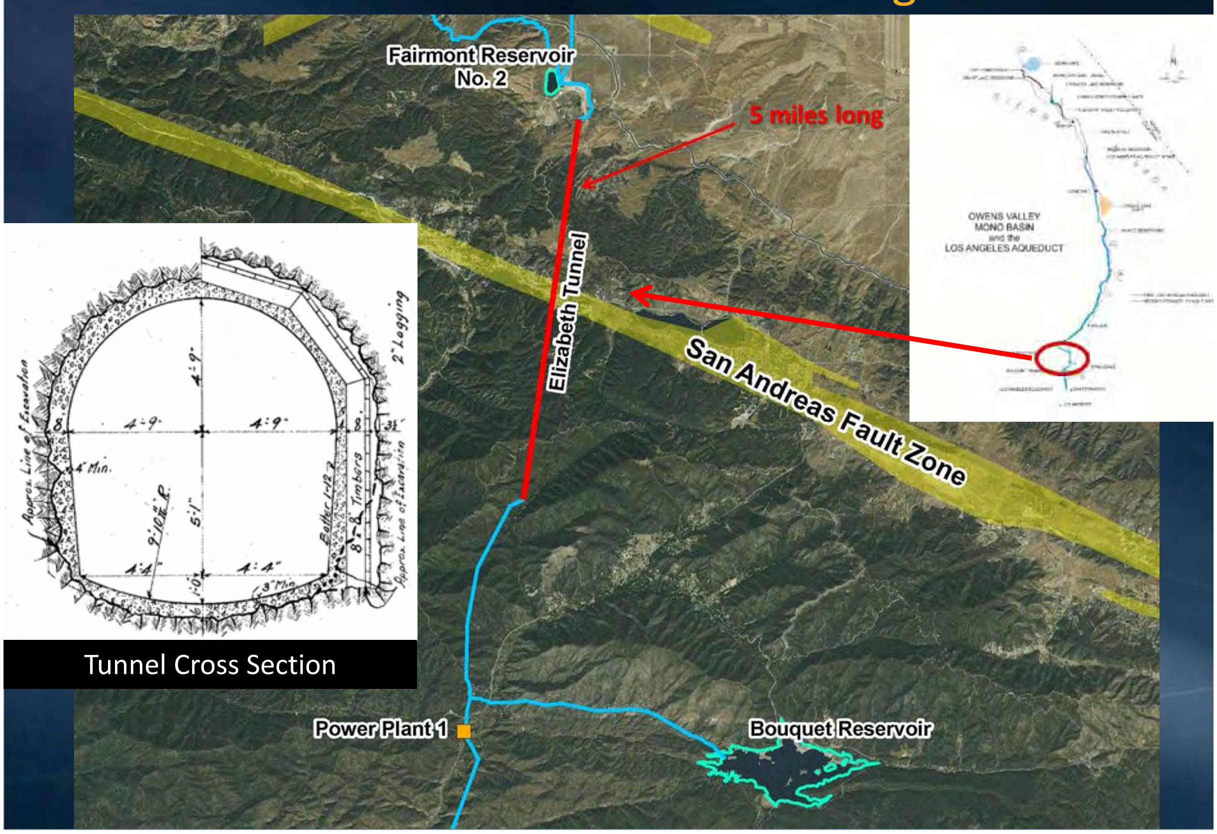
- Dam stability evaluations and seismic improvements (in progress)
  - Bouquet Canyon Dams
  - North Haiwee Dam
  - South Haiwee Dam
  - Tinemaha Dam
- Terminal Hill Tunnel Seismic Improvements (completed)
- Elizabeth Tunnel Seismic Enhancement Project (in progress)
- Detailed evaluation of SAF at Elizabeth Tunnel crossing (in progress)
- Engineered solution for maximum SAF fault offset (coming soon)

Terminal Hill Tunnel

- Terminal Hill is location of cascades in north San Fernando Valley
- Damaged SLAA in 1971 and 1994 from severe ridge shattering and out-of-phase motion
- SLAA flows over top of hill
- Replaced with tunnel and shaft



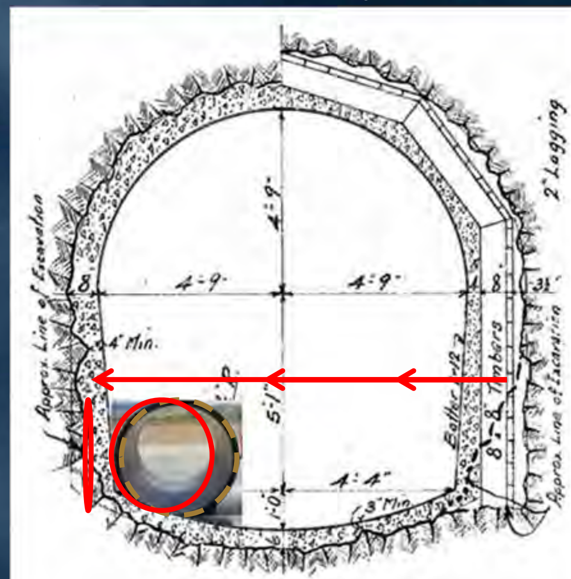
Seismic Enhancement - San Andreas Crossing



Tunnel Cross Section

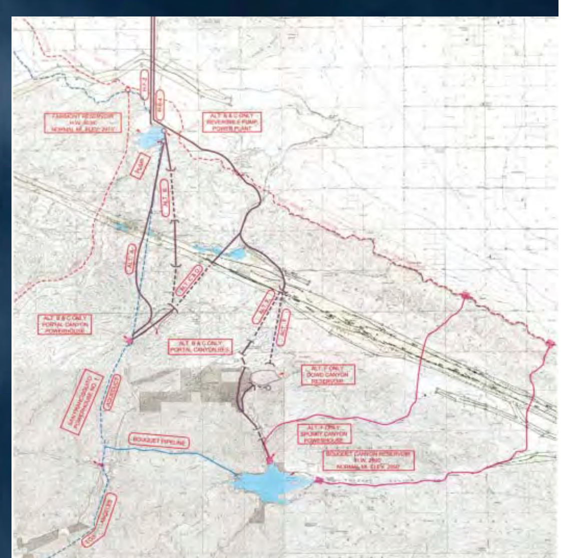
Seismic Enhancement Project

- Increase probability of flow through Elizabeth Tunnel following a San Andreas Earthquake



LADWP Resilience Program

- Engineered solution for largest San Andreas Fault offset
- Maximum offset may reach 20' to 30'
- Investigate characteristics of San Andreas Fault at the crossing location
- Identify alternatives and determine if they are cost effective
- Will need to make repairs after such an event
- Important to determine if it is better to mitigate before the event



Los Angeles Aqueducts Seismic Hazards

Owens Valley Fault, Largest Documented CA earthquake
(40 years before construction, LAA has not experienced large earthquake)

Sierra Nevada Fault

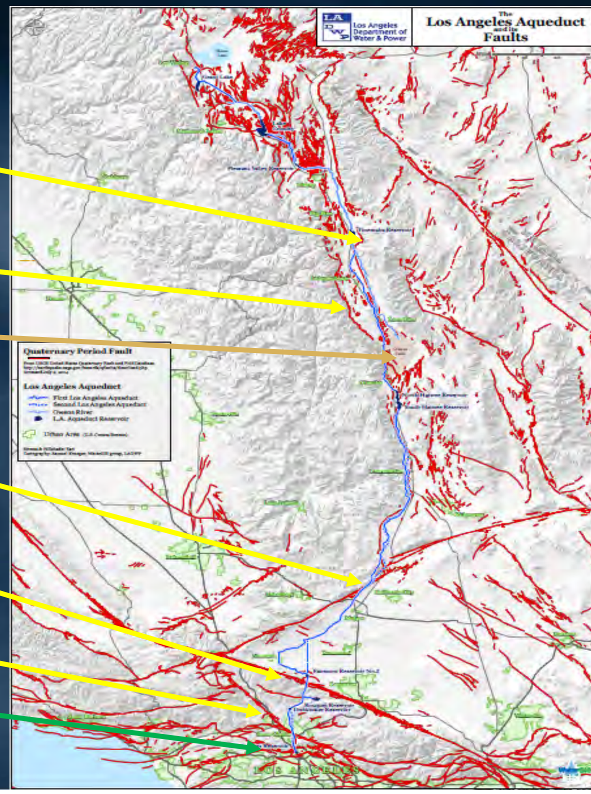
Los Angeles Aqueducts

Garlock Fault

San Andreas Fault

San Gabriel Fault

Los Angeles

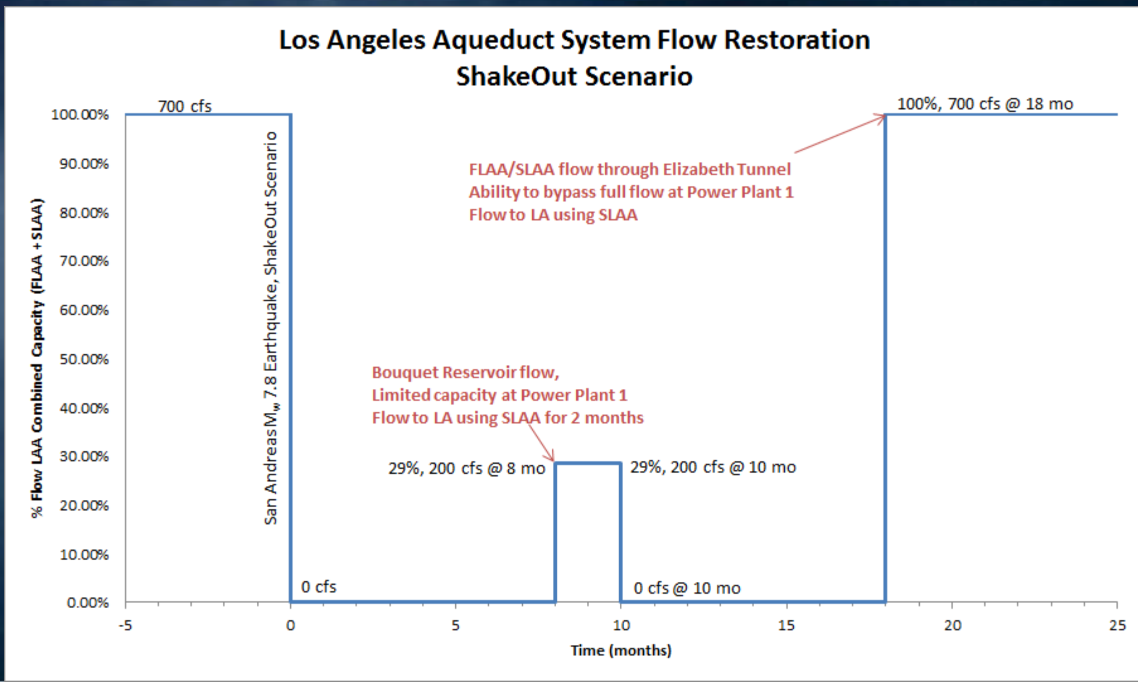


Emergency Response

- Emergency Response Plans in place
- Emergency materials (too many to list here)
- Equipment used on normal basis (too many to list here)
- Support crews for SAF event will come from Owens Valley and mutual assistance agreements with EBMUD, LVVWA, MWD, DWR, etc.
- Planning to implement exercises
- Based on ShakeOut evaluation need to improve response plans, relocate materials and supplies, etc.

LAA Flow Restoration

(preliminary, based on current conditions)



Next Steps

- Assess results so far to determine best way to move forward
- Work with MWD and DWR to determine how to work together to improve water supply restoration time
- Prepare scenario emergency response and restoration plan (ERRP) accounting for known vulnerabilities
- Determine mitigations to undertake in advance of the SAF earthquake and which to repair afterward
  - Modify ERRP as improvements are completed

Next Steps

- Re-assess ground motion and liquefaction hazards defined for ShakeOut
- Finalize ShakeOut assessment
- Evaluate other hazards along LAA
- Assess in-basin water supplies usable during disaster (how much and how long)
- Look into how long before people begin to depart and effect LA economy relative to reduced water supply

Continual Progress

- The Resilience Program is intended to be a continual process of seismic evaluation and implementing any identified cost-effective improvements to meet LA water supply needs
- Investigate the many seismic hazards
- Identify "tolerable" community recovery relative to imported water supply and great earthquakes
- The Resilient Water Supply Task force should be perpetual and revisit assumptions on a periodic basis (every 5 or 10 years)

SEISMIC RESILIENCE WATER SUPPLY TASK FORCE

California Aqueduct

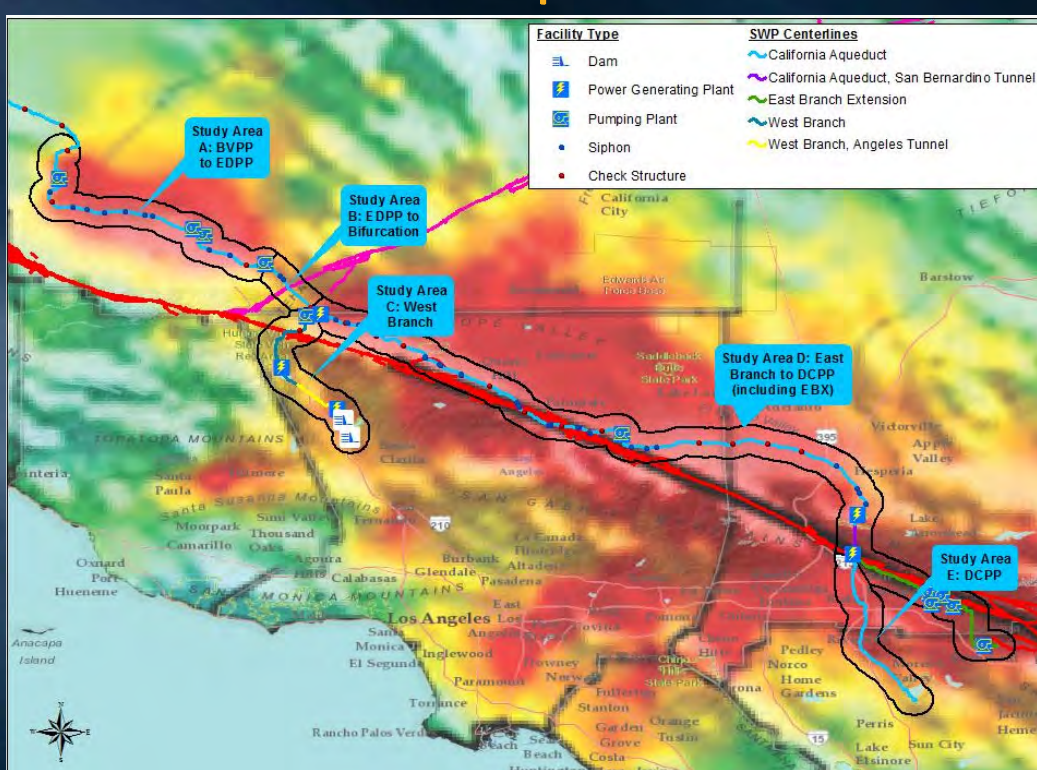
Aqueduct Workshop
March 30, 2016

Topics

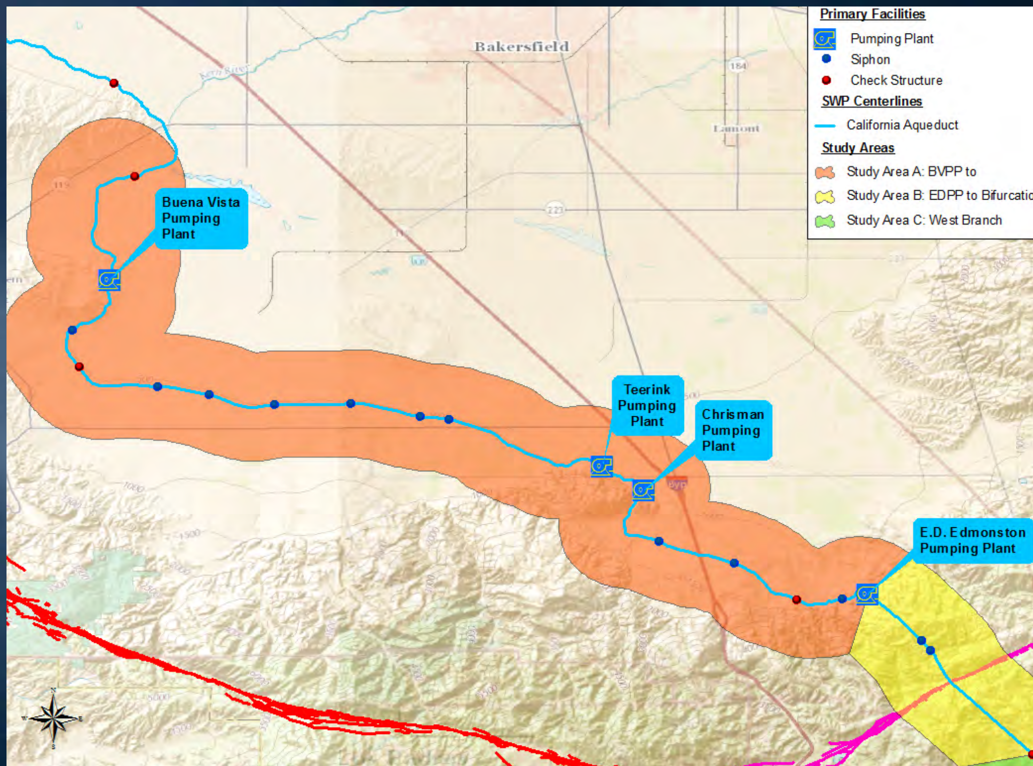
- SWP System Overview
- Findings and Assumptions
- Seismic Preparedness
- Return-to-Service Estimates

Study Areas

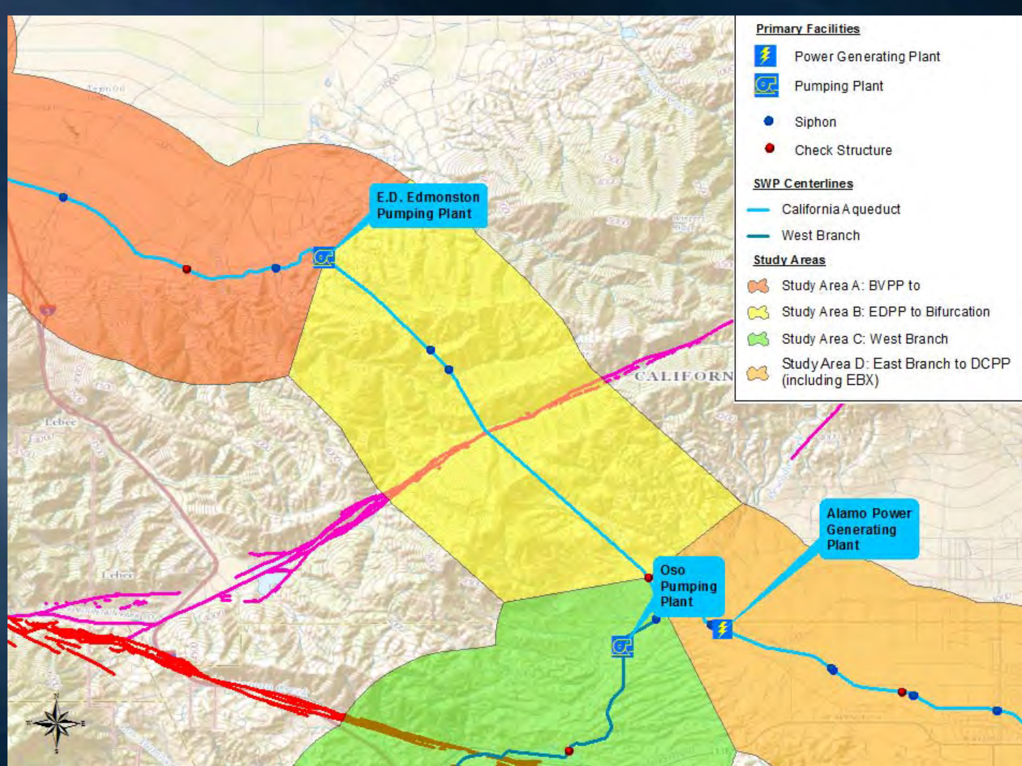
GG2008 Shake Map



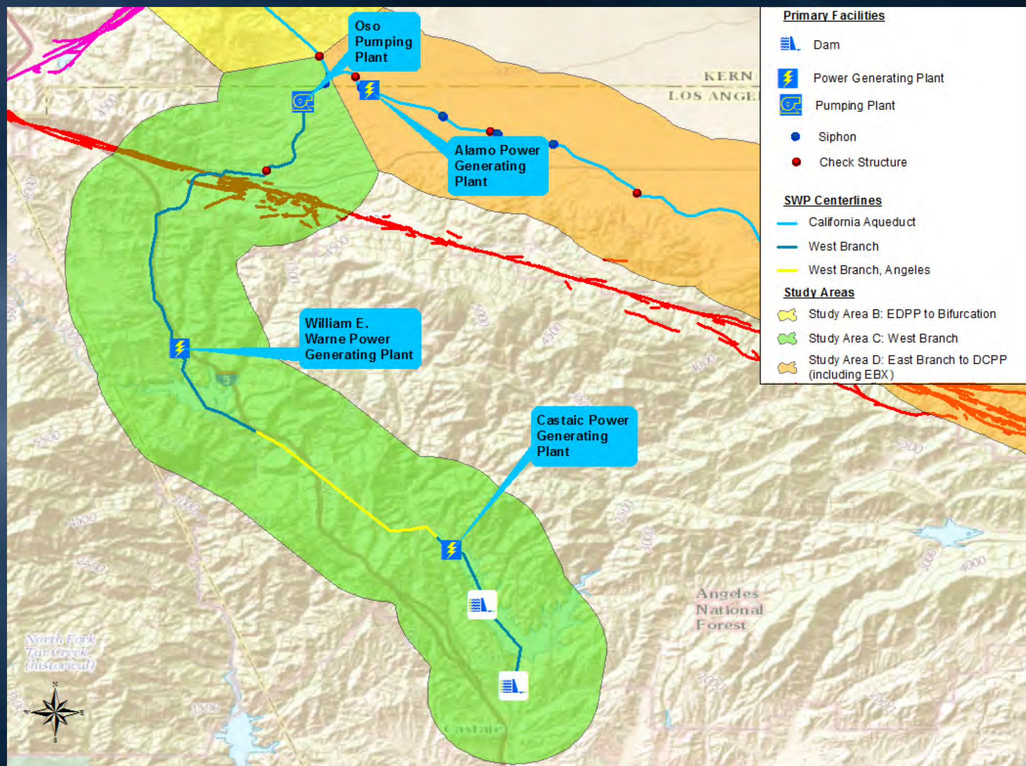
Study Area A: Buena Vista to Edmonston



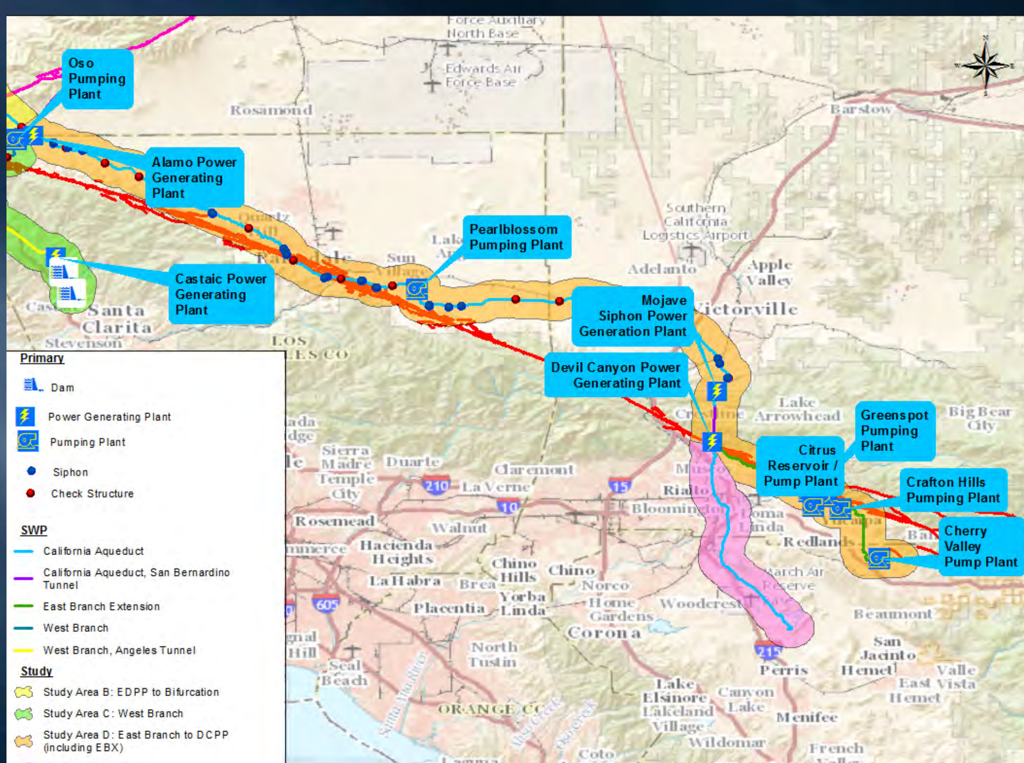
Study Area B: Edmonston to Bifurcation



Study Area C: West Branch



Study Area D: East Branch to DCPP & EBX



Fault Crossings near Palmdale

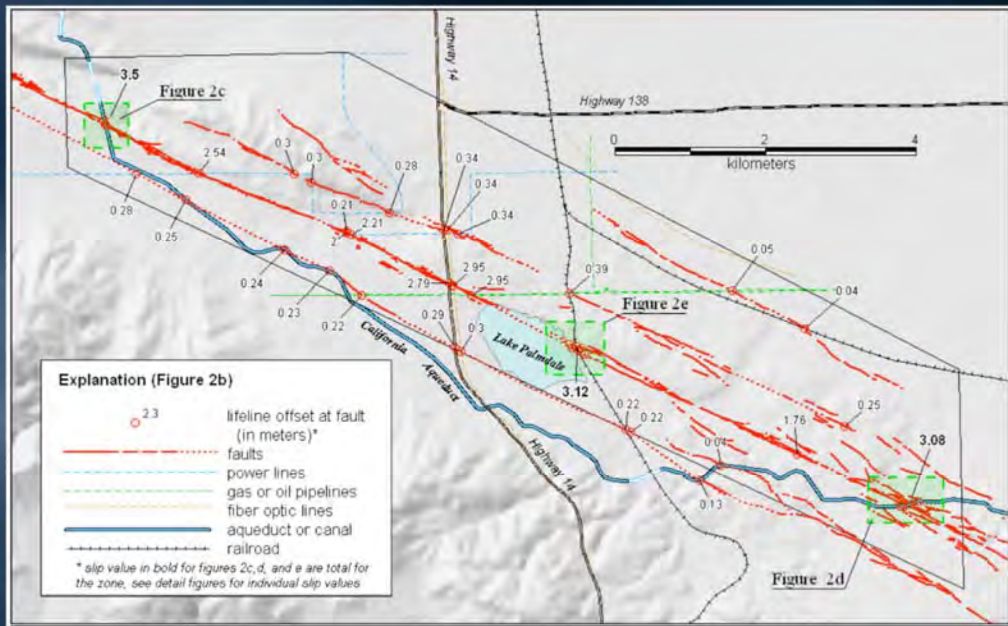
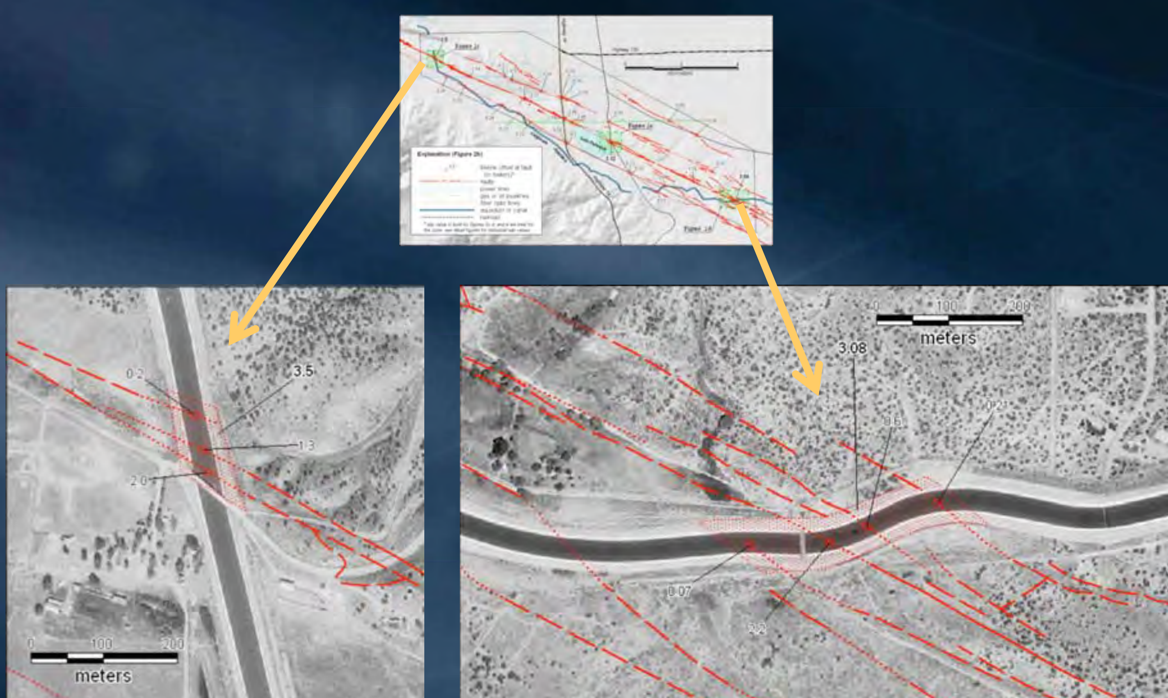
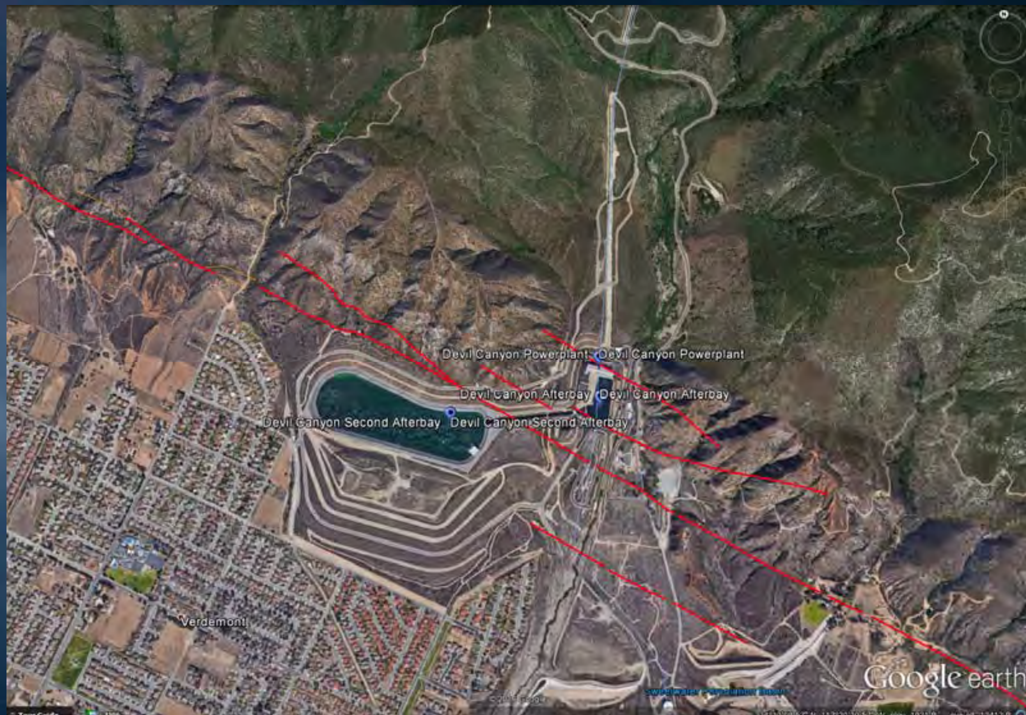


Figure 2b – right-lateral displacement of lifelines at fault crossings within Palmdale focus area. See detail areas (Figures 2c, 2d and 2e) for multiple offset lifelines and structures.

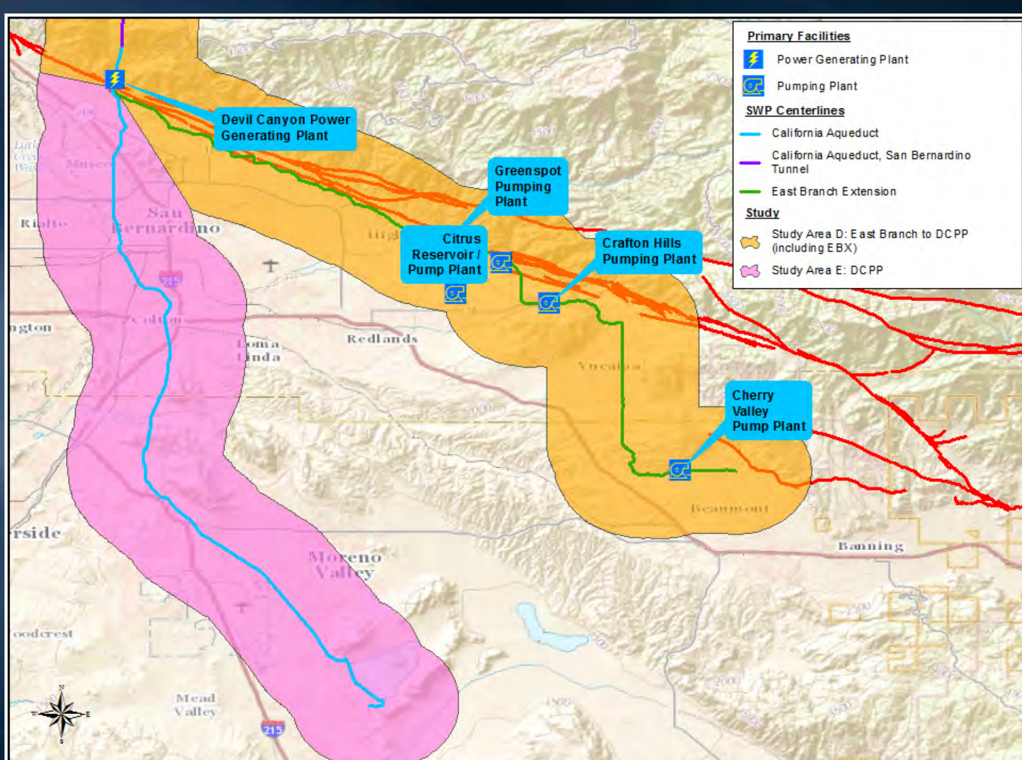
Fault Crossings near Palmdale



Fault Crossings at Devil Canyon PP



Study Area E: Devil Canyon to Perris



Findings and Assumptions

- 15 pumping and generating plants in close proximity to SAFZ
  - *Will be subjected to extreme shaking*
- *~80 miles of CAAQ within 3 miles of SAFZ*
- Area D – East Branch
  - Many facilities/features leads to high vulnerability
- Return-to-service estimates
  - No catastrophic damage to plants
    - Fire or flooding, tilted units, crane operability

Seismic Preparedness

- Agency Approach
  - Designers expected damage to conveyance features
    - Most SWP facilities and features were constructed above ground to expedite repairs
  - Field Division-wide and FERC facility-specific Emergency Action Plans

Seismic Preparedness

- Emergency Response Capabilities
  - 420 O&M staff in San Joaquin and Southern FDs
    - 80 Civil Maintenance personnel
    - 130 Plant Maintenance personnel
  - O&M Centers near Grapevine and Pearblossom
    - Limited mobile equipment fleets
  - 700 additional O&M staff and mobile equipment in 3 northern FDs and HQ
  - Emergency Contracting authority
    - State Contract Act

Agency Q & A



Agenda

- Introductions/Overview
- Description of Regional Water Systems
- Overview of Seismic Event Impacts

Break

- Aqueduct Damage and Recovery (by Agency)
- Post-Event Water Supply Discussion

Lunch

- Feedback on Key Issues
- Creativity Session

Break

- Next steps

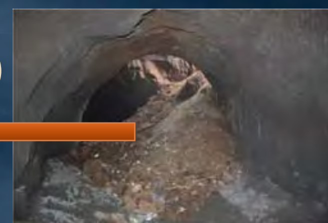
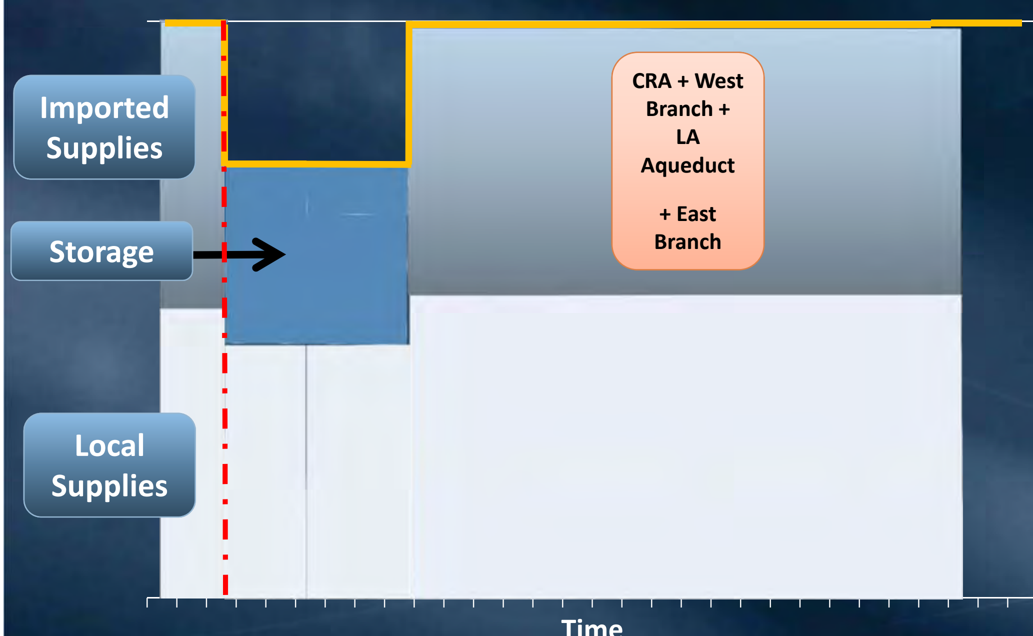


Diagram 1
Historical Planning Assumptions for Aqueduct Recovery



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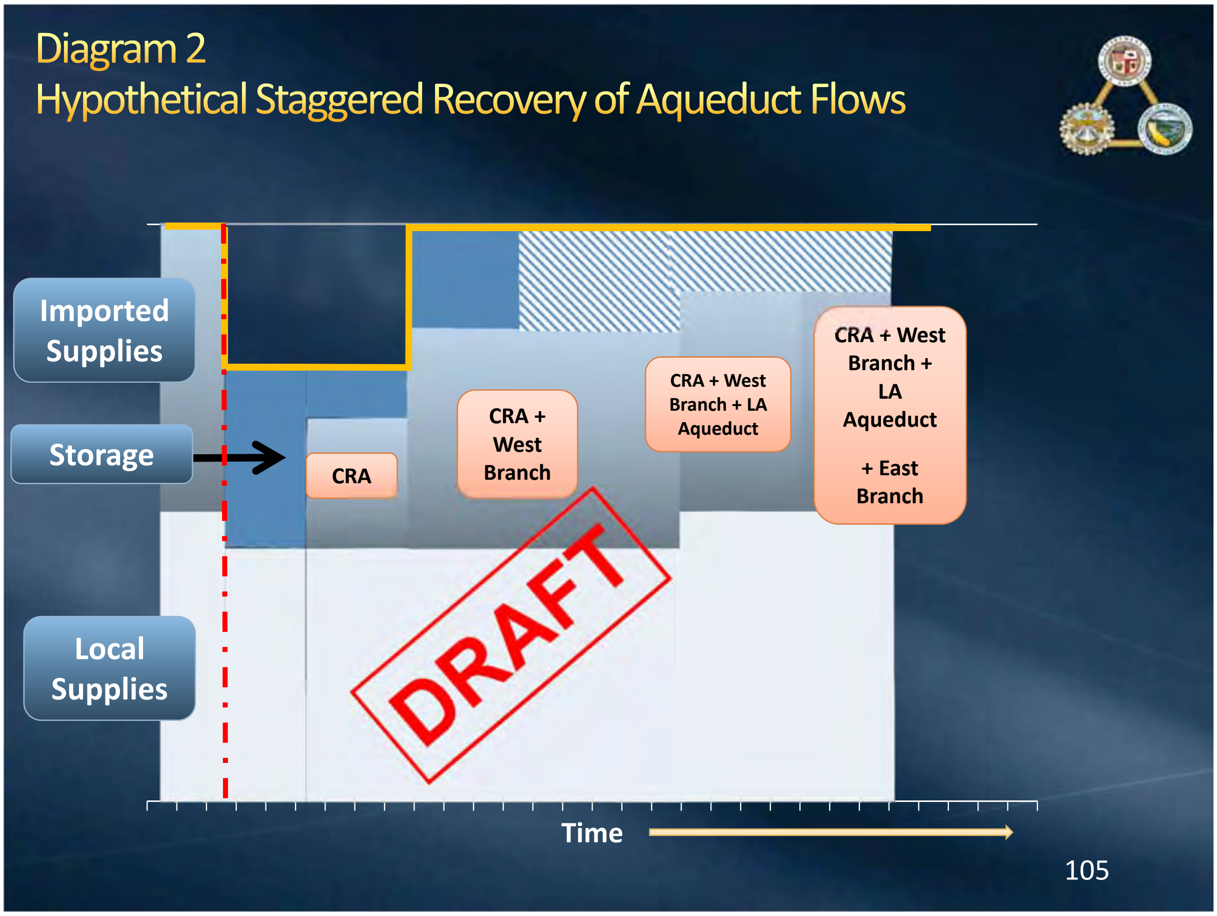
Diagram 2
Hypothetical Staggered Recovery of Aqueduct Flows
Imported Supplies
Storage
Local Supplies
CRA
CRA + West Branch
CRA + West Branch + LA Aqueduct
CRA + West Branch + LA Aqueduct
+ East Branch
DRAFT
Time
105

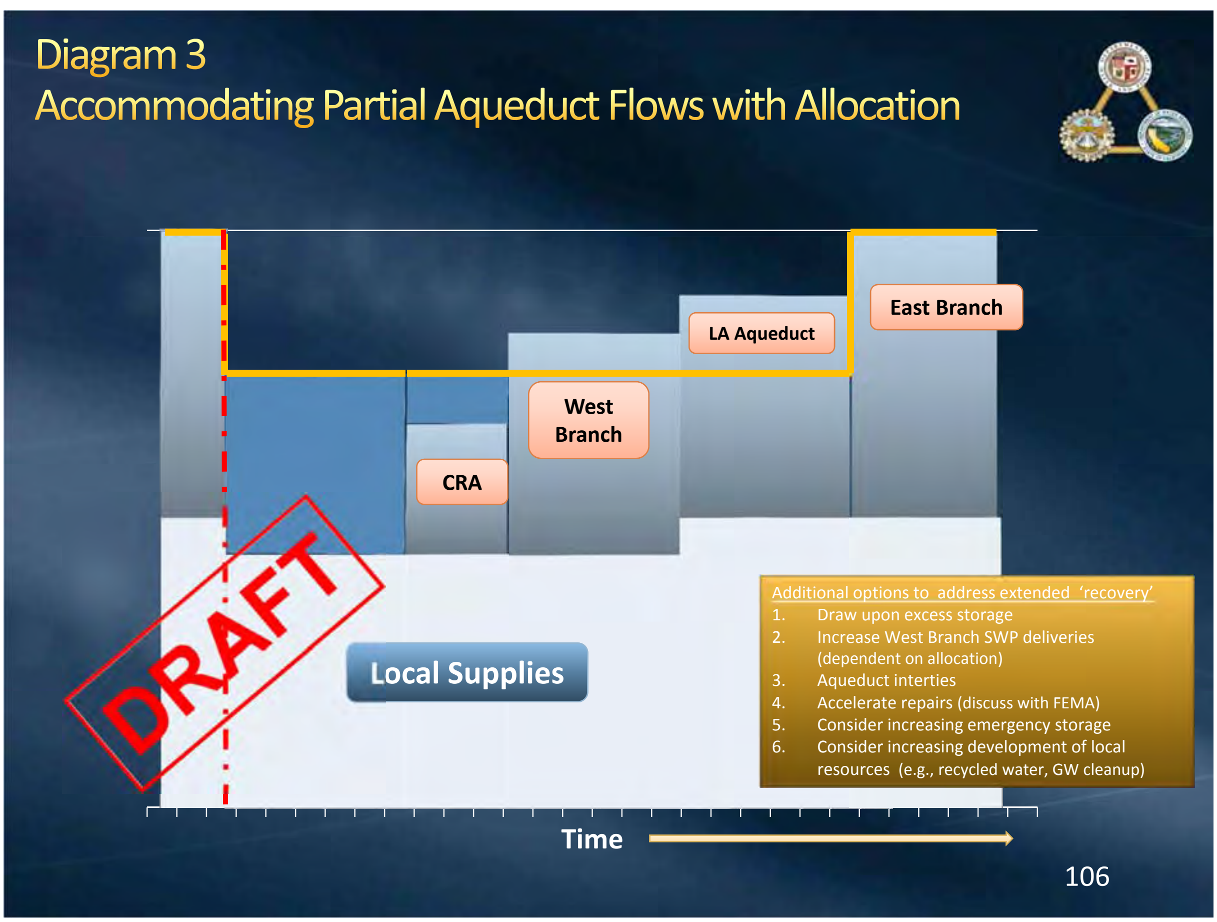
Diagram 3
Accommodating Partial Aqueduct Flows with Allocation
East Branch
LA Aqueduct
West Branch
CRA
Local Supplies
DRAFT
Additional options to address extended 'recovery'
1. Draw upon excess storage
2. Increase West Branch SWP deliveries (dependent on allocation)
3. Aqueduct interties
4. Accelerate repairs (discuss with FEMA)
5. Consider increasing emergency storage
6. Consider increasing development of local resources (e.g., recycled water, GW cleanup)
Time
106

Lunch Break



Agenda

- Introductions/Overview
- Description of Regional Water Systems
- Overview of Seismic Event Impacts

Break

- Aqueduct Damage and Recovery (by Agency)
- Baseline Post-Event Water Supply

Lunch

- Feedback on Key Issues
- Creativity Session

Break

- Next steps



Feedback on Morning Presentations



Creativity Session



Afternoon Break



THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Appendix 6

Fixed Assumptions

2016 AQUEDUCT WORKSHOP

Seismic Resilience Water Supply Task Force

FIXED ASSUMPTIONS

1. SCENARIO: 2008 "GREAT CALIFORNIA SHAKE OUT" 7.8 M EVENT*
   - DWR, LADWP, and MWD aqueducts are all damaged
   - Extent of damage is "reasonably expected to worst-case"
   - Damage & expected repair times determined by respective aqueduct owners
     - Duration (& capacity) for partial restoration of flow
     - Duration for restoration of full flow

2. WE ARE LOOKING AT THIS EVENT AS IF WE WERE ONE AGENCY

3. FOCUS ON IMPORTED WATER SYSTEMS, NOT DAMAGE WITHIN THE BASIN

4. OTHER
   - 6-month supply of water is available within region
     - Consistent with MWD planning documents
   - Repairs to most in-basin facilities 6-month supply of water is available within region
   - Repairs will be prioritized to ensure emergency supplies are available to all
   - LADWP Aqueduct personnel will not be reassigned within basin
   - Exclude business resumption issues (to be considered external to workshop)

**Scenarios of lesser damage can be considered after the workshop*

Updated 6/6/2017

Appendix 7

Metropolitan’s Emergency Resource Mix

Metropolitan Water District Emergency Resources

Seismic Resilience Water Supply Task Force

January 25, 2015

This document was prepared to facilitate discussions of the Resilient Water Supply Task Force regarding potential sharing of resources after emergency events impacting the regions imported water facilities. It provides an overview of the Metropolitan Water District of Southern California (Metropolitan) resources that are maintained to respond to urgent and/or emergency events that impact Metropolitan water deliveries. For this document, resources are defined as the functions, skills, materials, tools, staffing and equipment needed to respond to urgent and emergency events.

Metropolitan Resources

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 Metropolitan's construction contracts, Metropolitan retains the ability to mobilize contractors to perform emergency work on an as-needed basis. Metropolitan also 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. Recent investments in these shops allow Metropolitan to fabricate large-diameter pipe to repair at least two simultaneous pipeline breaks utilizing in-house capabilities.

The Engineering Services Group and the Operations Support Services Section are integral components of Metropolitan's Emergency Response Organization. The diverse groups of technical and engineering staff provide a wide range of support services to Metropolitan's core operational functions. The following are resource staffing and equipment that are maintained by Metropolitan to allow for effective damage assessment, planning, design, logistics, and project implementation and tracking:

- Damage Assessment
    - Field patrols
    - Damage Assessment Teams (DATs)
    - Underwater Inspection
- Planning
    - Project Management and controls

Metropolitan Water District Emergency Resources

Seismic Resilience Water Supply Task Force

January 25, 2015

- Business and financial tracking support
- Environmental Planning and Certification
- Safety & Environmental Compliance

- Design
  - Engineering disciplines (Civil, Electrical, I&C, Mechanical, Structural)
  - Information Technology
- Logistics
  - Fleet vehicles and fuel
  - Large equipment transportation
  - Mobile generators, various sizes
  - Mobile light towers
- Project Implementation
  - Inspection
  - Material testing
  - Manufacturing, machining, fabrication and equipment refurbishment
  - General construction
  - Equipment testing

Emergency Response Coordination

The onset of a response event requires coordination from the activated Command Center at the Metropolitan's Eagle Rock Control Center. Once an event is reported or the earthquake threshold has been met, all facilities initiate area patrols to investigate and report initial conditions. The Emergency Operations Center (EOC) may be activated along with one or more field Incident Command Centers (ICCs). The Engineering Damage Assessment Teams (DATs) are deployed to ascertain the level of damage and provide preliminary observational information to the Incident Command Centers who then deliver it to the EOC. The EOC Planning and Operations Sections will then decide how to proceed at this point in order to meet the needs or demands of the situation and communicate with any impacted parties including Metropolitan's Member Agencies or other impacted agencies.

Staffing and Skillsets

Metropolitan keeps a confidential listing of all response staff and their contact information. In case of an emergency, the respective manager will initiate standby teams to determine staff availability; and until the need and timing is assessed.

The following is a sample list of Metropolitan operations staff trained with multiple skill sets that are available to respond to Emergencies. At this time, there are approximately 40

Metropolitan Water District Emergency Resources

Seismic Resilience Water Supply Task Force

January 25, 2015

staff members who can be called for standby. Similar lists are maintained by other groups to address other key functional areas.

Staff Trade	Alternate Skill	Alternate Skill	Alternate Skill
Equipment Operator			
	Excavator	Loader	Dump Truck
	Oiler	Loader	Dump Truck
	Oiler	Low-bed	Dump Truck
	Motor Grader	Water Truck	Dump Truck
	Heavy Crane		
	Crane	Loader	Water Truck
	Backhoe	Loader	Water Truck
Shop Welder	Specialized	Exotic welds	
Welder	Mechanic	Concrete	Shoring
Carpenter	Concrete Work	Forms	Shoring
Electrician			
Shop Mechanic	Major Specialty	Minor Specialty	

Fabrication Capabilities

Metropolitan maintains machining, fabrication and coating capabilities to ensure rapid response to emergency events impacting large-diameter pipelines and other infrastructure. The shop equipment consists of large diameter pipe rollers, plasma cutters, welders, vertical mills, lathes, mills and other equipment. This equipment can handle up to 12 foot diameter pipeline and valves. Metropolitan's coating shop includes a permanent large media blasting booth with unloading capabilities and a temperature controlled spray booth. Additionally, staff is very proficient with mortar lining application and in-situ injection repair.

Metropolitan also maintains a list of external vendors who provide materials or services to support Metropolitan during normal working and emergency operations.

Construction Equipment

Metropolitan's also owns large construction equipment such as motor graders, backhoes, cranes, dozers, dump trucks, excavators and compactors, as well as mobile equipment including compressors, generators, and both small and large capacity fork lifts that provides significant emergency response capabilities.

Metropolitan Water District Emergency Resources

Seismic Resilience Water Supply Task Force

January 25, 2015

Emergency Stock Inventory

Metropolitan maintains a minimum stock inventory of materials to be prepared for emergency events. The following is a sample list of material inventory.

Material Description	Quantity
1/4” ASTM A-36 plate, 10’ X 40’	400 sq. ft.
3/8” ASTM A-36 plate, 10’ X 40’	4000 sq. ft.
1/ 2” ASTM A-36 plate, 10’ X 40’	2000 sq. ft.
3/4" ASTM A-36 plate, 10' X 40'	400 sq. ft.
1" ASTM A-36 PLATE	400 sq. ft.
3/8” 316-L stainless steel plate, 10’ X 40’	800 sq. ft.
1/2” 316-L stainless steel plate, 10’ X 40’	1200 sq. ft.
3/4" 316-L stainless steel plate, 10' X 40'	400 sq. ft.
.045” 316L in-flux welding wire (Kobelco)	200 lbs.
.045” 309L in-flux welding wire (Kobelco)	200 lbs.
1/16” 316L solid welding wire (Kobelco)	200 lbs.
5/64” 316L solid welding wire (Kobelco)	150 lbs.
5/64” Lincoln L60 welding wire	250 lbs.
1/8” 316L stick electrode	120 lbs.
5/32” 316L stick electrode	200 lbs.
.045” 309L in-flux welding wire	200 lbs.
1/6” 309L solid welding wire (Kobelco)	150 lbs.
5/64” 309L solid welding wire (Kobelco)	150 lbs.
1/8” 309L stick electrode	120 lbs.
5/32” 309L stick electrode	200 lbs.
.045" Lincoln 71M welding wire	350 lbs.
Lincoln Blue Max welding flux (stainless)	400 lbs.
Lincoln 860 welding flux (carbon)	400 lbs.
Liquid dye penetrant, developer, cleaner	12 cans
24" 150 lb. Slip-on/Blind Flanges	10
24" 300 lb. Slip-on/Blind Flanges	10
30" 150 lb. Slip-on/Blind Flanges	10
30" 300 lb. Slip-on/Blind Flanges	10
2 ½ inch dia. 4140 stud material	12' section
1/4" x 3" flt stk A-36 cold rolled	20' section
3/8" x 3" flt stk A-36 cold rolled	20' section
1/2" x 3" flt stk A-36 cold rolled	20' section
3/4" x 3" flt stk A-36 cold rolled	20' section
1" x 3" flt stk A-36 cold rolled	20' section
1/4" x 1" flt stk SS316L	12' section
1/4" x 2" flt stk SS316L	12' section
1/4" x 3" flt stk SS316L	12' section
3/8" x 1" flt stk SS316L	12' section
3/8" x 2" flt stk SS316L	12' section
3/8" x 3" flt stk SS316L	12' section

Material Description	Quantity
1/2" x 1" flt stk SS316L	12' section
1/2" x 2" flt stk SS316L	12' section
1/2" x 3" flt stk SS316L	12' section
3/4" x 1" flt stk SS316L	12' section
3/4" x 2" flt stk SS316L	12' section
3/4" x 3" flt stk SS316L	12' section
1" x 1" flt stk SS316L	12' section
1" x 2" flt stk SS316L	12' section
1" x 3" flt stk SS316L	12' section
1/4" sq. stk A-36 cold rolled	6' section
3/8" sq. stk A-36 cold rolled	6' section
7/16" sq. stk A-36 cold rolled	6' section
1/2" sq. stk A-36 cold rolled	6' section
5/8" sq. stk A-36 cold rolled	6' section
3/4" sq. stk A-36 cold rolled	6' section
7/8" sq. stk A-36 cold rolled	6' section
1" sq. stk A-36 cold rolled	6' section
1 1/4" sq. stk A-36 cold rolled	6' section
1 1/2" sq. stk A-36 cold rolled	6' section
1 3/4" sq. stk A-36 cold rolled	6' section
2" sq. stk A-36 cold rolled	6' section
1/4" sq. stk SS316L	6' section
3/8" sq. stk SS316L	6' section
7/16" sq. stk SS316L	6' section
1/2" sq. stk SS316L	6' section
5/8" sq. stk SS316L	6' section
3/4" sq. stk SS316L	6' section
7/8" sq. stk SS316L	6' section
1" sq. stk SS316L	6' section
1 1/4" sq. stk SS316L	6' section
1 1/2" sq. stk SS316L	6' section
1 3/4" sq. stk SS316L	6' section
2" sq. stk SS316L	6' section
Hex 3" 4140 (Nuts)	6' section
1" Brass rnd stk	6' section
2" Brass rnd stk	6' section
3" Brass rnd stk	6' section
1" Bronze rnd stk	6' section
2" Bronze rnd stk	6' section
3" Bronze rnd stk	6' section

Appendix 8

Aqueduct Workshop Findings

Seismic Resilience Water Supply Task Force
March 2016 Aqueduct Workshop Findings
May 3, 2016

Aqueduct Workshop Participants concluded the following:

Multi-agency coordination is beneficial for the region

- LADWP's Resilience Program's Expert Panel noted the significance of the largest municipal utility, largest water wholesaler, and largest state-owned water project, joining together to address a major hazard for the first time
- Cooperative investigations help identify regional priorities; and for events impacting all aqueducts, the priority within Metropolitan's service area will be to restore the West Branch and the CRA as quickly as possible:
  - The region needs imported water from both the east and west
  - The West Branch can supply the greatest area

  Note: It is recognized that DWR would also have a priority to restore service to other East Branch customers

- Common issues can be studied more efficiently together
- A mutual plan for coordinating contractors and resources will benefit all
  - If we are not cooperating post event, we will be competing
  - We all will have to look outside the region for all resources
- Approaching Southern California Edison together will be more effective than if approached independently
- We want to maintain the momentum we now have in working together

Historical planning assumptions have been challenged

- Our historical assumption regarding potential outages of DWR, LADWP and MWD imported water supplies after a major seismic event have been challenged
  - Restoration of full aqueduct capacities could take much more than six months for each agency
  - Restoration of partial aqueduct flows could take at least two months
  - Actual post event imported water supply conditions could vary significantly
- We should revisit our scenario resource planning for a major outage (outage assumptions, available storage, conservation assumptions, local supply…)

Our region can become better prepared for seismic events

- We all need to understand our seismic vulnerabilities better than we do today.
- We need to better understand the full range of hazards associated with earthquakes (after shocks, fault rupture, fires…)

Seismic Resilience Water Supply Task Force
March 2016 Aqueduct Workshop Findings
May 3, 2016

The Task Force should continue to meet

- It is important to maintain close collaboration as each agency continues evaluating vulnerabilities and implementing improvements
- As it was recognized that some imported water is better than no water, the task force can facilitate the investigation of multi-agency approaches to accelerate the restoration of imported water flows
- As it was recognized that power is a critical dependency, the task force should include power utilities in follow-up discussions
- The task force can help deliver a consistent message to executive management of each agency

The following "Next Steps" will help the region:

Individually, each agency should:

- Build executive management support and participation
- Seek funding to complete investigations and follow-up tasks
  - Identify Task Force efforts as Major O&M activities
  - Seek capital funding for detailed investigations/project implementation
- Identify existing aqueduct vulnerabilities in order of priority, and:
  - Identify potential mitigation options
  - Implement cost effective options
  - Develop contingency plans for loss (if there is no cost effective mitigation)
- Consider American Lifelines Alliance (ALA) water system reliability guidelines
- Assess response capabilities, compare to needs, and identify gaps
- Develop canned post event repairs for:
  - Common failures
  - Key 'critical' failures (e.g., Whitewater Tunnel #2)
- Revisit planning assumptions (e.g., what outage scenarios should be evaluated, how long can various levels of conservation be sustained, etc.)
- Provide SEMS/NIMS training to staff as necessary

Seismic Resilience Water Supply Task Force
March 2016 Aqueduct Workshop Findings
May 3, 2016

Collectively, the Task Force should:

- Maintain close coordination regarding seismic investigations
    - Share detailed approaches to seismic assessments & upgrades (e.g., Have MWD structural engineers explain the details of the Seismic Upgrades Program to DWR and LADWP staff)
    - Evaluate the seismic performance of structures, electrical equipment, and mechanical equipment (Review EPRI report on this issue)
    - Maintain a close coordination with USGS and CGS
    - Develop a long-term action item list
- Evaluate effective ways to increase system flexibility, such as:
    - Intertie between DWR east branch and SLAA at Fairmont
    - Intertie between FLAA and East branch pool 44 or Tehachapi after ba
    - Investigate pump-in options at east branch
- Jointly prepare for a coordinated emergency response
    - Establish a leadership structure for coordinated response to major events
        - Develop a unified command structure
        - Develop an org chart
    - Develop a database of available resources
        - Investigate sharing opportunities (including skilled staff, specialty consultants)
    - Evaluate how to procure assets (emergency power, materials, contracts, equipment, fuel…)
        - E.g., prearranged agreements with contractors (tunneling)
    - Plan and conduct joint emergency exercises, and focus on
        - Reaching consensus on regional priorities
        - Sharing resources to accelerate key repairs
        - Plan for personnel unavailability
    - Share emergency response plans and consider funding methods in response to an event (and plan for it) (*this was from expert panel)*
    - Ink an emergency response plan between agencies
        - This will facilitate the sharing of resources and streamline interfaces with CAL OES and FEMA
    - Review approach for emergency in-basin water services

Appendix 9

Steering Committee Briefing Materials

Seismic Resilience Water Supply Task Force
Discussion of Aqueduct Workshop Findings
May 4, 2016

DRAFT

Attendees

LADWP	Metropolitan	DWR
Craig Davis	Dave Clark (Phone)	Phil LeCocq (phone)
Patrick Horton		Dave Rennie (phone)
Abebaw Anbessaw		David Duval (phone)
Jim Yannotta (phone)		Jeanne Kuttel (phone)
Mike Grahek (phone)		
Bill Van Wagoner		
Susan Rowghani		
Patricia Whelan (Phone) Mayor's office		

1. LADWP Expert Panel Feedback (C. Davis)

   A memorandum was provided to attendees from the LADWP Resilience Expert Panel having their input on the Aqueduct Workshop. Their overall impression was very good. They felt the workshop was highly successful and unprecedented. The Panel made some suggestions on how to improve the Task Force effort moving forward.

2. Highlights of Findings (See handout)

   An overview of the handout on Workshop Findings was presented.

3. Key Issues (D. Clark)

   a. Restoration of aqueduct flows will take longer than previously assumed

   b. We do have mitigation options that we can evaluate and prioritize

   These two issues were highlighted as key results of the workshop. All agreed these are initial findings and more review and evaluation needs to be undertaken to better understand: (i) the confidence we have in these key findings and (ii) learn more about what this may mean to the agencies. Items (i) and (ii) are prudent understandings to gain so we can describe seismic risks and potential impacts to others with consistency and a greater degree of confidence.

4. Strategy for Moving Forward (D. Clark)

   a. Refine near-term action item list (0-6 month activities)

   b. Identify and implement seismic mitigation measures:

      i. Near-term (2016-2021).

         Examples:

         1. Prepare a DWR/DWP/MWD emergency response agreement

Seismic Resilience Water Supply Task Force
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DRAFT

2. Complete joint evaluation of common vulnerabilities (Power, large mechanical and electrical equipment, etc.)
3. Implement recommended CRA mitigation measures

ii. Mid-term (2021-2026)

Examples:

1. Install HDPE pipe in Elizabeth Tunnel
2. Strengthen at-risk portions of CRA tunnels
3. Provide lateral bracing for penstocks
4. Procure additional spare ceramics

iii. Long-term (>2026)

Examples:

1. Implement aqueduct interties?
2. Implement some in-basin improvements?

5. Discussion

It was recognized that significant improvements in seismic resiliency will require a sustained effort by each agency. The above strategy for setting realistic goals was summarized. An emphasis was placed on agency resources needed to move forward. The success of the Task Force will depend upon a commitment from each agency. Realistic goals are also necessary since each agency has other, competing high-priority work.

It was agreed to roughly target the following meeting schedule:

- Monthly Task Force meetings
- Quarterly Management Oversight Committee meetings

A top priority is to refine San Andreas Fault scenarios to help identify and coordinate meaningful agency and Task Force goals. This will help the three Agencies can then identify how to budget, prioritize and resource tasks consistently.

Another item of priority is to create agreements and an organizational structure that is workable to allow the three agencies to collaborate, make priority decisions, and take proper action during emergency events to restore imported water to Southern California as rapidly as possible. This was discussed with due consideration that an earthquake on the San Andreas Fault could occur at any time.

Appendix 10

Conference Call Notes on "Seismic Performance of Large Equipment"

SEISMIC PERFORMANCE OF LARGE EQUIPMENT

May 23, 2016 DWR/LADWP/MWD/SDG&E Conference Call

June 9, 2016

Contacts

DWR

- David Rennie, DWR/DWP/MWD Seismic Task Force 916-653-2827
- Phil Lecoq, DWR/DWP/MWD Seismic Task Force 916-653-6593

SDG&E

- Michael Colburn, Major Projects 858-654-8656
- Craig Riker, SDG&E Civil/Structural Engineering 858-654-1654
- Robert Mayer, SDG&E Substation Engineering & Design 858-654-1119

MWD

- David Clark, DWR/DWP/MWD Seismic Task Force 213-217-6070
- Albert Grimm, Power Design 213-217-7109

LADWP

- Craig Davis, DWR/DWP/MWD Seismic Task Force 213-367-2319
- John Otoshi ,Water System Mechanical Design 213-367-0401
- Emmanuel Tan Water System Electrical Design 213-367-3627
- Russel Woll, Water System Electrical Design 213-367-3822
- Daniel Delgadillo, Water System Electrical Design (student) 213-367-3822
- Joe Resong Water System Civil/Structural Design 213-367-0834
- Eduardo Malacon, Power System Civil Design 213-367-0090
- Roberto Gonzales, Power Generation Station Design 213-367-3366
- Carl Horvath, Power System Structural Design 213-367-7230
- Jennifer Vanegas, Power System Geology and Soils 213-367-0091
- William Rainbird, Power System Small Hydo-Generation 661-294-3402

2. Background

DWR, LAWDP, and MWD formed a Seismic Resilient Water Supply Task Force to evaluate ways to improve the reliability of imported water to Southern California. One avenue to explore was to consider the seismic vulnerabilities of large equipment (mechanical and electrical) and power systems and potential mitigation options to address these vulnerabilities.

3. Agency experience and recommendations

SDG&E discussed the failures that occurred at their Imperial Valley substation near El Centro as a result of the 2010 Easter Sunday Sierra El Mayor earthquake. In this event, forces were estimated between 0.28 and 0.42g at the substation. Transformer Bushings cracked, lightening resisters cracked, oil leaks developed, and wires fell. However, they were able to bypass this 500 kv substation within one day. No damage to foundations, anchor bolts, or radiators (even though there was some movement). They have replaced ceramic with composite bushings on 230V systems. Use of dog-bones can help reduce vulnerabilities and redesigning buses to put less strain on bushings can help. They have also moved from using bolts to anchor large transformers to welding to embedded steel beams. This is both easier and more robust.

For design, IEEE 693 is used (1g ground acceleration vs. 0.5g for old designs). For buildings, they use UBC but with highest safety factors, “essential facilities”). They also are developing a strategy for providing spare transformers that factors in various vulnerabilities and system expansion associated with their capital program. IT is not desired to have transformers unused for long periods , so the inventory of spares is rotated as equipment is ordered for new projects to support the construction (capital) program.

SEISMIC PERFORMANCE OF LARGE EQUIPMENT

May 23, 2016 DWR/LADWP/MWD/SDG&E Conference Call

June 9, 2016

LADWP experience was similar in the 1994 earthquake. All failures were associated with facilities that had not been designed to meet IEEE693. EPRI had reported that transmission line post insulators were subject to failure but not the newer composite type. For international investigations, following big events, anchor bolts have been sheared and some foundations have also been damaged. LADWP did have some damage in 1994 where large ground motions were experienced reaching up to 1.0g acceleration. Also, some failures can occur months after the event.

LADWP Power system engineers noted that although standards have improved, many manufacturers are not quite up to speed on these standards.

An additional recommendation was to use fire walls between transformers.

Action items

MWD follow-up request: A small group of MWD employees would appreciate a SDG&E switchyard to ascertain firsthand some of the seismic improvements that were made and will make contact with Robert Mayer to schedule this.