

**MEETING OF THE
BOARD OF DIRECTORS OF THE
MUNICIPAL WATER DISTRICT OF ORANGE COUNTY**
Jointly with the
PLANNING & OPERATIONS COMMITTEE
March 2, 2015, 8:30 a.m.
MWDOC Conference Room 101

P&O Committee:

Director Osborne, Chair
Director Barbre
Director Hinman

Staff: R. Hunter, K. Seckel, R. Bell,
H. De La Torre, P. Meszaros, J. Berg

Ex Officio Member: L. Dick

MWDOC Committee meetings are noticed and held as joint meetings of the Committee and the entire Board of Directors and all members of the Board of Directors may attend and participate in the discussion. Each Committee has designated Committee members, and other members of the Board are designated alternate committee members. If less than a quorum of the full Board is in attendance, the Board meeting will be adjourned for lack of a quorum and the meeting will proceed as a meeting of the Committee with those Committee members and alternate members in attendance acting as the Committee.

PUBLIC COMMENTS - Public comments on agenda items and items under the jurisdiction of the Committee should be made at this time.

ITEMS RECEIVED TOO LATE TO BE AGENDIZED - Determine there is a need to take immediate action on item(s) and that the need for action came to the attention of the District subsequent to the posting of the Agenda. (Requires a unanimous vote of the Committee)

ITEMS DISTRIBUTED TO THE BOARD LESS THAN 72 HOURS PRIOR TO MEETING --

Pursuant to Government Code section 54957.5, non-exempt public records that relate to open session agenda items and are distributed to a majority of the Board less than seventy-two (72) hours prior to the meeting will be available for public inspection in the lobby of the District's business office located at 18700 Ward Street, Fountain Valley, California 92708, during regular business hours. When practical, these public records will also be made available on the District's Internet Web site, accessible at <http://www.mwdoc.com>.

ACTION ITEMS

1. BUREAU OF RECLAMATION CALFED WATER USE EFFICIENCY GRANT RESOLUTION
2. TWO NEW OC WATER RELIABILITY STUDY AUTHORIZATIONS – (A) ANALYSIS AND MAPPING OF SEISMIC HAZARDS AND (B) FACILITY VULNERABILITY AND RECOVERY ASSESSMENT – AUTHORIZATION FOR PROFESSIONAL SERVICE AGREEMENTS

DISCUSSION ITEMS

3. PRESENTATION REGARDING SMARTIMER PROGRAM RESULTS
(Approximate presentation time: 10 minutes)

INFORMATION ITEMS (The following items are for informational purposes only – background information is included in the packet. Discussion is not necessary unless a Director requests.)

4. STATUS REPORTS
- a. Ongoing MWDOC Reliability and Engineering/Planning Projects
 - b. WEROC
 - c. Water Use Efficiency Projects
 - d. Water Use Efficiency Programs Savings and Implementation Report
5. REVIEW OF ISSUES RELATED TO CONSTRUCTION PROGRAMS, WATER USE EFFICIENCY, FACILITY AND EQUIPMENT MAINTENANCE, WATER STORAGE, WATER QUALITY, CONJUNCTIVE USE PROGRAMS, EDUCATION, DISTRICT FACILITIES, and MEMBER-AGENCY RELATIONS

ADJOURNMENT

NOTE: At the discretion of the Committee, all items appearing on this agenda, whether or not expressly listed for action, may be deliberated, and may be subject to action by the Committee. On those items designated for Board action, the Committee reviews the items and makes a recommendation for final action to the full Board of Directors; final action will be taken by the Board of Directors. Agendas for Committee and Board meetings may be obtained from the District Secretary. Members of the public are advised that the Board consideration process includes consideration of each agenda item by one or more Committees indicated on the Board Action Sheet. Attendance at Committee meetings and the Board meeting considering an item consequently is advised.

Accommodations for the Disabled. Any person may make a request for a disability-related modification or accommodation needed for that person to be able to participate in the public meeting by telephoning Maribeth Goldsby, District Secretary, at (714) 963-3058, or writing to Municipal Water District of Orange County at P.O. Box 20895, Fountain Valley, CA 92728. Requests must specify the nature of the disability and the type of accommodation requested. A telephone number or other contact information should be included so that District staff may discuss appropriate arrangements. Persons requesting a disability-related accommodation should make the request with adequate time before the meeting for the District to provide the requested accommodation.



ACTION ITEM

March 18, 2015

TO: Board of Directors

FROM: **Planning & Operations Committee**
(Directors Osborne, Barbre & Hinman)

Robert Hunter
General Manager

Staff Contact:

J. Berg
WUE Programs Manager

SUBJECT: Bureau of Reclamation CALFED Water Use Efficiency Grant Resolution

STAFF RECOMMENDATION

Staff recommends the Board of Directors adopt the proposed resolution in support of MWDOC's 2015 CALFED Water Use Efficiency grant application to be submitted to the Bureau of Reclamation by March 20, 2015.

COMMITTEE RECOMMENDATION

Committee recommends (To be determined at Committee Meeting)

DETAILED REPORT

In January 2015, the Bureau of Reclamation released its "Bay-Delta Restoration Program: CALFED Water Use Efficiency Grants for FY2015" Funding Opportunity Announcement (FOA). The objective of this announcement is to invite proposals to leverage investments and resources by cost sharing with Reclamation on projects that save water, improve energy efficiency, address endangered species and other environmental issues, and facilitate water transfers to new uses. A total of \$8 million is available for project awards within the state of California which is within the Mid-Pacific Region of the Department of the Interior, Bureau of Reclamation. The Bureau may award up to \$750,000 per agreement and estimates approximately 4 to 12 agreements will be awarded.

Staff will be submitting an application proposing a Comprehensive Landscape Water Use Efficiency Program which will provide incentive funding to promote landscape transformation for highly visible sites focusing on schools, public spaces, and roadways.

Budgeted (Y/N): N/A	Budgeted amount: N/A	Core __	Choice <u>X</u>
Action item amount: N/A	Line item: N/A		
Fiscal Impact (explain if unbudgeted): N/A			

The FOA requires all applications to include an official Board Resolution supporting the grant application. The proposed Resolution containing the required content is attached for your consideration.

RESOLUTION NO. _____
RESOLUTION OF THE BOARD OF DIRECTORS OF MUNICIPAL WATER DISTRICT
OF ORANGE COUNTY SUPPORTING A BUREAU OF RECLAMATION 2015 BAY-
DELTA RESTORATION PROGRAM:
CALFED WATER USE EFFICIENCY GRANT APPLICATION

WHEREAS, the Municipal Water District of Orange County submitted an application to the Bureau of Reclamation for funding for an Comprehensive Landscape Water Use Efficiency Program: Highly Visible Sites to improve urban landscape water use efficiency in the Municipal Water District of Orange County service area,

WHEREAS, the Municipal Water District of Orange County is committed to developing and implementing a comprehensive water use efficiency program designed to meet our local water supply reliability goals, comply with the Best Management Practices for urban water conservation in California, and exceed the Governor's call for a 20% reduction in urban per capita water use by 2020,

NOW, THEREFORE, BE IT RESOLVED, that the Municipal Water District of Orange County Board of Directors designates Robert J. Hunter, General Manager, as the official who has reviewed and supports the application submittal and the legal authority to enter into an agreement on behalf of the District, and designates Joseph M. Berg, Water Use Efficiency Programs Manager, as the District's representative to sign the progress reports and approve reimbursement claims.

NOW, THEREFORE, BE IT FURTHER RESOLVED, that the Municipal Water District of Orange County Board of Directors assures its capability to provide the amount of funding and in-kind contributions specified in the funding plan.

NOW, THEREFORE, BE IT FURTHER RESOLVED, that the Municipal Water District of Orange County will work with Reclamation to meet established deadlines for entering into a cooperative agreement.

Said Resolution was adopted on March 18, 2015, by the following roll call vote:

AYES:

NOES:

ABSENT:

ABSTAIN:

I HEREBY CERTIFY the foregoing is a full, true, and correct copy of Resolution No. ____ adopted by the Board of Directors of Municipal Water District of Orange County at its meeting held on March 18, 2015.

Maribeth Goldsby, Secretary
Municipal Water District of Orange County



ACTION ITEM

March 18, 2015

TO: Board of Directors

FROM: Planning and Operations Committee
(Directors Osborne, Barbre, Hinman)

Robert Hunter, General Manager

Staff Contact: K. Seckel/R.Bell

SUBJECT: Two NEW OC Water Reliability Study Authorizations – (A) Analysis and Mapping of Seismic Hazards and (B) Facility Vulnerability and Recovery Assessment – Authorization for Professional Service Agreements

STAFF RECOMMENDATION

Staff recommends that the Board of Directors authorize the General Manager to enter into two professional service agreements: (1) GeoPentech, Inc in the approximate amount of \$77,600 to perform Part A Analysis and Mapping of Seismic Hazards and (2) G&E Engineering in the approximate amount of \$41,000 to perform Part B Facility Vulnerability and Recovery Planning (the dollar amounts are subject to final negotiation). Both of these efforts will be utilized in the OC Water Reliability Study work. The additional work was presented to the OC Water Reliability Study Workgroup subcommittee who concurred with the approach and the consultant selection.

COMMITTEE RECOMMENDATION

To be determined at the Committee meeting . . .

Budgeted (Y/N): Y	Budgeted amount: \$340,000	Core X	Choice
Action item amount: \$120,000	Line item: Engineering + Carryover from the last fiscal year		
Fiscal Impact (explain if unbudgeted): The budgeted amount is comprised of this year's budget in Programs 21 and 23 including the carryover from the prior fiscal year. So far, approximately \$220,000 has been encumbered for the CDM Smith towards the OC Water Reliability Study work. While this specific seismic work was not anticipated, the budget for the OC Water Reliability Study had other components that will not be done or that will carryover into the next fiscal year and can be included in the budget for 2015-16.			

SUMMARY

In the process of starting the SYSTEM portion of the OC Reliability Study by MWDOC staff, staff confirmed that the 2005 seismic mapping was **NOT** sufficient to prepare the SYSTEM reliability analysis at the technical level desired. Staff conducted research into NEW approaches that would provide the ability to analyze seismic impacts to facilities, particularly wells in OC, to determine the level of GAPS between emergency supplies and emergency demands that might occur. Staff prepared a Scope of Work, received four proposals, and now is recommending that approximately \$120,000 of technical work be completed to assist in the reliability analysis. Staff believes the work is well founded in planning for our water future in OC and should be pursued. The OC Water Reliability Workgroup and the consultant selection subcommittee concurred with the recommended work. We believe this is the first time that technical work on analyzing potential impacts to wells has been approached. OCWD and SJBA staff have been supportive of the approach.

DETAILED REPORT

As part of the OC Water Reliability Study, MWDOC staff took on the responsible for completing the SYSTEM reliability assessment and planning for the OC Water Reliability Study Scope of Work. Staff planned on using the existing seismic mapping/shaking data from 2005 for the analysis. The Scope of Work for the OC Water Reliability Study included only limited involvement from CDM-Smith, our main consultant, to provide assistance to MWDOC on the approach for estimating well and pipeline impacts to local agency systems based on ground accelerations generated by five potential faults in the County and three major faults outside of the County. Staff met with CDM-Smith and their geotechnical engineer and seismic expert and OCWD staff to discuss the best manner to approach this work. At the meeting, we learned that the 2005 mapping information on seismic ground accelerations in OC had been significantly revised in recent years as much progress has been made in the field of seismology and analysis of shaking intensities based on analytical improvements. In general, the anticipated peak ground accelerations and peak ground deformations now being estimated are much higher than the prior estimates prepared in 2005 with new seismic design criteria and codes being developed.

The second item discussed was how to estimate potential damage to wells without having to complete a specific assessment on each well. There are approximately 185 major production wells in the County; damage from various shaking intensities could range from breaks in the wellhead piping that might require only simple repairs, loss of power, loss of disinfection facilities, and actual casing failures or misalignments that could render susceptible wells to outages for 6 to 9 months or more. In conjunction with these discussions between OCWD, MWDOC and CDM-Smith, we were advised that technical (structural, mechanical and geotechnical) earthquake engineering expertise should be sought to help evaluate how many wells in the groundwater basin may be at risk and what possible failure modes might occur from major earthquakes. We were advised that wells located in areas susceptible to earthquake induced liquefaction might be severely damaged and knocked out of service. These are areas where depths to first water are shallow, extending to depths to 50 feet below ground surface, and the soil structure is not well consolidated.

Based on the NEW information, staff began further research into an updated assessment for the entire county with particular emphasis on potential impacts to water supply wells and regional transmission pipelines using new and informed seismic vulnerability, mitigation and recovery planning information. Not only knowing what facilities might be vulnerable, but also knowing what improvements can be made to mitigate shaking or what steps might be taken to expedite recovery efforts would also be important to the resiliency of the local water supplies in OC. The technical work may also form the basis of grants for improvements to SYSTEM reliability in OC.

Staff met with engineering staff from MWDSC, spoke with engineering staff from LADWP and the California Department of Water Resources to discuss seismic vulnerability to the imported water system and planning efforts to better understand seismic risks, areas of needed improvements, and outage potential and recovery assessments. Staff has also spoken with Dr. Lisa Grant, seismologist at UCI and Dr. Lucy Jones, seismologist with the USGS concerning earthquake risks to the imported water system and to OC.

Staff identified several consultants with differing specialties that could help us with this type of work and discussed various approaches to conduct this work. Based on these discussions and review of available information, staff developed a scope of work for the “Seismic Vulnerability, Mitigation and Recovery Planning” work and identified consultants who have the most up to date information, core expertise, qualifications and capabilities to perform this work. The work was divided into (A) Analysis and Mapping of Seismic Hazards and (B) Facility Vulnerability and Recovery Assessment. Parts A & B require different qualifications and capabilities from the consultants. The answers we are trying to ascertain through this work has never been undertaken to this level before in OC, but based on the recent discussions, the work will help to address several questions related to potential earthquake risks to the major water supply facilities in OC and in particular, the risk to wells. The information developed will be directly applicable to help guide the water supply reliability planning and earthquake preparedness activities in OC. In addition, the new work will provide information for the 2017 update to the Multi-Hazard Mitigation Plan.

To solicit consultant proposals for this work, staff prepared and issued a Request for Proposal (RFP) to firms identified as having core expertise in two facets of needed work: (A) Analysis and Mapping of Seismic Hazards and (B) Facility Vulnerability and Recovery Assessment. As noted, staff coordinated and received comments from several agencies and experts in preparation of the scope of work.

MWDOC received four excellent written proposals on February 16, 2015 from:

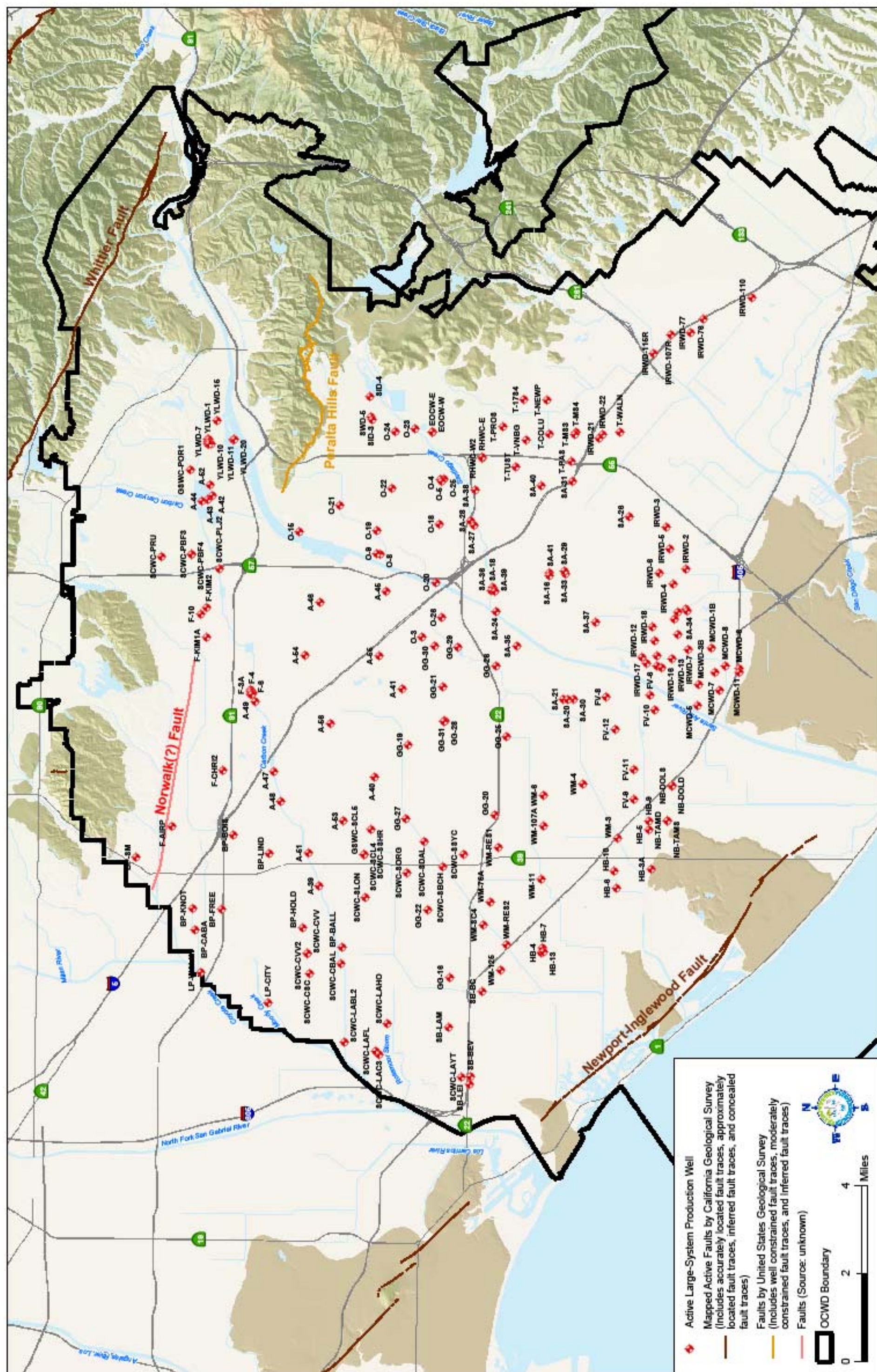
- Earth Consultants International (Part A)
- GeoPentech (Part A)
- G&E Engineering (Part B)
- Ballantyne Consulting (Part B)

The first two consultants are known to us and have done quite a bit of work in OC. The two latter consultants are both specialty consultants who spend essentially 100% of their time in analyzing potential impacts from seismic shaking and designing mitigation for key facilities. Mitigation can include redundancy in facilities, strengthening of facilities or designing

flexibility into the performance of facilities, but it can also involve efforts to speed up recovery and restoration of facilities. Both consultants have a methodology for analyzing key facilities based on ground shaking, the local geology and the design of the facilities. Both consultants have analyzed the impacts from prior earthquakes and should be able to help us to better understand our risk profile. The purpose of this work is not to individually analyze the approximate 185 large water supply production wells in the county, but to conduct a regional approach to determine what level of risks might be present and to provide information to help improve the resiliency of OC's water supply system. The results could say that we only have limited exposure to well failures or that the failures might be located in certain areas where the geology poses additional concerns or it might say that this is a really big issue and it might require follow-up work. This type of work has never been undertaken in OC and until just recently, we were not familiar with the experts that conduct this type of work.

After receiving and reviewing the proposals, additional supplementary information was requested on Part B to more fully detail the proposed approach and methodology to assess potential damages to water supply wells, especially in areas of potential liquefaction. Those revised proposals were received on February 23. The OC Water Reliability Study Work Group Selection Committee consisted of representatives from OCWD, SMWD, Anaheim and CDM Smith as well as MWDOC staff. The selection committee concurred with the evaluation and recommended selection of GeoPentech for PART A and G&E Engineering for Part B. It is estimated that this work will require about four months to complete. The estimated cost for this work is in the range of \$120,000 plus/minus \$20,000 as final negotiation of the scope will be necessary. This work is a core function and is included as part of the OC Water Reliability Study work.

The GeoPentech and G&E Engineering proposals are attached. Also attached is a graphic showing the locations of the major production wells in the groundwater basin.



Proposal for North Orange County Water Supply System Reliability Plan Seismic Vulnerability and Recovery Assessment

*Prepared for:
MWDOC*

Prepared by:

*G&E Engineering Systems Inc.
6315 Swainland Rd
Oakland, CA 94611
(510) 595-9453
eidinger@geengineeringsystems.com*

February 23, 2015

1.0 Task Outline

This proposal describes engineering services to be provided by G&E Engineering Systems Inc. for the Seismic Vulnerability and Recovery Assessment of MWDOC's North Orange County Water Supply System. This proposal is submitted in response to the RFP for the Project dated February, 2015 (Final Draft dated February 11 2015); and updated to reflect your request for more information dated February 23, 2015.

This scope of work is in response to the "Part B" element of the RFP. We assume that MWDOC will retain a third part to perform the "Part A" element of the RFP.

The intent of the work is to provide MWDOC with three main deliverables:

- Task B.1. What will happen to the water supply system, given a series of possible scenario earthquakes, for the water system in its current configuration? How much damage will there be? Which pipelines / wells will be damaged? What will be the impact on water delivery to customers (for potable water, for fighting post-earthquake fires)? How long will the outages last? Who will be best able to make the needed repairs? What will be the direct and indirect economic impacts?
- Task B.2. What strategies can MWDOC adopt now to reduce the impact of earthquakes? This might include pipeline upgrades, well improvements; additional storage; changes in emergency response strategies; addition of spare parts; etc. How much will these cost? Will these be cost effective?
- Task B.3. Reports, Meetings and Communication of Findings

UPDATE. On February 23 2015, MWDOC requested additional information with regards to the potential of liquefaction in Orange County, and how that might impact wells. This information is provided in this revised proposal, indicated by text in bold italic format.

Part A: Seismic Hazard Assessment

Part A is intended to be performed by others. Herein, we only highlight the key work to be done, and include the effort needed by G&E to interface with the Part A contractor.

Task A1. Characterize NOC and Nearby Active Faults.

Prepare maps of the Whittier, Puente Hills, Peralta Hills, San Joaquin Hills and Newport Inglewood faults (local faults) and San Andreas, San Jacinto and Elsinore (regional faults) in GIS format (presumed to be .shp file, ArcGIS 10.2). Include shape files showing locations of major water supply facilities (wells, treatment plants, regional water distribution pipelines).

Deliverable to G&E: Shape Files with GIS information, including all attributes. Report with description of the faults, seismicity, etc. G&E cost: \$0.

Task A.2. Characterize Southern California Active Faults.

Describe ruptures along the San Andreas, San Jacinto and Elsinore faults that might damage MWDSC and DWR main facilities (Colorado River Aqueduct, Edmunston Pumping Plant, C.V. Porter Tunnel and East Branch Facilities, as well as MWDSC main feeders to Orange County).

Note: G&E is very familiar with many facilities of the State Water Project and the MWDSC. G&E has performed seismic inspections and evaluations of SWP facilities (canals, pipelines, pump stations, substations) and MWDSC facilities (water treatment plants, tunnels, pipelines). G&E has reports on the damage potential to power supply for Edmunston pumping plant.

Deliverable to G&E: Report with description of the faults, seismicity, and upstream MWDSC and DWR facilities. G&E cost: \$0.

Task A.3. Provide Currently Available MCE Earthquake Scenarios for NOC.

Provide maps with PGA, PGV motions for selected scenario earthquakes. Characterize surface faulting (location, width of zone, amount of offset, distribution of offset motions) based on site specific information.

Provide maps with liquefaction susceptibility near regional water treatment plants, wells and transmission pipelines.

UPDATE. On February 23 2015, MWDOC requested additional information with regards to the potential of liquefaction in Orange County, and how that might impact wells. Under Task A.3, G&E requests that the Part A contractor provide the following:

- *Well logs, historical, throughout Orange County, showing depth to ground water.*
- *Interpretation of how the depth to water affects the potential for liquefaction (with PGA triggers)*
- *Interpretation of Liquefaction Hazard maps develop by the CGS (or others, including URS) with regards to quantified interpretation as to qualitative terms like "High, Moderate, Low" with regards to percentage of areas within a uniformly graded area that can liquefy.*
- *G&E has developed this type of information in the past, and to the extent that the Part A contractor needs to work collaboratively with G&E, G&E will provide the interface, meetings and technical reviews as part of an optional PART B work effort.*

In addition, the issue of liquefaction along shallow creeks should be generally refined as compared to what is available in available regional liquefaction maps. We will request the Part A contractor to refine these maps and models to establish permanent ground deformation (PGD) estimates at the depth or below of the regional transmission pipelines next to regional creeks; PGDs at elevations higher than the transmission pipelines are generally not damaging to the pipes.

Deliverable to G&E. All maps will be provided in GIS format (.shp files). A report will be provided that describes the basis for the seismic ground shaking hazards (PGA, PGV, spectra). G&E will use liquefaction triggering models to convert the liquefaction susceptibility into permanent ground deformations that are relevant to projecting damage for transmission pipelines, wells and water treatment plants. G&E cost: included with Part B.

G&E cost: optional, up to 40 hours professional time to work collaboratively with the Part A contractor to establish suitable liquefaction models.

Task A.4. Interface with Part B Consultant (G&E).

Prepare GIS maps and corresponding reports showing hazards and risk and facilities.

G&E cost: \$0.

Part B: Facility Vulnerability and Recovery Planning

The intent of the Part B work is to provide MWDOC with the following deliverables:

- Task B.1. What will happen to the water supply system, given a series of possible scenario earthquakes, for the water system in its current configuration? How much damage will there be? Which pipelines / wells / treatment plants will be damaged? What will be the impact on water delivery to customers (for potable water, for fighting post-earthquake fires)? How long will the outages last? Who will be best able to make the needed repairs? What will be the direct and indirect economic impacts?
- Task B.2. Recommend strategies can MWDOC adopt now to reduce the impact of earthquakes. This might include pipeline upgrades; well improvements; additional storage; changes in emergency response strategies; addition of spare parts; etc. How much will these cost? Will these be cost effective?
- Task B.3. Reports and Meetings and Communication of the Findings

Task B.1. Case Study and Recommendations for Seismic Resiliency.

Data collection. Mr. Eidinger will attend a meeting with MWDOC with at project outset, to conduct a project kickoff meeting. Prior to this meeting, Mr. Eidinger will provide a list of data to be collected. Generally, this sill include:

- MWDOC and member agency water supply planning reports.
- GIS of pipelines, wells and water treatment plants. If available, GIS of distribution systems (not essential for the current work, but helpful for providing maps and considering concurrent damage issues).
- Plans and profiles (original design drawings) for major transmission pipelines. Leak history on these pipelines.
- Workforce capability to make post-earthquake repairs (in-house, and using contractors)

Field inspection. Mr. Eidinger will visit well fields to inspect a sample of installation practices. This will include the well head; power supply; use of rigid and flexible couplings and pipelines; issues related to liquefaction. Including the project kickoff meeting, this is planned for two days in the field to perform facility inspections.

Seismic Evaluation. Mr. Eidinger will evaluate the likely performance of the following transmission facilities for each scenario earthquake:

- Transmission pipelines. Damage due to ground shaking; liquefaction; fault offset. Describe style of damage (leaks to appurtenances like air release and blow offs, branch connections); breaks on the main barrel of the pipe (joint pull parts; failure of wires in prestressed concrete cylinder pipes; wrinkling of steel pipes; etc). Describe damage locations. For each major reach of pipe, describe likelihood that pipe will retain its function after the earthquake (still provides some flow) or require shutdown and repair. Describe repair strategies (manpower, work required, equipment required). Describe repair times, based on total system-wide damage and best strategy to restore the system to as many customers as possible.
- Wells. Describe potential for changes to the aquifer (rises / drops, change in water quality). Describe damage potential to well casings at depth and in the top 30 feet. Describe well head damage potential, including differential settlements. Describe potential for loss of offsite power, and bus connections / quick connect couplings available needed to restore power using permanent or portable emergency generators. Describe damage potential for pipelines from the wellhead to treatment (local tanks, etc.) and to transmission facilities. Describe availability of portable generators from third parties (mutual aid, contractors, etc.) versus need to have self-owned facilities.
- Water Treatment Plants. Describe damage potential for: operations buildings; filters; sedimentation basis; chemical systems (tanks, buried pipes); pumps; tanks; etc.

UPDATE. On February 23 2015, MWDOC requested additional information with regards to the potential of liquefaction and subsequent damage to wells in Orange County.

RESPONSE. G&E has worked with nearly every major water agency around the world over the past 25 years that have undergone earthquakes. Many of these agencies have wells. Many of these wells worked successfully after the earthquake (once power was restored); but some wells failed partially or entirely.

As part of the current effort, we understand that there may be as many as 500 wells in Orange County. We will request from MWDOC with data collection for as many wells as possible, including the following:

- ***Style of well: casing type (diameter, wall t, joinery), depth to ground water; screen / slots type; pump type (submersible or shaft driven); style of seals; style of casings in the top 30± feet; and to the extent available, original well logs, plans and profiles of well head facilities (including pipes, local settling tanks, water quality / treatment processes). With this information, field inspection will be done (as listed above) for selected wells that are more important and in***

more sensitive locations (mapped in high ground water table locations with moderate to high liquefaction potential).

- *Historical well performance (in terms of initial yields and latest yield information, and ongoing maintenance actions). Wells that have already undergone more than 25% loss of yield, attributed other than to drawdown of the aquifer, may already have some amount of sanding / obstruction, and are more risky with regards to accelerated drop in yield after strong ground shaking.*
- *The potential for damage in an earthquake to a well will depend on site-specific information. Two flavors of damage will be considered: changes to the aquifer and damage to the well itself.*
- *As part of this effort, we will develop case histories of well success and well failures from past earthquakes. This will include shallow wells with thin walled casing pipes (considerable amount of damage in past earthquakes) as well as deep wells (often 500 feet or deeper). Case histories will include:*
 - *Performance of Orange County wells in past earthquakes (1933 Long Beach, 1986 Offshore; 1987 Whittier; 1994 Northridge, etc.). While the damage to Orange County wells in these particular events may be limited / nil, this information will provide a firm benchmark as to the minimum levels of shaking at which no damage occurs.*
 - *Performance of wells in the recent August 2014 Napa earthquake. In Carneros Valley, all water is supplied by wells. Levels of shaking in this area were high ($PGA > 0.4g$ common), and the area is mapped as having high liquefaction potential (USGS). Damage / non-damage and water quality issues from these well owners is being collected by DWR, and we will tabulate the available performance.*
 - *Performance of wells in the 2010 and 2011 Christchurch New Zealand earthquakes. The water supply in Christchurch is provided entirely by wells, with more than 180 wells in service at the time of the earthquakes. Portions of Christchurch liquefied. About 25% of all wells suffered damage, ranging from repairable (at the well head, often needed 100 to 200 manhours of effort) to non-repairable (at depth, requires a new well to be drilled). Sanding, damaged casings, well head damage all occurred. We will tabulate this damage for the style of wells in Christchurch, and use that to correlate to the type of wells in Orange County. G&E has worked extensively with the Christchurch City Council (Water Department) since this earthquake, and has visited with the water department 5 times.*
 - *Performance of wells in the 1989 Loma Prieta earthquake. More than 100 wells were exposed to moderate to strong ground shaking, including those in the City of San Jose water department, the City of Santa Clara water department, the city of Sunnyvale water department, Cal Water (Los Altos water department), Palo Alto water department, East Palo Alto water department; Stanford University water department. Mr. Eidinger works with all these water agencies on seismic vulnerability assessments. For this effort, he will tabulate all*

the wells; their performance in 1989 (success / failure); their location with regards to liquefaction susceptibility maps (very high, high, moderate, low, etc.), and their actual motions (PGA). Note: several older shallow wells failed in liquefaction zones and required new wells to be drilled; but most wells subjected to moderate to high levels of shaking performed well.

- *Based on the case histories, we will correlate the potential for damage at each of the MWDOC wells (about 500), based on known similarities in terms of well design (casings, well head configurations, etc.), versus the PGDs (permanent ground deformations in terms of settlements and lateral spreads) projected at the well locations. From this, will indicate the likely damage / non-damage situation by well, for each scenario earthquake; style of repair strategies (drill a new well; fix an above ground pipe; etc.); impacts of loss of power (form SCE or other local agency); need for emergency generators (permanent, portable, size) and quick connect couplings.*
- *Note: to develop the most accurate liquefaction models, there may be some effort needed by the Part B contractor to work with and modify, as suitable, the liquefaction maps and models with the Part A contractor. We recommend up to 40 manhours for this interface effort (optional); lacking this, we will use the Part A liquefaction models directly.*

For each scenario earthquake, we will project water demand for the hours and days post earthquake, in three areas:

- Normal demand (winter time, summer time conditions) for potable, sanitary and economic uses.
- Water lost through leaking / broken pipes. This demand can exceed normal demand.
- Water demand for fire fighting. For each scenario earthquake, we will project the number of fire ignitions and the potential for fire spread. G&E has written the industry standard on this topic, "Fire Following Earthquake", a 300+ page book that addresses fire ignitions, fire spread models, and mitigation measures that can be adopted by water agencies, fire agencies, gas companies, etc.

Mr. Eidinger will describe the outages in terms of "water not delivered" by using of graphs / charts that show the recovery of the water supply (horizontal axis) versus the customers with water delivered (vertical axis). The area "above" the curve is the "customer-days" of non-served water. The larger this quantity, the larger the direct and indirect economic impacts.

Mr. Eidinger will use fragility models to establish these damage estimates. Mr. Eidinger "wrote the book" on water system fragility models (ALA 2001) and has conducted detailed investigations of essentially every water system, world-wide, for every major

earthquake since the mid-1980s. Further, G&E regularly puts these findings into practical practice: Mr. Eidinger has designed more than 300 water pipes crossing active faults and through liquefaction zones; Mr. Eidinger also regularly designs water tanks, water treatment plant and wells for seismic loads. Mr. Eidinger has written several books on design of water facilities, including the industry standard "Seismic Design of Water Pipelines" (ALA 2005) and "Seismic Evaluation of Water Transmission Systems" (ASCE 1999).

Mr. Eidinger has also written many reports on the practical impacts to water system in recent earthquakes. These include (name and magnitude of earthquake, publication date)

- Napa M 6.0, California (2014). TCLEE (in press)
- Lushan M 6.6 China (2013). ASCE TCLEE 2014.
- Tohoku M 9.0 Japan (2011). ASCE TCLEE 2014.
- Christchurch M 7.2, M 6.2, M 6.2 New Zealand (2010-2011). ASCE TCLEE 2013; EERI 2014.
- Chile M 8.8 (2010). ASCE TCLEE 2012.
- Sichuan M 8.0 China (2008). ASCE TCLEE 2010.
- Palo Robles M 6.5, California (2003). ASCE TCLEE 2004. EERI 2004.
- Napa M 5.6 California (2000). ASCE 2001.
- Denali M 7.7 Alaska (2002). ASCE TCLEE 2003.
- Arequipa M 8.5, Peru (2001). ASCE TCLEE 2002.
- Gujarat M 7.6 India (2001). ASCE TCLEE 2002.
- Kobe M 7.0 Japan (1995). ASCE TCLEE 1996.
- Northridge M 6.8, California (1994). ASCE 2001.
- Loma Prieta M 6.9, California (1989). USGS 1990.

As Chairman of ASCE's committee for Seismic Design of Water and Wastewater Facilities, Mr. Eidinger has worked extensively with many US and international experts on the seismic design of water facilities. Mr. Eidinger regularly works with water utilities and manufacturers outside of the US, dealing with seismic design and evaluation of their facilities, including:

- City of Kobe Water Department
- City of Tokyo Water Department
- City of Sendai Water Department
- Kubota Pipeline Company (Manufacturer of Seismic Resistant Pipelines)
- Miyagi Prefecture Water Department
- City of Auckland New Zealand Water Department
- Mekorot (Israel) Water Department
- Bio Bio (Concepcion, Chile) Water Department

Mr. Eidinger also works closely with many leading University researchers on the seismic testing and evaluation of water systems, including:

- Prof. Tom O'Rourke, Cornell University

- Prof. Mike O'Rourke, RPI
- Prof. M. Shinozuka, U.C. Irvine
- And others

Mitigation and Emergency Response. Depending upon the findings in Task B.1, Mr. Eiding will develop a list of mitigation and emergency response strategies. Some of these are listed in Task B.2. Other strategies may include:

- Seismic upgrade of selected pipelines at fault crossings or liquefaction zones. We will describe the style of upgrade (type of pipe, length of pipe, details, etc.) , and upgrade costs.
- Replacement / upgrade of major pipelines due to age effects.
- Upgrade of water tanks (anchorage, sloshing, etc.)
- Upgrade of wells heads (change pipe outlet details, change style of casings, ground improvement, etc.)
- **Need to drill new wells or change maintenance efforts on existing wells**
- Stock spare parts (pipes, valves, butt straps, etc.)
- Improve emergency response capability (training, how to activate and manage large quantities of mutual aid)
- Equipment (excavators, welders, dump trucks, compactors, lighting, etc.)
- Install quick connect couplings
- Add storage (raw water or potable water as suitable)
- Construct new wells, as well as infrastructure (pipe, valve, etc.) to connect to transmission or distribution systems.

Task B.2. Local and Regional Supply Emergency Power, Interconnections and Isolation Valves

Given the impacts found from Task B.1, we will describe the portion of the loss of water supply (as a function of time) that is attributable to loss of offsite power (SCE or other agencies). We will factor in the current availability of portable or fixed emergency generators (or portable pumps).

EMERGENCY GENERATORS. Given the post-earthquake needs for water, especially for fire fighting purposes (which is highly time sensitive), and in conjunction with likely power restoration times by SCE (and other agencies), we will describe the benefits of having more portable / fixed emergency generators, including those for well fields; water treatment plants, as well as within the distribution systems. We will discuss the sizes (kilowatts), fuel supply, initial capital costs, ongoing maintenance costs for these emergency generators. We will discuss the cost effectiveness of having self-owned generators, or generators available via mutual aid / contractors.

VALVES. We will examine the state of damage to the pipeline / well / treatment plant network, including the locations of turnouts to major customers / retailers. Given the geographic location of the existing infrastructure and the seismic hazards (especially fault offset and liquefaction zones), we will recommend the installation of additional in-

line isolation valves (butterfly generally), and whether they should be manual (lower cost) or automatic (higher cost). For "automatic" valves, we will describe the best suited power sources (batteries, hydraulic, pneumatic); as well as in-line sensors (flow, pressure, acceleration) and computer logic suitable for automatic (or semi-automatic) operation. At well fields, we will make recommendations for additional valves. At water treatment plants, we will make recommendations for raw water bypass systems (including valves, pipe, air gaps, etc.)

INTECONNECTIONS. Depending on the findings, it might be possible to obtain emergency water supply to various agencies via interconnections to other agencies. These are often low flow (under 2,000 gpm or so), but major interconnections (10 to 50 MGD range) might also be warranted. We will consider concurrent damage to each agency, with the intent of providing supply as suitable from agencies that have seismic-reliable systems.

Examples. G&E has previously done many similar projects. A few are described below.

- EBMUD owns 175 pump stations. In 1991, EBMUD then had 1 fixed and 6 portable emergency generators. After conducting a seismic vulnerability assessment, based on G&E's recommendations, and in conjunction with PG&E power supply and concurrent fire risk, EBMUD procured 7 additional emergency generators and portable pumps; and installed 75 quick connect couplings and 82 sets of isolation valves with additional manifold connections.
- The goal of the EBMUD upgrade effort was to provide the maximum flexibility to respond to any range of likely earthquake outcomes, while keeping capital and ongoing maintenance costs within acceptable levels.
- City of Hayward. Assessed efficacy of through-system interconnections and development of local wells. In the last decade, Hayward has constructed emergency wells (enough to supply winter demand), as well as new interconnections (30 MGD) between EBMUD and SFPUC and Hayward.
- City of Palo Alto. Recommended new wells to supplement surface water supply from a regional wholesaler (SFPUC). The new wells have been built.
- City of Mercer Island. Recommended new wells to supplement surface water supply from a regional wholesaler (City of Seattle). The new wells have been built.
- Purissima Hills Water District. Recommended interconnection of nearby City of Los Altos water system for emergency water supply from wells. The interconnection pipeline has been built.

Task B.3. Maps, Reports, Presentations

G&E will prepare all its findings in a report that will be submitted to MWDOC, OCWD and CDM Smith. The report will be prepared in a format that is suitable to the agencies (planned is "WORD" format, with graphics in .jpg). We will use GIS for map backgrounds, (the GIS data is developed by the Part A contractor).

For the current effort, we assume that G&E will prepare for and attend four meetings during the course of the work, in order to present findings.

G&E can provide hundreds of maps, detailed databases, but to keep costs down for the current effort, the development of new databases and use of SERA GIS software is an optional effort (not included in this proposal).

2.0 Project Management

The technical lead for this effort will be Mr. John Eidinger. His resume is attached. Along with his technical responsibilities for the project, he will also be responsible for organizing the project effort. To ensure good communications between MWDOC and G&E, Mr. Eidinger will attend telecom or in-person meetings with MWDOC's Project Manager. These meetings will be scheduled on a regular monthly basis, and take about 1 hour each; in conjunction with project technical or special meetings. For each meeting, Mr. Eidinger will prepare a status report, go over monthly progress, schedule, costs incurred to date, projected work for the following month, technical issues which may require input from MWDOC's Project Manager or from other MWDOC staff.

For each meeting, Mr. Eidinger will provide record meeting minutes, and submit the meeting minutes with monthly status reports. To the extent practical, agenda, meeting notes, technical memoranda etc. will be in electronic form.

3.0 Project Qualifications

3.1 Key Staff Experience

Mr. John Eidinger will be the Technical Lead for this work, and will be the primary point of contract between MWDOC and G&E. He will also be technically responsible for all aspects of the Part B work.

Mr. Eidinger has working knowledge of MWDSC's water system. He has visited several MWDSC sites and has knowledge of the structural issues related to MWDSC's pipelines and tunnels.

Mr. Eidinger has 37 years experience in earthquake engineering, with the most recent 25 years devoted to seismic assessment of water systems, including seismic design of water pipes across active faults and thorough liquefaction zones. Mr. John Eidinger is a internationally recognized expert in the seismic performance of water systems and design of water pipes through faults, liquefaction and landslide hazard zones. He has written and chaired committees for four books on the various aspects of seismic design for water systems, including:

Seismic Guidelines for Water Pipes, 256 pages, published by FEMA / ALA

Fire Following Earthquake, 325 pages, published by ASCE / NFPA

Fragilities for Water System Components, 250 pages, published by ALA / FEMA

Guidelines for the Evaluation of Water Transmission Facilities, 196 pages, ASCE

Mr. Eidinger has also published more than 70 technical papers on seismic issues for lifelines, more than 25 directly related to the performance of water systems in earthquakes. He has performed evaluations and designs of over 350 water pipelines that cross earthquake faults, including SFPUC's BDPL 1, 2, 3 and 4 pipelines (5 to 10 feet of offset, Hayward fault); EBMUD's 60" El Portal pipeline (5 feet offset, Hayward fault); EBMUD's 60", 72" and 87" Mokelumne Aqueducts (3 feet offset, Concord fault); EBMUD's 24" Crockett Aqueduct (5 feet offset, Hayward fault); EBMUD's 42" Southern Loop (7 feet offset, Calaveras fault); EBMUD's 36" Lake Temescal pipeline (5 feet offset, Hayward fault); and several dozen more EBMUD pipes ranging from 12-inch to 36-inch diameter; several of Hayward Water Department's 8" to 24" pipelines (all 5 feet offset, Hayward fault); the City of San Diego's 24" to 54" pipelines crossing the Rose Canyon and Silver Stand Faults (up to 5 feet offset); MWD's 120-inch Upper Feeder across the Sierra Madre fault (over 5 feet reverse thrust offset); MWD's 54" Palos Verdes feeder over the Eagle Rock fault (2 feet offset); SCVWD's twin bore 66-inch pipelines where they cross the Calaveras fault (one leaked in the 1989 Loma Prieta earthquake); Thames Water's 87" pipeline where it successfully took 10 feet of right lateral offset (with leaks) in the 1999 Izmit earthquake; Alyeska's 48" oil pipeline where it successfully withstood 14 feet of right lateral offset in the 2002 Denali (Alaska) earthquake; and many more. He has worked with leading researchers in Japan in

developing updated techniques to evaluate pipelines to withstand fault offset. Mr. Eidinger will be the Lead Pipeline Engineer.

Mr. Eidinger was in responsible charge (stamped drawings) of the 60-inch, 66-inch BDPL 1 and 2 pipelines crossing the Hayward fault (SFPUC); the 42-inch Southern Loop (EBMUD); and the 72" BDPL 5 crossing the Hayward fault. He wrote the upgrade alternatives report for BDPL 3 and 4 when they cross the Hayward fault. He performed the engineering analyses and developed the details and the CER reports for the Alameda Siphon 4 and BDPL 3A pipelines.

Mr. Eidinger works closely with USGS and many leading geologic consultants in Southern California and in the San Francisco Bay Area to assess the seismicity of faults, including historic and predicted future patterns of fault offset. Mr. Eidinger has worked with firms including GeoPentech; AMEC / Geomatrix; WLA / LCI; URS, and others in southern California.

Mr. Eidinger has also performed detailed hydraulic modeling of many water systems, including all of SFPUC's large diameter pipelines, all of EBMUD's large diameter pipelines, to study their hydraulic response under normal operations and earthquake conditions. He has also developed state-of-the-practice hydraulic models to examine earthquake-induced hydrodynamic forces that are a factor in the earthquake design of pipelines.

Mr. Eidinger is a licensed Civil Engineer and Structural Engineer in California.

3.2 G&E Related Experience

G&E is a firm specializing in the seismic assessment of wastewater, water, power and related lifeline utilities. G&E staff have extensive experience in the seismic evaluation of underground pipelines, wells, tanks, reservoirs, the analysis of pipelines through liquefaction zones, evaluation of pipe aging / replacement due to effects of corrosion and ongoing leak history, field inspection of pumping plants, seismic evaluation of water and wastewater treatment plants, the evaluation of existing buildings under seismic motions for life safety and post-earthquake functionality requirements, and associated design efforts.

G&E was incorporated in 1991, and has been successfully working for wastewater, water and power utilities over the past 25 years. G&E has worked with over 100 water and electric utility clients during this time period. G&E's work mix is typically 25% to 75% wastewater and water and 25% to 75% electric utilities in any given year.

In Southern California, G&E has performed seismic vulnerability assessments for the following water systems within the past 15 years: San Diego County Water Agency, City of San Diego, Helix Water District, Burbank, Pasadena, Fountain Valley, Westlake, East Los Angeles, Redondo Beach, Dominguez, Big Bear Lake.

In Orange County, G&E is performed detailed seismic assessments and mitigation for the major power companies, including SCE and SDG&E. This includes ongoing seismic work at San Onofre, and regional assessment of major high voltage transmission systems (230 kV and 500 kV).

In the Pacific Northwest, G&E has performed seismic vulnerability assessments for the following water agencies: City of Everett, Clackamas River Water, Oregon City, City of Albany Oregon, Portland Water Bureau, Eugene, Mercer Island. G&E has done seismic evaluation of every BC Hydro and BPA substation in BC, Oregon and Washington, include all those in and near Vancouver, Burnaby, Coquitlam, North Vancouver, Richmond, Sea Island (Vancouver Airport), Annacis Island, Delta, Surrey.

In the past 25 years, G&E has performed seismic vulnerability evaluations for many water systems in Northern California, including: City of San Francisco (SFPUC), East Bay Municipal Utility District (EBMUD), Zone 7, Santa Clara Valley Water District (SCVWD), South Bay Aqueduct (DWR / State Water Project), Hayward, Milpitas, City of Santa Clara, Sunnyvale, Mountain View, Cal Water Los Altos, Palo Alto, Stanford University, Cal Water Livermore, Coastside County, Bear Gulch, Menlo Park, Redwood City, San Mateo, San Carlos, Belmont, Burlingame, Brisbane, Daly City, South San Francisco, Contra Costa Water District, the City of Berkeley (specialized fire fighting system).

Mr. Eidinger has prepared U.S. nation-wide procedures for FEMA, the American Lifelines Alliance, ASCE, and the U.S. National Institute of Building Sciences for water system seismic vulnerability assessments. These have undergone substantive peer review by numerous experts, and can be considered the "state-of-the-practice" in this area. G&E has authored 3 books (cumulatively over 700 pages long) include:

2001: Water System Fragility. This includes detailed pipeline fragility models for all major US and international earthquakes through 2000. Since then we have collected a lot of new data for water pipeline performance from Concepcion (2010 Chile M 8.8); Sendai (Japan M 9.0 2011); Christchurch (2010 and 2011 earthquake sequence); China (2008 and 2013) and other earthquakes.

2005: Guidelines for the Seismic Design of Water Pipelines. This is considered by many US water utilities as the "state of the practice" for design of new water pipelines through liquefaction, landslide and faulting zones. The guidelines cover every kind of water pipe, ranging from 96" diameter transmission pipelines, to 5/8" diameter service lateral connections, and all sizes in between. The guidelines cover use of Kubota ductile iron "chained" jointed pipe; HDPE pipe, and where it is reasonable and sound to use PVC, Tyton-jointed ductile iron, welded steel, and many other kinds of pipes.

Mr. Eidinger has developed many capital seismic improvement programs for water utilities, and have made many presentations to Boards of Directors, the Public and other stakeholders in the decision making process.

In the past 25 years, Mr. Eidinger has successfully obtained FEMA grant money for seismic upgrade for several water and wastewater utilities, with typical funding between \$1.5 million and \$3 million for each project. These upgrades cover items such as open cut reservoirs, concrete tanks, steel tanks, EBAA Flexextend installations, building upgrades,

pump station upgrades, equipment upgrades, remediation / upgrade of pipes at fault crossings. While FEMA does not provide grants in Canada, the benefit cost models used to establish the cost effectiveness of these grants is directly applicable.

G&E has been actively involved with many transmission pipeline fault crossing and liquefaction seismic upgrade programs with many water utilities. These efforts include more than 300 water pipelines that cross active faults and go through liquefaction or landslide zones. G&E has performed these services in Northern California for pipelines crossing the San Andreas, Hayward, Calaveras and Serra faults; in Southern California, for pipelines crossing the Rose Canyon, Silver Strand, La Nacion, Elsinore, Raymond, Newport-Inglewood, Palos Verdes and Eagle Rock faults.

Client Contacts. G&E has performed similar seismic vulnerability assessment work for many water agencies, including: City of San Diego/ San Diego County Water Authority (Mike Conner, 858-522-6856); Cal Water (many water districts in the Los Angeles Basin, Mr. Bryan Kunic, 408-367-8312); and more than 50 others.

For this project, we expect that fault offset risk for water transmission pipelines will be one of the major elements of the overall vulnerability assessment. It is important to understand that not all pipes "break" due to fault offset, and this should be factored into making suitable upgrade plans for MWDOC. The following table provides a listing of some of the larger water pipelines that G&E has designed (or evaluated as acceptable) across faults. In addition to these large diameter pipes, G&E has done similar services for pipelines through liquefaction and landslide zones.

Pipe	Fault	Utility	Pipe	Fault	Utility
60" BDPL 1	Hayward	SFPUC	66" BDPL 2	Hayward	SFPUC
72" BDPL 5	Hayward	SFPUC	78" BDPL 3	Hayward	SFPUC
96" BDPL 4	Hayward	SFPUC	72" BDPL 3A (CER)	Hayward	SFPUC
36" Line A	Serra	SFPUC	78" Line N	Serra	SFPUC
96" Sunol (AAR)	Calaveras	SFPUC	72" Alameda Siphon 4 (CER)	Calaveras	SFPUC
60" El Portal	Hayward	EBMUD	42" South	Hayward	EBMUD
54" South	Hayward	EBMUD	87" Mokelumne 3	Concord	EBMUD
42" Southern Loop	Calaveras	EBMUD	72" Mokelumne 2	Concord	EBMUD
60" Mokelumne 1	Concord	EBMUD	48" PCCP	Hayward	ACWD
42" Steel	Hayward	ACWD	30" Brown	Hayward	ACWD
24" Zone A	Hayward	Hayward	16" Central	Hayward	Hayward
60" Lower Feeder	Palos Verdes	MWD	108" Upper Feeder	Sierra Madre	MWD
Aqueduct 1	Elsinore	SDCWA	Aqueduct 2	Elsinore	SDCWA
Aqueduct 3	Elsinore	SDCWA	Aqueduct 4	Elsinore	SDCWA
Aqueduct 5	Elsinore	SDCWA	36" Thorn Street	Rose Canyon	San Diego
24" Upas Street	Rose Canyon	San Diego			

A few example projects where G&E has been the lead engineer and designer of pipelines that cross faults include the following:

72" BDPL 5 pipeline across the Hayward fault. G&E developed the conceptual design, all alternatives, and the final design for this pipeline. It is constructed in 2011. This pipeline crosses the Hayward fault on sliding supports through a creek. G&E worked with all agencies (ACFCD, city of Fremont, etc.) to coordinate the design, select trench methods through busy streets (Grimmer and Paseo Padre) that were acceptable to the City. G&E developed all plans, profiles, detail drawings, technical specifications, cost estimates. G&E reviewed the fabricator's submittals (steel and welding) and contractors submittals.

60" and 66" diameter Bay Division Pipelines 1 and 2. These pipelines were built in 1923 and 1934, respectively. They are owned by the San Francisco Public Utilities Commission (SFPUC). G&E was retained by the SFPUC to evaluate the ability of these pipelines to absorb fault offset, and to develop alternative design methods to retrofit (replace) the pipelines to that they would reliably be able to withstand probable and maximum earthquakes on the Hayward fault. G&E developed more than ten retrofit design concepts. The ultimately chosen retrofit design was to use 60" x 11/16" and 66" x 3/4" steel pipes, using butt welds, changing to double lap welds and finally converting back to original riveted or thin-walled welded steel pipe. The pipelines are now constructed. G&E conducted material tests for the original pipes (including rivets); established acceptance criteria for the new and old pipes; conducted field soil-pipeline

skin friction tests; performed coating tests; performed global and local finite element models as part of design-by-analysis; developed cost estimates; assisted with corrosion protection for the new pipes; laid out designs for isolation valve vaults; developed rapid anchorage schemes (done to limit impact on busy roads that the City of Fremont wished to avoid); developed construction drawings and specifications. The figure below shows actual construction of the BDPL 1 and 2 pipes at the Hayward fault, showing the new soldier pile wall (far right), 60" BDPL 1 (ribbed pipe in foreground is in the pipe anchor zone, smooth pipe (with welder) is in the background); BDPL 2 (already constructed, far left). A special controlled density backfill trench was used to improve anchorage in the anchor zones, while a protected-pea gravel trench (trapezoidal shape) was used in the fault crossing zone. The ribbed pipes were used to rapidly anchor the pipes, thereby reducing the length of pipe that had to be replaced, and thus lowering project costs. Client



BDPL 1 and 2 Fault Crossing Design Details

Bypass system, SFPUC, Hayward fault. G&E laid out the design for a bypass system using flexible hose and double sets of 6-outlet manifolds. We also developed alternatives using 24" diameter high density polyethylene pipe.

78" and 96" diameter Bay Division Pipelines 3 and 4. These pipelines were built in 1952 and 1963, respectively. G&E was retained by the SFPUC to evaluate the ability of these pipelines to absorb fault offset, and to develop alternative design methods to retrofit (replace) the pipelines to that they would reliably be able to withstand probable and maximum earthquakes on the Hayward fault. These pipeline normally carry more than 170 MGD flows to serve Milpitas, San Jose, Santa Clara, Sunnyvale, Mountain View, Palo Alto and other cities. The existing pipelines are either segmented reinforced or prestressed concrete pipes. They cross the Hayward fault at an angle that forces them into compression and bending. Should the pipes fail, release of water may erode away portions of Interstate 680 and Mission Boulevard. G&E calculated flow and inundation zones due to break of the pipes. In conjunction with the SFPUC, G&E applied to FEMA for co-funding of the fault mitigation project. G&E laid out the requirements for isolation valve

vaults. G&E is developed design alternatives to replace the pipes, include heavy wall pipe within a new articulated culvert.

66" diameter Alameda Siphon 4. This is a new pipeline to be built in 2006/2007. G&E was retained by the SFPUC to develop the alignment and design the new pipe to accommodate up to 5 feet of fault offset (Calaveras fault) as well as intermittent settlements or lateral spreads due to liquefaction. G&E performed detailed structural analyses; cost estimates; developed plans and profiles.

96" diameter Sunol Valley Pipeline. This pipeline is a planned future upgrade for the SFPUC water system in Sunol Valley. G&E was retained by the SFPUC to develop the alignment and design the new pipe to accommodate up to 5 feet of fault offset (Calaveras fault) as well as landslides, liquefaction at a creek crossing, and sympathetic movement of the Sinbad fault. G&E performed detailed structural analyses; cost estimates; developed plans and profiles.

42" diameter Crow Canyon Pipeline. This pipeline is a new pipe that was designed and engineered by G&E through the Calaveras fault crossing zone. G&E worked with EBMUD (pipe owner) to develop an alignment that would optimize pipe performance, while minimizing impacts to the existing streets and nearby property owners. Ultimately, EBMUD selected an alignment that would not be optimal for pipe stress / strain, but which satisfied other important project criteria (like not upsetting the City of San Ramon too much). Given these practical issues, G&E designed the pipeline to provide as much capability of absorb fault offset as possible (about 3 to 5 feet, reliably), and included a bypass system (using standardized 12-inch diameter flex hose) that could be used in case the fault offset is larger. G&E worked with the steel pipe fabricator (Ameron) to develop suitable steel and fabrication requirements. The pipe was constructed in 2003 under budget and is now in service.

Pipeline: 36" diameter Dingee Main Pipeline. This pipeline was built in 1936. It is owned by EBMUD. It crosses the Hayward fault through the crest of the Lake Temescal dam, and also in a culvert under Highway 24. The retrofit design accommodates fault offset allows for rapid repair and bypass using 12-inch diameter flex hose should the fault move through the dam.

Other EBMUD water pipelines. G&E prepared contract documents to upgrade more than a dozen other water pipelines (12" to 36" diameter) that cross the Hayward fault or active landslides in the EBMUD system. G&E also did risk evaluation of the likelihood of survival for more than 200 pipelines in the EBMUD potable water system (4" to 66"); from that study, in conjunction with hydraulic modeling, G&E established the amount of flex hose to be purchased by EBMUD (5" to 12" diameter); EBMUD adopted these recommendations, and now has 17,000 feet of various diameter and length flex hose. G&E helped specify the design and storage requirements for the 12" hose. G&E performed design reviews of EBMUD-internal designs for upgrades of the 60" El Sobrante bypass pipeline and the 24" Crockett Aqueduct whey the cross the Hayward fault.

City of Hayward Water Department. G&E was retained by the City of Hayward to perform peer review of new pipelines (16" and 24" diameter) that cross the Hayward fault. G&E also laid out the conceptual design for three new pipelines (12") that cross the Hayward fault.

City of San Diego Water Department. G&E developed a pipe upgrade program for the San Diego Water Department, including installing new isolation valve and bypass systems for 16 major pipes (16" to 48" diameter) that cross the Rose Canyon and Silver Strand faults. G&E helped secure co-funding by FEMA for this project (\$4,000,000).

G&E performed seismic risk evaluations of the **three EBMUD Mokelumne Aqueducts** where they cross the Concord fault in Concord. While the design of each of these large pipes differs, evaluations show that none of the pipes are capable of reliably surviving Concord fault offset. Should they break, they will take many weeks to repair. Given this situation, Mr. Eidinger developed a \$700,000 seismic retrofit that would avoid major (and expensive) upgrade of the Mokelumne Aqueducts at the Concord fault, while still providing reliable service to all EBMUD customers after a Concord M 6.5+ earthquake. Other alternatives, costing up to \$100,000,000, were considered. This upgrade has been implemented (final design by EBMUD internal staff).

Depending on the costs, importance and system characteristics, G&E has implemented seismic mitigation for these pipelines using a range of methods, including:

- Complete pipe replacement through the fault, with the new pipe being fault tolerant (capable of surviving several feet of offset without break).
- Installation of manual isolation valves either side of the fault zone. Should the pipe break, the valves are closed to isolate the damage, and allow pressure and flows to be maintained elsewhere in the water system.
- Installation of remotely-actuated automatic isolation valves. By "remotely actuated", it is meant that the valves have their own standby source of power (either hydraulic or electric), and with suitable instrumentation (motion, flow and pressure) so that a remote operator (via SCADA) can decide whether or not to close (or re-open) the valve. Completely automatic valves (using the instrument data alone to decide whether to close the valve) is rarely adopted by larger water utilities, unless there is a clear and present risk to immediately life safety or large inundation / erosion issues where minutes are critical to making the isolation decision.
- Installation of suitable manifolds (or, re-using existing fire hydrants with suitable outlets and adapter rings) to allow use of above ground large diameter (5" to 6") or ultra large diameter (8" to 12") flex hose, or aluminum pipe. The hose is manually installed within a few hours post-earthquake to re-establish water flows for customer use, while permanent repairs (taking days or weeks) are made to the

damaged pipeline.

- Procurement of suitable types of above ground hose that serves post-earthquake purposes throughout the water system, as well as day-to-day mini-emergency needs. Alternately, rely on the hose via mutual aid (a possible strategy for City of Hayward). Flex hose should to be designed and stored in consideration of available manpower, storage locations, shelf-life, deployment, attachment connections, maintenance, chlorination /disinfection considerations.
- Do nothing – accept the risk and consequences that some pipes might break or leak, but allow for such in the utility's emergency response and recovery plans. (Manage the Damage strategy). This strategy can be effectively used to lower capital construction costs used where available redundancy and system needs, and other constraints, make it appropriate.

4.0 Project Cost

The estimated cost for this project is provided below. The work will be performed on a time and materials basis in accordance with G&E rate schedule 2015.

Task B.1. \$17,000.

Task B.2. \$10,000.

Task B.3. \$14,000.

Total. \$41,000.

Part A. Optional. Up to 40 hours professional time to interface wit the Part A contractor to establish suitable liquefaction models.

5.0 Project Schedule

The schedule to perform the work is as follows:

Notice to Proceed	March 7 (target date).
Task 1. Evaluation	NTP + 10 weeks
Task 2. Recommendations	NTP + 12 weeks
Task 3. Reports Meetings	NTP + 16 weeks

A master project schedule showing all review cycles and subtasks will be provided one week after Notice to Proceed.

6.0 Resume for Mr. Eiding

Attached.

Rate Schedule, Reimbursable Expenses and Payment

G&E ENGINEERING SYSTEMS INC.
RATE SCHEDULE 2015
Effective through December 31, 2015

Engineering Rate Schedule (Regular and Overtime Hours)

Principal	\$215.00
Senior Technical Specialist	\$205.00
Technical Specialist	\$195.00
Senior Engineer	\$156.00
Engineer	\$135.00
Drafter	\$125.00
Administrative	\$62.00

Labor costs include salary, fringes, overhead, general and administrative, and profit. Labor costs are valid through December 31, 2015, and increase by 3% for the twelve months following. Rates for subsequent calendar years are subject to annual changes.

Reimbursable Expenses

- a. Mileage standard IRS rate per mile
- b. Expenses of travel, subsistence and communications outside of the San Francisco Bay Area, in connection with the Project. Air travel will be by coach rates.
- c. Expense of the reproduction and messenger delivery of project work and other documents.
- d. Expense of outside services including sub-consultants, mock-ups, models, special drafting, display renderings, graphic art work, and photographic work at cost plus 10%.
- e. Expense of special supplies and materials. Color print media shall be charged at \$0.75 per sheet (A size) or \$1.50 per sheet (B size) or \$1.50 per square foot for large format sizes (D or E size). Large format (D or E size) black and white drawings shall be charged at \$1.00 per square foot.
- f. Expense of computers. Computer costs include rates for computer-based engineering calculations and CAD drafting. No charge for computers used for word-processing or other overhead activities.

Payment

Invoices shall be submitted on a monthly basis. Payment is due net 30 days. Any portion of an invoice that is not in dispute is payable net 30 days. Late payments shall be charged a 1.5% per month late charge; such late charges are over and above any stated maximum ceiling amounts.

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EDUCATION

B.S., Civil Engineering, Massachusetts Institute of Technology, 1975
M.E., Structural Engineering and Structural Mechanics, U.C. Berkeley 1978
M.S., Structural Engineering and Structural Mechanics, U.C. Berkeley 1982
M.B.A., Business Administration, U.C. Berkeley, 1984

LICENSES

Professional Engineer, Civil, California, C-31637
Structural Engineer, California, SE-2631
Professional Engineer, Civil, Alaska, 11276

QUALIFICATION SUMMARY

Mr. Eidinger has 37 years experience in the water and electric utility industries. He has a detailed background with the analysis, design, risk quantification and economic analysis of large diameter water pipelines, water treatment plants, wells, tunnels, pump stations, canals, bridges, buildings, mechanical and electrical equipment, electric substations. Over the past 25 years, he has worked with nearly every major water utility around the world to address how they performed after major earthquakes.

PROFESSIONAL EXPERIENCE

Mr. Eidinger is an industry-recognized expert on the seismic performance of pipelines and reliability of water systems in earthquakes. He has conducted post-earthquake reconnaissance efforts for many water transmission systems around the world including California, Alaska, Japan, Turkey, Peru, India, China, Chile and New Zealand. He has designed many pipelines through fault, liquefaction and landslide zones. Mr. Eidinger has evaluated the seismic performance and developed upgrade recommendations for most of the water treatment plants in the San Francisco Bay Area. Mr. Eidinger has worked extensively with nation-wide agencies (FEMA, ALA, NIBS, ASCE, AWWA, JWWA) to develop four books on seismic guidelines for seismic design of water transmission systems. He has published extensively on this and related topics.

For the City of San Diego, Mr. Eidinger quantified fault crossing locations for about 100 pipelines where they cross the Silver Strand and / or the Rose Canyon fault zone. These evaluations consider the activity of the fault segments, and the design characteristics of each individual pipeline. About 60 pipelines may break in the next characteristic earthquake on the Rose Canyon fault. Design retrofit strategies were developed to mitigate this problem, through a combination of new "fault resistant" pipelines, re-routes, isolation valves, temporary 400 psi 12" pipes.

For Palo Verdes Water (Cal Water), he evaluated the 60" to 96" Metropolitan Water District of Southern California pipelines for performance due to fault offset of the Newport Inglewood and Palos Verdes faults.

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For Pasadena Water and Power, he evaluated the performance of all 6" to 36" diameter pipelines where they cross the Eagle Rock, Raymond and Sierra Madre faults; as well as MWDSC's Upper Feeder and East Side Feeder. He has also designed seismic upgrades for several of their large open cut reservoirs.

For the City of Burbank, he assessed the seismic response of the wells and pipelines in the city's water system, as well as MWD's East Side feeder for surface water supply. He considered various possible earthquakes on the San Andreas, Verdugo, Sierra Madre, Puente Hills, Newport Inglewood, Elsinore, and more than 20 other faults in the region.

For the San Diego County Water Authority, Mr. Eidinger developed their seismic criteria, which includes fault offset of five larger diameter (60" and larger) treated and raw water pipelines that cross the active Elsinore fault. He developed post-earthquake repair times for each of these five pipelines, to help establish a suitable emergency response strategy for the City of San Diego.

For Redwood City, M. Eidinger developed a model to establish a short- and long-term water pipe replacement program that factors in both seismic, aging and corrosion-related pipeline issues.

For the City of Burbank, M. Eidinger developed a model to establish a short- and long-term water pipe replacement program that factors in both seismic, aging and corrosion-related pipeline issues.

For the SFPUC, Mr. Eidinger designed upgrades to three pipelines that cross the Serra fault, and two liquefaction zones. The existing pipelines include a 54" 1923-vintage riveted + lockbar steel pipe; a 61" welded steel pipe and a 66" lined prestressed concrete cylinder pipe. Modified pipes will use welded steel or DIP with seismic resistant joints (Kubota) in order to accommodate up to 2 feet of permanent ground deformations due to liquefaction or fault offset.

For EBMUD, he performed Monte Carlo seismic simulations of the raw water transmission system, including all tunnels and pipelines, to examine the reliability of the system to deliver water to each water treatment plant. He examined 8 different seismic retrofit strategies for the EBMUD system, ranging from \$6 million to over \$130 million, to examine the improvement in reliability for various levels of upgrade. Based on these studies, EBMUD adopted a \$6 million upgrade program for its raw water system that meets its seismic reliability requirements.

For SCVWD, Mr. Eidinger evaluated all their tunnels and pipelines to establish their likely performance in various future earthquakes,

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developed a suitable emergency response plan (with spare pipes). He evaluated the performance (and damage) of the twin 66" pipelines (using custom-made restrained-segmented joints) that cross the Calaveras fault, where one of the two pipes sustained damage in the 1989 Loma Prieta earthquake. He also developed the SCVWD seismic retrofit program that factors in the simultaneous seismic performance of SCVWD's wholesale customers. Due to the substantial reliability of some of SCVWD's wholesale customers (especially in the South Bay Area), the cost of SCVWD's seismic upgrade program was substantially reduced, while maintaining the overall seismic reliability goals for water usage in Santa Clara county. He performed economic analyses of the SCVWD system with and without various levels of possible seismic upgrades. He developed conceptual design upgrades for the Vasona pump station, and the operations buildings at Rinconada and Penitencia water treatment plants.

For Stanford University, Mr. Eidinger evaluation the water system for earthquakes, including all pipelines, pump stations and reservoirs. He developed a multi-stage seismic improvement plan for the University. He was also the engineer in charge of seismic upgrades for the Stanford high voltage electric system.

For the Purissima Hills Water District, Mr. Eidinger evaluation the water system for earthquakes, including all pipelines, pump stations and reservoirs.

For the City of Menlo Park, Mr. Eidinger evaluation the water system for earthquakes, including all pipelines, pump stations and reservoirs.

For the City of Mountain View, Mr. Eidinger evaluation the water system for earthquakes, including all pipelines, pump stations and reservoirs.

For the SFPUC, he has performed seismic reliability analyses for all water transmission pipelines and tunnels for ground shaking, liquefaction, landslide and fault offset. These analyses were performed to establish the reliability of SFPUC water to be delivered to the SCVWD system after earthquakes that jointly affect both water systems, as well as to the City of Palo Alto turnouts, as well as to establish a suitable emergency response and reliability program for the SFPUC.

For EBMUD, he quantified the need for medium diameter (6") and large diameter (12") flex hose for the entire water system, considering the need to rapidly restore water service throughout the EBMUD service area. The total length of hose considers hydraulic requirements to meet emergency flow rates; diameter and hook-up hardware; cost

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effectiveness; availability of manpower to mobilize and install the hose; availability of hose from mutual aid agencies.

For the SFPUC, Mr. Eidinge designed the new BDPL 5 pipeline (72" diameter) where it crosses the Hayward fault in Fremont. The design uses state-of-the-practice design-by-analysis methods. This included analyses using ANSR and SAP (nonlinear models), design of below ground and above ground pipelines, supports for the pipeline for a self-supporting pipeline bridge, deep foundations, retaining walls, encasement through roads, trenches, and necessary sliding surfaces. Mr. Eidinge stamped all contract drawings and specifications for the pipeline through the Hayward fault crossing zone.

For the SFPUC, Mr. Eidinge designed the connections from a 108" diameter steel pipe to two vertical concrete shafts, located in a zone prone to liquefaction in Newark and Ravenswood.

For the SFPUC, Mr. Eidinge developed the design details for 60", 66" and 72" pipes and their service laterals (8" to 12"), blow off and air and vacuum valve assemblies, to ensure reliable service due to earthquake-induced liquefaction. He has done similar work for EBMUD.

For the SFPUC, Mr. Eidinge designed two new pipelines (60" BDPL 1, 66" BDPL 2) where they cross the Hayward fault in Fremont. These designs use state-of-the-practice design-by-analysis methods. Tests were performed to validate pipe-soil friction; a suitable epoxy coating system that will not flake off / crack at high pipe strain; and steel material properties for existing pipes, in order to minimize length of pipe to be replaced. Mr. Eidinge also conducted experimental tests to establish the true ductility and load capabilities of the original 1923 and 1933 pipelines, including welds and rivets; these tests form the basis of the capability of the existing pipelines to withstand fault offset.

For the SFPUC, Mr. Eidinge evaluated the seismic capability of the BDPL 1 and 2 pipelines where they cross San Francisco Bay near the Dumbarton bridge. This included research into the original construction of these pipes, inspection of every wooden trestle support, evaluation of linings and coatings and actual corrosion of the pipes, nonlinear structural analysis of the pipes, hydrodynamic analyses to consider earthquake-induced water hammer, thermal analyses for heat-up cool-down for the above ground pipes, and developing a low cost maintenance upgrade to keep the pipes reliable for a ten year operating period until the new BDPL 5 pipeline is constructed.

For the SFPUC, Mr. Eidinge developed the design of the new 72" BDPL 3A where it crosses the Hayward fault. This included nonlinear

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structural analyses for the pipeline under a range of possible ground motions (inertial and offset), hydraulic analyses for a range of possible operating conditions (including simultaneous damage to all segments of the BDPL and Alameda Siphons); selection of location of isolation valve vaults, consistent with fault offset-induced forces, hydraulic analyses to consider leak rates should pipes be left unmitigated, and resulting inundation zones, considering available storm water culverts.

For the SFPUC, Mr. Eidinge developed the alternative analysis report for a possible new 96" diameter Sunol pipeline, able to withstand fault offset of the active Calaveras and potential active Sinbad faults. This work resulted in selection of a Alameda Siphon #4 pipeline. Mr. Eidinge designed the Alameda Siphon #4 through the 10% design stage, including route selection, and a range of nonlinear analyses.

For the SFPUC, Mr. Eidinge evaluated the performance and developed conceptual designs to upgrade two pipelines at the Harry Tracy Water Treatment Plant Line N (60" – 78") and Line A (36") to survive fault offset of the east and west strands of the Serra fault. As part of this work, he researched the original design basis of all pipelines at and near the water treatment plant, including all original design drawings and specifications, including multiple upgrades, re-routes and re-linings over the years from 1923 to 2008, of the SAPL 2, SAPL 3 and Sunset Supply pipelines.

For EBMUD, Mr. Eidinge designed the 42" Southern Loop pipeline where it crosses the Calaveras fault. The design ensures the pipe has a reasonably high reliability of surviving a fault offset, while maintaining its pressure boundary; a backup bypass system is included to accommodate very large offsets. He also examined the reliability of the pipeline to landslide movements along the Crow Canyon corridor. This pipeline is in current operation.

For EBMUD, Mr. Eidinge designed 16 pipelines where they cross faults or active landslide zones. Mitigation strategies included upgrade of the pipes so that they will not fail, including HDPE pipes, and the addition of failsafe isolation valves with bypass manifolds for use with ultra-large diameter flex hose.

For ACWD, he evaluated more than 100 water pipelines that cross the Hayward fault. He performed evaluation of ongoing performance due to fault creep for the two largest ACWD pipes that cross the Hayward fault (42", 48"). For ACWD's largest pipelines (16" and larger), he developed conceptual designs and costs for upgrade; the ACWD Board recently adopted a five year capital budget that includes the costs to implement these fault crossing upgrades.

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For Castro Valley Sanitary district, he evaluated the seismic capability of its 36" main sewer that crosses the Hayward fault. This pipe is a vitrified clay pipe in 6-foot segments, that has already sustained 8 inches of fault offset movement due to ongoing Hayward fault creep.

For the City of Hayward, Mr. Eidinger evaluated all of its major pipelines (12" to 24" diameter) that cross the Hayward fault. He has also designed replacement pipes that can sustain up to 5 feet of fault offset; these have already been installed for several of these pipelines.

For nearly all of the SFPUC wholesale customers, Mr. Eidinger has performed seismic reliability analyses of all their distribution pipes, wells, pump stations, reservoirs and tanks to establish how their system will perform post-earthquake. For these water systems, he considered the simultaneous "worst case" or "likely" or "possibly upgraded" performance of the SFPUC and SCVWD systems (for Hayward, also the EBMUD system), to establish a cost effective seismic upgrade program for each water agency. The wholesale customers include: Hayward, ACWD, Milpitas, Santa Clara, Sunnyvale, Mountain View, Purissima Hills, Palo Alto, Stanford University, Redwood City, Menlo Park, Bear Gulch, San Mateo, Belmont, San Carlos, Foster City, Brisbane, San Bruno, Burlingame, Daly City, South San Francisco.

For Humboldt Bay Municipal Water District, he evaluated all major portable and industrial water transmission pipelines (36" to 54" diameter), including fault crossings, a wooden trestle bridge system, and reliability of power supply. He developed seismic retrofits within a multi-tiered Capital Improvement Program budget.

Mr. Eidinger performed detailed structural evaluations of the 2.2 meter diameter steel butt welded Thames Water pipeline where it crossed the Anatolian fault. This pipe suffered minor leaks when it was subjected to 3 m of right lateral offset, forcing the pipeline into compression wrinkling. This pipe had not originally been designed for fault offset movements.

For the Alaska Natural Gas Transmission System, Mr. Eidinger developed the seismic and frost heave designs for the proposed 48" diameter buried natural gas pipeline.

Mr. Eidinger has evaluated the causes of damage to the 2 meter-diameter raw water pipeline that suffered compression bending and wrinkling failure due to the 1999 Chi Chi earthquake in Taiwan (Taiwan Water Company). This earthquake imposed more than 15 feet of reverse thrust motion on this low pressure pipeline, resulting in severe wrinkling and gross tearing of welds.

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Mr. Eidinger was in responsible charge of design for a new salt water fire fighting system for the City of Berkeley, California. This included 16 miles of 30" steel pipe and 12" flex hose, and a 20,000 gpm pump station. The design includes allowance for liquefaction to ensure reliable performance following earthquakes.

For EBMUD, Mr. Eidinger developed their detailed Emergency Response and Repair plan. This included evaluation of total repair efforts by type of pipe damage (ranging from 4" AC pipe to 78" PCCP pipe), as well as damage to 13 tunnels, 6 water treatment plants, over 125 pump stations and over 175 reservoirs.

For the SFPUC, Mr. Eidinger developed their detailed Emergency Response and Repair Plan. This included evaluation of total repair efforts by type of pipe damage (ranging from 60" steel pipe to 96" PCCP pipe), as well as damage to 6 tunnels, and 2 water treatment plants.

For the East Bay Dischargers Authority, he has developed seismic retrofits for its large diameter (48" to 96") force mains that take effluent from four wastewater treatment plants into San Francisco Bay.

PUBLICATIONS

Performance of Electric Power Systems in the 2010-2011 Christchurch New Zealand Earthquake Sequence, with A. Kwasinski, A. Tang, C. Tudo-Bornarel, EERI SPECTRA, February, 2014.

Telecommunications Systems Performance Christchurch Earthquakes, with A. Tang, A. Kwasinski, C. Foster, P. Anderson, EERI SPECTRA, February, 2014.

Lushan China Earthquake Impact to Power and Water Systems, ASCE Monograph 40, 2014.

Performance of Buried Power Cables due to Liquefaction, with L. Kempner, Cigre, Auckland, New Zealand, 2013.

Liquefaction Analysis of Towers at the Columbia River, with L. Kempner, Cigre, Auckland, New Zealand, 2013.

Seismic Response of Buried Cables due to Liquefaction, 3rd US-China-Japan Workshop on Lifelines, Chengdu, China, 2013.

Performance of Water System in Lushan Earthquake, 8th US-Japan-Taiwan Workshop of Earthquake Countermeasures for Water Utilities, Oakland, CA, 2013.

Performance of Water Systems during the Maule Mw 8.8 Earthquake of 27 February 2010, EERI SPECTRA, 2013.

Seismic Mitigation for Lifelines – Different Approaches in China and Japan, APWA Meeting, Berkeley, California, Nov 15 2012.

Wind and Ice Loading on Transmission Towers, with L. Kempner, Cigre, Paris, France, 2012.

JOHN M. EIDINGER

Reliability of Transmission Towers under Extreme Wind and Ice Loading, with L. Kempner, ASCE, Columbus, 2012.

High Voltage Transmission Line System Subject to Earthquake Scenarios, with L. Kempner, ASCE, Columbus, 2012.

Christchurch, Great Tohoku and Chile Earthquakes of 2010, 2011: Impact to Water Systems, EBMUD, 2012.

Christchurch Earthquake, Impact to Power Systems, ASCE Structures Congress, Las Vegas, April, 2011.

Wenchuan China Earthquake Impact to Power and Water Systems, ASCE Monograph 36, 2011.

September 4, 2010 M 7.1 Canterbury (Darfield), New Zealand Earthquake, Impact to Lifeline Systems, with A Tang, T. O'Rourke, Technical Council on Lifeline Earthquake Engineering, ASCE November, 2010.

Maule, Chile M 8.8 Earthquake of February 27, 2010, Impact to Water Systems, Technical Council on Lifeline Earthquake Engineering, ASCE September, 2010.

Replacing Seismically-Weak and Aging Water Pipes, EERI National Conference on Earthquake Engineering, Toronto, Canada, July, 2010.

Fragility of Non-Structural Components for FEMA Benefit Cost Analysis, BART and the BIG ONE, EERI National Conference on Earthquake Engineering, Toronto, Canada, July, 2010.

Wenchuan Earthquake – Impact to Lifelines, ASCE, Santa Rosa, California, December 9, 2009.

Magic R: Seismic Design of Steel Water Tanks, 6th AWWARF – JWWA Workshop on Seismic Design of Water Systems, Taipei, October, 2009.

Wenchuan Earthquake Impact to Power Systems, TCLEE Conference, ASCE, Oakland, California, June, 2009.

Seismic Upgrade of Pipes Across the Hayward Fault, 3rd Conference on Earthquake Hazards in the Eastern San Francisco Bay Area, Cal State Hayward, October 2008.

Seismic and Wind Design for Solar Panels, 14th World Conference on Earthquake Engineering, Beijing, China, October 2008.

Seismic Vulnerability Analyses for Lifelines, Presentation, Infrastructure Forum, Oregon Public Utilities Commission, <http://www.asce.org/files/pdf/instfound/5-Eidinger-InfrastructureSeismicVulnerabilityAssessments.pdf>, April, 2008.

Shakemap-Based Earthquake Emergency Response for Lifelines, With PG&E, Stu Nishenko, Marcia McLaren, AGU, December 2007.

Modeling the Landslide Risk for the BPA Transmission System, with Leon Kempner, Jared Perez, Donald Wells, DOGAMI Landslide Symposium, Portland Oregon, April, 2007.

JOHN M. EIDINGER

The 1906 Earthquake Impacts on the San Francisco and Santa Clara Water Systems – What We Learned, and What We are Doing About It, with Lota de Castro, Dennis Ma, EERI Spectra, April, 2006.

The 1906 Earthquake – What Happened at the Dumbarton Strait, with Luke Cheng, Mark Ketchum, Stephanie Wong, EERI 8th National Conference on Earthquake Engineering, 2006.

Seismic Risk of a High Voltage Electric Transmission Network, with Leon Kempner, Jared Perez, Anshel Schiff, EERI 8th National Conference on Earthquake Engineering, 2006.

GIS and Database Tools for BART Seismic Upgrade, EERI 8th National Conference on Earthquake Engineering, 2006.

BART (Train), BPA (Power), Pasadena (Water): Observations on Performance Based Seismic Upgrade Programs, PEER Annual Meeting, Walnut Creek, CA April 2005.

Seismic Guidelines for Water Pipelines, Chairman, American Lifelines Alliance, sponsored by FEMA, <http://homepage.mac.com/eidinger/> March, 2005.

The San Simeon, California, Earthquake of December 22, 2003, Water System Performance, Chapter Author, EERI Report, May, 2005.

Design Guideline for Seismic Resistant Water Pipeline Installations, 4th US-Japan Workshop for Seismic Performance for Water Utilities, Kobe, Japan, January 2005.

BART Seismic Upgrade – How Much? with Ed Matsuda, First International Conference of Urban Disaster Reduction, Kobe, Japan, January 18, 2005.

Design Guideline for Seismic Resistant Water Pipeline Installations, EERI Utility and Transportation Group Workshop for Water Utilities, October 28, 2004.

The 1906 San Francisco Earthquake and its Impact on the Water System, EERI Utility and Transportation Group Workshop for Water Utilities, October 28, 2004.

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“Girth Joints in Steel Pipelines Subjected to Wrinkling and Ovaling,” 5th U.S. Conference on Lifeline Earthquake Engineering, TCLEE, ASCE, Seattle, 1999.

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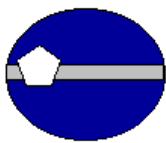
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Mr. Richard Bell, PE
Principal Engineer and Manager, Water Resources and Facility Planning
Municipal Water District of Orange County
18700 Ward Street
Fountain Valley, CA 92708

February 16, 2015

RE: Proposal for North Orange County System Reliability Study: Seismic Vulnerability and Recovery Assessment

Dear Mr. Bell:

GeoPentech is pleased to present this proposal in response to the Municipal Water District of Orange County's (MWDOC) Request for Proposal (RFP), dated February 11, 2015 for the North Orange County System Reliability Study: Seismic Vulnerability and Recovery Assessment (NOCSRS-SVRA). From within GeoPentech, and select outside individual consultants, we have assembled a team of seasoned seismic geologists, geotechnical earthquake engineers and lifeline earthquake engineers. The professionals on GeoPentech's team are experienced with seismic hazards in Southern California, and in particular in Orange County (OC), and have the experience and knowledge to provide MWDOC with high quality, focused services to meet the objectives of the NOCSRS-SVRA.

This proposal has five sections. Section 1 is this cover letter; Section 2 is a description of GeoPentech's proposed Scope of Work (SOW), which has been tailored in a format that is responsive to the SOW that was transmitted with MWDOC's RFP; Section 3 is a brief description of our company's relevant background; Section 4 identifies our proposed project manager (Tom Freeman), his expertise and qualifications, and a brief overview of GeoPentech's project management approach. The expertise and qualifications of the other members of GeoPentech's team (including our subject matter experts from academia and outside individual consultants) are also highlighted in Section 4. Section 5 identifies our team's expertise and experience with similar projects. More details regarding the expertise and relevant experience of each professional in the proposed GeoPentech team are provided through each individual's resume, which are provided in Attachment A. Attachment B presents a breakdown of our estimated budgets for the tasks identified in Section 2, the total estimated budget and hours, and our billing rates.

The professionals at GeoPentech, as well as our outside expert consultants, have provided decades of seismic hazard assessments, engineering, and hydrogeologic services for many public agencies and private firms in OC and Southern California. GeoPentech professionals are keenly aware of the challenges involved with conducting the type of regional-level studies being requested by MWDOC. We have worked with Metropolitan Water District of Southern California (MWD) and their member agencies, MWDOC and several of MWDOC's member Agencies, such as the Orange County Water District (OCWD), Los Angeles County Department of Public Works, Los Angeles Department of Water and Power, Southern California Edison Company, and Southern California Gas Company to provide state of the practice services while pushing the state-of-the-art in analysis and modeling. GeoPentech's team of professionals has a proven track record of providing our clients with strategic thinking on their seismic hazard issues and other geology and geotechnical matters.



We look forward to your review of our proposal and are prepared to respond to your questions. Should MWDOC select GeoPentech, we pledge our commitment to support MWDOC with your requests for professional consulting services.

Sincerely,

GeoPentech, Inc.

S. Thomas Freeman, PG, CHG, CEG
Principal/Vice President



2. Scope of Work

The proposed scope of work (SOW) presented here is based on our understanding of MWDOC's project goals. Some of the tasks identified by MWDOC have similar or overlapping scopes and thus herein these tasks have been combined into a single task for the purposes of scoping the work and costs. For example, the task of characterizing the physical and seismic properties of the active faults within Northern Orange County (NOC) has been grouped with the characterization of the San Andreas, San Jacinto, and Elsinore faults as the work is more efficiently completed under the same task. Part A, described below, entails the completion of the Seismic Hazard Assessments by GeoPentech, with assistance from seismic hazard experts in the academic community. We have also identified some Optional Part A Tasks, should MWDOC desire a more detailed study for specific facilities or different earthquake scenarios of interest. As requested in MWDC's RFP, Optional Part B tasks are also described, which entails gathering experienced earthquake lifeline engineers in formal workshop settings to identifying critical system vulnerabilities based on the results of the seismic hazard assessment completed in Part A.

Part A. Seismic Hazard Assessment

Study Objective: Provide an updated seismic hazard evaluation for NOC for critical water supply facilities. This will be accomplished by assembling information from the available literature bearing on the activity of faults in the area, estimated ground shaking hazard, and State zones for fault rupture hazard, liquefaction hazard, and earthquake-induced landsliding hazard. The results of this study will provide updated hazard information relative to the location of MWDOC facilities in NOC. We also outline optional tasks that could be undertaken if additional detail associated with specific facilities and/or scenario earthquakes is desired.

Task A.1. Identify and Characterize Faults of Interest

The aim of this task is to provide a map of the location of late Quaternary active faults throughout OC and to characterize known faults (surface faults and blind faults) of interest to the project in NOC from the available literature. The following faults will be characterized in this task: (i) Whittier; (ii) Puente Hills; (iii) Peralta Hills; (iv) San Joaquin Hills; (v) Newport-Inglewood; (vi) San Andreas; (vii) San Jacinto; and (viii) Elsinore. The characterization will include: (i) preparing a map or maps of the faults relative to critical water supply facilities in NOC; (ii) identifying the recency of activity (i.e., Holocene-active, Early Pleistocene-active, etc.) of the faults, including the timing of past ruptures where information is available; (iii) reporting of fault slip rate estimates; and (iv) estimating the Maximum Credible Earthquake (MCE; i.e., the 2,475-year average return period earthquake) for the faults. For the faults outside OC (i.e., the San Andreas, San Jacinto, and Elsinore), characterizations relative to key water supply sources (like the Colorado River Aqueduct and the State Water Project California Aqueduct) will be provided.

Key data sources include the United States Geological Survey (USGS) database, the California Geological Survey (CGS) database, the Uniform California Earthquake Rupture Forecast version 3 (UCERF3), the Southern San Andreas ShakeOut Scenario, and other sources as appropriate, such as our recent work for Southern California Edison Company for the San Onofre Nuclear Generating Station (SONGS) and for Metropolitan Water District on the San Andreas Fault. Subject-matter experts from academia will also be consulted to provide expert opinions as appropriate.

The key deliverables of this task will be the following: (i) maps showing the location and geometry of the faults, relative to critical water supply facilities (e.g., water supply wells, treatment plants, regional distribution pipelines, groundwater replenishment basins; etc.), on a typical GIS base (e.g., topography, satellite imagery, major highways and roadways, etc.); (ii) ArcGIS shapefiles or layers containing the fault attributes and geometry; (iii) a map of historic earthquakes and instrumentally-recorded seismicity in Southern California; and (iv) tabulated fault characterization information.

Task A.2. Identify Broad-Scale Ground Shaking Hazard

The aim of this task is to assemble from the available literature a map or maps of calculated ground shaking at the spectral periods of interest (e.g., PGA and 1-second).

The primary data source for this task will be the 2014 National Seismic Hazard Maps (NSHM). This version of the



NSHM will be the basis for the seismic design criteria in the next building code update (ASCE 7-15, which will be adopted by CBC 2016). The NSHM provides regional-scale hazard corresponding to a 2% probability of exceedance in 50 years, which is the 2,475-year average return period. The basis for the NSHM hazard in California is the Uniform California Earthquake Rupture Forecast version 3 (UCERF3) fault model and the Next Generation Attenuation West 2 (NGA West 2) ground motion attenuation relationships.

For this task, the key deliverable will be a map of the 2014 NSHM ground motions corresponding to a 2% probability of exceedance in 50 years (2,475-year hazard level) for NOC, relative to critical NOC water supply facilities.

Task A.3. Identify Potential Primary Fault Rupture Hazard Areas

The aim of this task is to assemble from the available literature a map or maps of potential primary fault rupture hazard areas, relative to critical NOC water supply facilities.

Key data sources include the California Alquist-Priolo hazard zones (AP Zones) and other known fault crossings identified in Task A.1 (including blind thrusts) that may not yet be included in the State AP Zones. Primary fault offsets (e.g., 1 meter, 10 centimeters, etc.) will be estimated using common (empirical) magnitude-area-displacement regressions. Subject-matter experts from academia will also be consulted to provide fault offset estimates based on their professional judgment.



Map showing key NOC water supply facilities (courtesy of MWD OC)

which identify required zones of investigation for liquefaction and earthquake-induced landslide hazards. Subject-matter experts from academia will be consulted to identify generalized areas of potential coseismic uplift and subsidence.

Key deliverables of this task will include the following: (i) maps showing the location of the Seismic Hazard Zones, relative to critical water supply facilities (e.g., water supply wells, treatment plants, regional distribution pipelines, groundwater replenishment basins; etc.), on a typical GIS base (e.g., topography, satellite imagery, major highways and roadways, etc.); (ii) ArcGIS shapefiles or layers containing the Seismic Hazard Zones; and (iii) maps identifying generalized areas of potential coseismic uplift or subsidence.

Task A.5. Reporting and Presentations

Key deliverables of this task will include the following: (i) maps showing the location of the AP Zones, relative to critical water supply facilities (e.g., water supply wells, treatment plants, regional distribution pipelines, groundwater replenishment basins; etc.), on a typical GIS base (e.g., topography, satellite imagery, major highways and roadways, etc.); (ii) ArcGIS shapefiles or layers containing AP Zones; and (iii) tabulated primary fault rupture offset estimates.

Task A.4. Identify Potential Secondary Earthquake Hazard Areas

The aim of this task is to assemble from the available literature a map or maps of potential secondary earthquake hazard areas (i.e., liquefaction, earthquake-induced landslide hazards, and warping due to uplift and subsidence), relative to critical NOC water supply facilities.

The primary data source for this task will be the California Seismic Hazard Zones Maps,



The aim of this task is to prepare one draft technical memorandum and one final technical memorandum documenting the results of Part A and to prepare for and carry out four (4) presentations to MWDOC, OCWD, CDM Smith, and the OC Water Reliability Study Working Group. Note that two of the four presentations are included in the optional task B1 (Workshops) described later and would be contingent on carrying out that optional task.

Optional Part A Tasks for Specific Facility and/or Scenario Earthquakes

The above tasks (i.e., A.1 through A.5) rely on published information to provide broad-scale (countywide scale) information; however, such broad-scale information may lack sufficient detail for scenario-specific concerns for critical NOC water supply facilities. These optional tasks focus on specific facilities and/or specific earthquake scenarios that can refine the hazard assessments to provide more detailed information. Some examples of the applicability of these optional tasks include: (i) selection of a scenario earthquake, mapping of the ground motions generated by the scenario earthquake along a MWDOC supply or distribution system, and estimated primary fault displacement where critical NOC water supply or distribution facility crosses the causative fault; and/or (ii) additional estimation of regional-scale deformation associated with a scenario earthquake, such as uplift and subsidence, along a feeder that might be sensitive to hydraulic grade changes. The results from these optional tasks would help hydraulic and facilities engineers more specifically identify areas of concern in the water supply and distribution system and inform subsequent planning, such as areas that could be readily retrofitted to withstand the deformation or to enhance post-event emergency response.

Optional Task A.O.1 for Scenario-Specific Ground Shaking Hazard

The aim of this task is to define one scenario earthquake for one fault and compute the ground shaking at the spectral periods of interest (e.g., PGA and 1-second) for specific critical NOC water supply facilities or along the MWDOC distribution system. This optional task would supplement the 2014 NSHM ground motions corresponding to a 2% probability of exceedance in 50 years (2,475-year hazard level) in Task A.2 by focusing on specific earthquake scenarios of interest to MWDOC. The results would be presented in the form of maps and tabulated spectra for each computed site. Ground shaking between computed sites would be interpolated. The costs shown in Attachment B represent one scenario earthquake for one fault, but this task can be repeated for different scenarios and different faults, as requested by the Client, and the cost would scale accordingly. The results of this optional task would be included in the Task A.5 Reporting and Presentations.

Optional Task A.O.2 for Scenario-Specific Ground Deformation

The aim of this task is to define one scenario earthquake for one fault and estimate the regional ground deformation that would be caused by the scenario event, along the MWDOC distribution system. This optional task would enhance the primary fault rupture hazards in Task A.3 by estimating a range of possible fault rupture offsets and also the regional warping (e.g., uplift and subsidence) that accompanies significant earthquakes. The results would be presented in the form of maps, profiles, and tabulated horizontal and vertical deformations would be provided at the regional grid points analyzed and/or critical NOC water supply locations of interest. The costs shown in Attachment B represent one scenario earthquake for one fault, but this task can be repeated for different scenarios and different faults, as requested by the Client, and the cost would scale accordingly. The results of this optional task would be included in the Task A.5 Reporting and Presentations.

Optional Part B: Facility Vulnerability and Recovery Planning

Study Objective: Conduct a workshop with a panel of key experts to assess the vulnerability of critical NOC water facilities, based on the results from the Part A Seismic Hazards Assessment. The goal of the workshop will be to evaluate and recommend approaches to seismically retrofit facilities, reduce the severity of facility outages, assess recovery times, and identify means to reduce recovery times, in context of the results from the Part A Seismic Hazards Assessment.

Study Approach: It is our understanding that the above objective is to be accomplished using pertinent past experiences and engineering judgment rather than quantitative analysis per se.



To this end, we propose to utilize combined experiences and engineering judgment of a group of experts who addressed similar tasks numerous times in the past. When experiences and engineering judgment are sought under the stated objective, appropriately synthesized consensus positions are considered to add more value.

Under Task B1 the currently envisioned names of experts are listed and their resumes are included in Attachment A. The proposed process would be to finalize the list after having specific discussions with MWDOC. For the final group of experts, the products would consist of consensus decisions and opinions and results of specific assignments to selected experts, helped by assistants, who would be doing some “homework” to facilitate the process. The overall process would focus on the stated objectives through a general facilitator, and a group leader for specific issues would facilitate an efficient progress toward the specific objectives.

Optional Task B1. Workshops

As an option to MWDOC, the aim of this task is to assemble a panel of five (5) key experts plus representatives from MWDOC, OCWD, and CDM Smith in two (2) workshops to assess the vulnerability of critical NOC water facilities, based on the results from the Part A Seismic Hazards Assessment. These two workshops will constitute two (2) of the four (4) presentations initially identified in Task A5. The panel of experts is expected to include the following individuals listed below. Note, Dr. Thomas O'Rourke, if available, will participate remotely through internet and will take part in the Task B1 workshops via webinar in order to save MWDOC travel costs, or if he is already present in Southern California, as he often is, at the time of the Workshops he may be able to participate directly. Tom is currently out of the country and we were unavailable to contact him at this time to discuss his possible involvement on this assignment. Tom is an internationally recognized expert geotechnical/lifeline engineer and we know him well, after having worked with him over the last several decades on several similar assignments, many here in Southern California. If he is available, we trust he will be interested in working on this assignment.

- Dr. Thomas O'Rourke, Geotechnical/Earthquake Engineer, with expertise in lifeline performance during earthquakes.
- Dr. Yoshi Moriwaki, Geotechnical/Earthquake Engineer, with expertise in earthquake engineering of Water Facilities.
- Eric Fordham, Hydrogeologist and Engineering Geologist, with expertise in large production water supply wells.
- Ronald Eguchi, Risk Analyst, with expertise in lifeline earthquake engineering risk analysis and management.
- Douglas Honegger, Lifelines Engineer, with expertise in geohazards and lifelines.

Resumes of these individuals are included in Attachment A.

It is anticipated that the workshop attendees will review the final report from the Part A Seismic Hazards Assessment in preparation for the workshops, and part of the first workshop will include a presentation and review of the results from Part A. The workshops are anticipated to cover the following topics:

- Select One Case Study and Identify Recommendations for Seismic Resiliency
 - Based on a large scenario earthquake, provide a planning-level review of the materials, design, construction, and retrofit approaches and methods that can be used to improve the resiliency of NOC water supply systems to significant earthquakes. Improvements include curtailing damage and reducing recovery times.
 - For a typical production well and wellhead, select a case study to identify methods to improve the capability of wells to resist damage from significant earthquakes.
- Identify Local and Regional Supply Emergency Power, Interconnections, and Isolation Valves
 - Provide recommendations on MWDOC's emergency power survey/study findings.



- Identify possibilities to enhance system redundancy and add isolation valves to reduce shortages during emergency outages (including well fields with regional pipeline connections).
- Identify the Types of at-risk Local Water Supply Facilities
- Approaches to Reduce Earthquake Damages to Water Supply Facilities, Recovery Times and Bolster Community Protection

Optional Task B2. Workshop Documentation

The aim of this optional task is to document the presentations and discussions that occur at the workshop to ensure the participants and entities have a written record of the recommendations and ideas discussed in the workshop. One draft document will be prepared for review and comment by key workshop personnel and one final draft document will be completed.

3. Company Background

GeoPentech is a registered Small Business Enterprise (SBE) specialty consulting firm, founded in 2000 by five partners who have over 140 combined years of specialized consulting experience in geologic, hydrogeologic, geotechnical, and earthquake engineering. GeoPentech currently has 14 professionals with consulting experience in hydrogeology, geophysics, engineering and seismic geology, and geotechnical and earthquake engineering. GeoPentech's organizational structure consists of our five Principal engineers and geologists who manage our projects, delegate work to the staff professionals in the office, and review and approve all reports that are produced. All of our professionals hold post-graduate degrees and professional registrations in the State of California.

Supporting our clients on seismic hazard-related issues is one of our key services. GeoPentech supports our clients on their seismic hazard-related projects by providing the full spectrum of seismic geology and earthquake engineering consulting services, including seismic source characterization, ground motion evaluations, fault rupture hazards, and secondary earthquake deformation hazards. GeoPentech also assists our clients on groundwater-related projects, including groundwater basin characterization, groundwater supply issues, water quality, groundwater modeling, well installation and development, groundwater monitoring, and assessing the potential for ground surface subsidence or heave.

The GeoPentech office is located in Southern California at: 525 North Cabrillo Park Drive, Suite 280, Santa Ana, CA 92701. We can be reached by phone at our office at (714) 796-9100 and by facsimile at (714) 796-9191. All contract implementation will be performed from this office location under the direction of GeoPentech's representative and Principal Geologist, Mr. Tom Freeman. His mobile phone number is (714) 325-2994 and his e-mail address is tom_freeman@geopentech.com.

4. Project Team

GeoPentech's approach to serving MWD OC is founded on the philosophy of thinking and working as an extension of your staff. Our experience has proven that fostering this type of partnership with our clients serves the best interest of both participants.

GeoPentech understands that effective organization and management of the Project Team is the key to successfully accomplishing the project objectives and achieving quality services in a cost-effective manner. We have assembled a team of experienced experts to support MWD OC with their consulting needs. Our team's Project Manager (Tom Freeman) is experienced with managing and coordinating large and complex seismic geology and seismic hazard projects, such as the Colorado River Aqueduct San Geronio Pass Seismic Event Vulnerability Study for the Metropolitan Water District of Southern California and the Seismic Source Characterization for Southern California Edison Company's San Onofre Nuclear Generating Station.

Tom Freeman was selected for this project based on his technical expertise, as well as his track record in completing comparable assignments. GeoPentech's approach emphasizes the Project Manager working directly with MWD OC's designated representative, as well as supervising the individual team members. The Project Manager has the full



responsibility for meeting the project's technical and contractual requirements, as well as managing day-to-day activities including direct communication with MWDOC on various task assignments and communicating these needs to the project team members. To minimize management costs and to maximize the technical emphasis we are placing on this project, the Project Manager will have a dual role as both managing the project and serving as the technical manager.

We have gathered a team of well qualified, experienced professionals to support MWDOC's needs and have Task Leaders available with special expertise in the needed scientific specialties to assist with the seismic hazard evaluation tasks that may arise. Task leaders will report directly to the Project Manager, who will provide MWDOC with a single point of contact. Working under the Task Leaders, supporting technical and administrative staff will ensure that the activities required for the successful completion of tasks are completed. Brief summary resumes for each of the key team members are provided in Attachment A. Full resumes, as well as resumes for supporting staff, are available upon request. Supporting staff will have the responsibility of providing as-needed services on tasks related to their expertise.

PROJECT MANAGER
Tom Freeman, PG, CHG, CEG

The key contact between MWDOC and GeoPentech will be Tom Freeman, located in GeoPentech's Santa Ana office. Administratively, Mr. Freeman will serve as the project manager and technically, he will serve as the

team's lead seismic geologist responsible for the technical elements of studies completed for MWDOC. As a California Registered Geologist with specialty certifications in engineering geology and hydrogeology, Mr. Freeman has managed the assembly of data and the preparation of final reports for complex regional-scale projects. His experience has helped clients examine the feasibility of their projects and develop plans for their cost effective and timely completion, including examining alternative scenarios, and ranking and rating to identify the optimal program.

Mr. Freeman will be supported by the other GeoPentech geologists and engineers, including Steven Duke (Task Leader), Eric Fordham, Yoshi Moriwaki (Project Technical Advisor), Rambod Hadidi (Task Leader), Andrew Dinsick, Justin Zumbro, and Alexandra Sarmiento.

PROJECT TECHNICAL ADVISOR
Eric Fordham, PG, CEG, CHG

We have selected Eric Fordham PG, CEG, CHG as the Technical Advisor for the project. Mr. Fordham, Principal with GeoPentech, has managed or contributed to various types of small to large, multi-disciplinary water

facility projects for over 30 years, spanning from field, laboratory, and instrumentation work through analysis and evaluation to project management.

Mr. Fordham has extensive experience evaluating his client's groundwater supply wells to address well capacity and water quality issues and provides recommendations to mitigate supply and water quality issues. Mr. Fordham has utilized various methods to investigate well issues including downhole video, downhole geophysics, spinner/flow testing, depth specific water quality testing, continuous pumping tests and step-tests for well performance. He has assessed the vulnerability of supply wells to shaking and vibrations from earthquakes, road noise and construction activities.

PROJECT TECHNICAL ADVISOR
Yoshi Moriwaki, PhD, PE, GE

We have selected Yoshi Moriwaki, PE, GE as the Technical Advisor for the project. Dr. Moriwaki, Principal with GeoPentech, has managed or contributed to various types of small to large, multi-disciplinary civil

engineering projects for over 45 years, spanning from field, laboratory, and instrumentation work through analysis and evaluation to project management.

Dr. Moriwaki has extensive experience in comprehensive seismic hazard evaluations (earthquake ground motions, liquefaction, soil-structure interaction, mitigation measures, etc.) for numerous sites and facilities, including dams, underground structures, pipelines, and bridge sites in many parts of the United States (California, Alaska, Utah, Missouri, New York, etc.) and the world (Canada, Japan, Indonesia, Australia, Germany, etc.).



TASK LEADERS

Steven Duke, RGp, PG, CEG, CHg
Rambod Hadidi, PhD, PE, GE

Each task will be led by a California-registered geologist or engineer experienced with the implementation of similar studies, and knowledgeable with resources and methodologies required to successfully implement MWDOC's required seismic hazard assessments. Mr. Duke has over 20

years of experience in the fields of hydrogeology, engineering geology, seismic geology, and engineering geophysics. Dr. Hadidi has more than 14 years of experience in geotechnical and earthquake engineering on a wide range of infrastructure projects, for both private and public sectors, locally, nationally, and globally with a wide range of complexity and size. The staff assigned to duties under each task will report directly to the Task Leader. Each Task Leader will be responsible for coordinating the activities of their support staff with other task leaders. The following professionals from GeoPentech will support the task leaders:

Professionals	State of California Registration	Years of Experience
Doug Wahl	Civil Engineering (PE)	6
Andrew Dinsick	Civil Engineering (PE)	12
Justin Zumbro	Geology (PG)	15
Alexandra Sarmiento	Geology (PG)	5

In addition to our in-house personnel, GeoPentech will be assisted by respected geoscientists in the academic community. GeoPentech regularly consults respected subject-matter experts and has established working relationships with leading academic geoscientists, such as Dr. Thomas Rockwell (San Diego State University) and Dr. Lisa Grant-Ludwig (University of California, Irvine). Dr. Rockwell's and Dr. Grant-Ludwig's resumes are included in Attachment A, and we have budgeted time for Dr. Rockwell's participation in this project, as shown in Attachment B. Because of university-related restrictions, Dr. Grant-Ludwig cannot charge consultancy fees at this time, so we have not included her in the budget in Attachment B. However, Dr. Grant-Ludwig has expressed interest in this project and has agreed to advise the project team when she is available at no fee, which is permitted by her university commitments. As discussed above under the optional SOW for Part B, the resumes of our other recommended subconsultants are also provided in Attachment A.

5. Experience

As shown in the Service Matrix (Table 1) presented below, GeoPentech has extensive experience in all aspects of the professional seismic geology and geotechnical engineering services needed by our clients including, but not limited to:

- ❑ Engineering and Seismic Geology
- ❑ Geotechnical Earthquake Engineering
- ❑ Seismic Hazard Analysis
- ❑ Ground Motion Evaluation
- ❑ Liquefaction Evaluation
- ❑ Landslide Evaluation
- ❑ A host of other geotechnical engineering, engineering geology, and earthquake engineering requirements that can come into play for water agency services, including short and long term planning.

The matrix shown in Table 1 lists selected groundwater and water supply projects completed by professionals of GeoPentech for several private and government entities such as the Los Angeles County Department of Public Works (LACDPW), the Los Angeles Department of Water and Power (LADWP), Metropolitan Water District of Southern California (MWD), the Water Replenishment District of Southern California and other clients with similar technical requirements. For each project, a checkmark "✓" is placed in the applicable spaces for various areas of the



services provided by the professionals of GeoPentech.

Table 1 clearly shows that *through our project experience, GeoPentech professionals have excellent technical expertise and qualification* to provide the seismic hazard evaluation services that MWDOC needs, including the ability to provide effective technical evaluation and strategic thinking to assist MWDOC with various seismic hazard assessment activities. The table also shows that many of these selected projects are similar in nature to this MWDOC assignment.

The successful completion of the example projects listed in the service matrix includes *completing projects within budget and schedule* and in a manner consistent with the client's vision of how the project should be completed. Paying attention to these important non-technical aspects of each project is one of the characteristics and attributes of GeoPentech and its professionals.



Table 1. Key Services Provided By GeoPentech

KEY SERVICES									
PROJECTS	Water Supply Regional/Planning Level Studies	Site Investigations	Laboratory Testing	Groundwater Wells, Groundwater & Ground Monitoring	Modeling & Analyses	Seismic Hazard Evaluation	Geotechnical Engineering and Design	Rpt/Presentation Prep., Workshops & Meetings	Construction Phase Services
LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS PROJECTS									
LA County Dominguez Gap Seawater Barrier Injection Wells Micro-Tunnel		✓				✓		✓	✓
Seawater Barrier Alternatives Evaluation	✓					✓	✓	✓	
WATER REPLENISHMENT DISTRICT OF SOUTHERN CALIFORNIA									
Dominguez Gap Spreading Grounds	✓	✓	✓	✓	✓		✓	✓	
Alamitos Seawater Barrier Replacement/Augmentation Using a Passive Deep Soil Mix (DSM)	✓	✓	✓	✓	✓	✓	✓	✓	✓
LOS ANGELES DEPARTMENT OF WATER AND POWER PROJECTS									
LA Reservoir Backwash Ponds Evaluation		✓	✓	✓	✓			✓	
Hollywood Reservoir Water Quality Improvement Project		✓	✓	✓	✓	✓	✓	✓	✓
Elysian Reservoir Water Quality Improvement Project		✓	✓	✓	✓	✓	✓	✓	
LA Reservoir Water Quality Improvement Project	✓							✓	
Stone Canyon Reservoir & Pipeline		✓	✓				✓	✓	
LA Aqueduct/Pacific Oil Pipeline Crossing Fault Study		✓	✓		✓	✓	✓		✓
2nd LA Aqueduct/Terminal Hill Seismic Retrofit	✓		✓	✓	✓	✓	✓	✓	✓
Bouquet Canyon Reservoir Seismic Hazard Assessment		✓	✓	✓	✓	✓	✓	✓	
Griffith Park So Water Tank & Directionally Drilled		✓	✓	✓			✓	✓	
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA PROJECTS									
Tonner Tunnel-Yorba Linda Feeder									✓
Hayfield Lake Groundwater Storage Project	✓	✓	✓	✓	✓	✓	✓	✓	
Upper Chuckwalla Valley Groundwater Storage Project	✓	✓	✓	✓	✓	✓	✓	✓	
Cadiz Groundwater Storage Feasibility Studies	✓	✓			✓			✓	
Diamond Valley Reservoir Project	✓	✓	✓	✓	✓	✓	✓	✓	✓
Central Pool Augmentation Project	✓	✓	✓	✓	✓				
Lake Mathews Intake Structure		✓	✓		✓				✓
MWD Service Area Groundwater Assessment Study	✓		✓					✓	
Inland Feeder Pipelines, Tunnels and Fault Crossings	✓	✓	✓	✓	✓		✓	✓	✓
Foothill Feeder/San Fernando Tunnel	✓				✓			✓	
Orange County Reservoir		✓	✓	✓	✓				
Diemer Filtration Plant		✓	✓	✓	✓	✓	✓	✓	✓
Colorado River Aqueduct	✓	✓	✓		✓				
2nd Lower Feeder	✓	✓							
Upper Feeder San Gabriel Intake Structure		✓				✓	✓	✓	
MWDOC & MEMBER AGENCIES' PROJECTS									
Talbert Barrier									✓
Allen McCollough Pipeline		✓	✓		✓	✓	✓		
Burris Pit		✓	✓		✓	✓	✓		
Santiago Dam - Irvine Lake				✓					
South Orange County Water Rehabilitation Study		✓				✓	✓	✓	
Walnut Canyon Reservoir				✓					
Upper Chiquita Reservoir	✓	✓	✓	✓	✓	✓	✓	✓	✓
South Orange Coastal Ocean Desalination Project	✓				✓				
OTHER RELEVANT PROJECTS									
San Onofre Nuclear Generating Station	✓	✓	✓	✓	✓	✓	✓	✓	✓
Newport/Inglewood Fault Study at Bolsa Chica		✓	✓		✓	✓		✓	
Newport/Inglewood Fault Study at Bixby Knoll		✓	✓		✓	✓		✓	
Irvine-Corona Expressway Tunnel	✓				✓			✓	
Arroyo Trabuco Golf Course Water Reliability Study	✓	✓	✓	✓	✓			✓	✓
Orchard Hills Groundwater Study		✓	✓	✓	✓		✓	✓	
City of Chino Hydrogeologic Support	✓	✓	✓	✓	✓		✓	✓	



Attachment A

Resumes of Project Team Members

GeoPentech, Inc. Professionals

Tom Freeman
Eric Fordham
Yoshi Moriwaki
Steven Duke
Rambod Hadidi

Professional Subconsultants

Ronald Eguchi, (ImageCat, Inc.)
Douglas Honegger, (D.G. Honegger Consulting)
Tom Rockwell, (California State University-San Diego)

Other Candidate Professional Subconsultants

Lisa Grant Ludwig, (University of California, Irvine¹)
Tom O'Rourke, (Connell University²)

¹ Will have limited availability (with no fee) during current academic period. Potentially more availability as a subconsultant (with fee) during summer months non-academic period. Resume included

² May be remotely available for Part B workshop participation through website conference linkage or if workshop schedule is compatible with one of his regular west coast visits. Resume included and hourly billing rate is also included in Attachment B.



GeoPentech Resumes

EDUCATION

University of California,
Berkeley: MS, Geological
Engineering, 1974

University of California, Santa
Barbara: BA, Geology, 1972

REGISTRATION

Professional Geologist:
California, 1978, No. 3483
expiration 03/31/15

Certified Engineering
Geologist: California, 1978,
No. 1015 expiration 03/31/15

Certified Hydrogeologist:
California, 2001, No. 712
expiration 03/31/15

PROFESSIONAL HISTORY

GeoPentech, 2000 – Present

URS/Woodward-Clyde, 1997-
1999

Woodward-Clyde Consultants,
1972-1997

AFFILIATIONS

American Society of Civil
Engineers

Geological Society of America

South Coast Geological Society

Association of Engineering
Geologists

National Groundwater
Association

AREAS OF EXPERTISE

- Engineering Geology
- Hydrogeology
- Seismic Geology
- Environmental Geology

EXPERIENCE SUMMARY

Mr. Freeman has over 42 years of consulting experience, specializes in evaluating the physical and performance characteristics of soil, rock, and groundwater and in assessing active faults, landslides, and other geologic hazards for input into planning, design, and construction of various types of projects in California, throughout the United States and overseas; ranging from individual short on-call assignments to managing multi-disciplinary teams on technically complex projects involving rigorous regulatory and public reviews.

He has worked with the full spectrum of geological, geotechnical, geophysical, and hydrogeology investigation techniques ranging from planning level reconnaissance, geology/geomorphology mapping, geophysical surveys, soil and rock borings, and in situ testing and laboratory testing. Work commonly involves evaluating subsurface geologic stratigraphy through an understanding of environments of deposition and geologic processes, faulting through an exhaustive background in seismic geology, groundwater flow and chemistry including groundwater monitoring, recharge, storage and utilization.

He has managed the assembly of the data and the preparation of the final reports. His experiences have been used helping clients examine the feasibility of their projects and developing plans for their cost effective and timely completion, including examining alternative scenarios and ranking and rating to identify the optimal program. He has also applied his knowledge toward focusing design phase investigations toward finalizing designs and preparation of specifications. He is also experienced in construction monitoring and evaluating operating facilities for maintenance, modifications and seismic safety compliance and assisting with conflict resolution.

SPECIFIC PROJECT EXPERIENCE INCLUDES:

Colorado River Aqueduct (CRA) Whitewater Tunnel #2 Seismic Vulnerability Assessment, Metropolitan Water District of Southern California (2014). Mr. Freeman assisted the Metropolitan Water District of Southern California (MWD) in organizing, conducting, and participating in a planning level workshop focused on the post-earthquake repair options to the Whitewater Tunnel #2 if it is severely damaged following a major earthquake along the San Andreas Fault beneath San Geronio Pass. The participants in the workshop included all relevant MWD department managers and engineers, and key internationally recognized tunnel contractors, and consulting engineers. Mr.

Freeman provided the engineering geology and geoseismic characteristics of the region around the Whitewater Tunnel #2 and coordinated the preparation and reviews of the proceedings that documented the information gained from the workshop. He also assisted MWD's staff in the preparation of long-range plans to address the potential seismic hazards to the tunnel.

Colorado River Aqueduct (CRA) San Geronio Pass Seismic Vulnerability Study, Metropolitan Water District of Southern California (2012-2014). Over the last several decades, Mr. Freeman has assisted engineers at the Metropolitan Water District of Southern California (MWD) address potential seismic hazard along the Colorado River Aqueduct and at its reservoirs and other facilities. This work has included applying his skills and experiences in seismic geology and site characterization to develop appropriate deterministic and probabilistic design parameters for measures to minimize active fault and ground motion hazards at the facilities. Recently, Mr. Freeman manage and lead a team of geoscientist, including several internationally recognized academic geoseismic researchers in the evaluation of the vulnerability of the CRA to forecasted major earthquakes along the San Andreas Fault where is trends beneath the CRA beneath San Geronio Pass. This vulnerability study included assessing the seismic geology, paleogeomorphology, paleoseismology, recorded seismology and geodetics and developing interpretation of the 3D configuration of the San Andreas Fault beneath the region of San Geronio Pass and to use this 3D configuration to model like surface fault displacements and ground deformations during the forecasted future earthquakes. These studies included preparation and conducting several workshops and meetings as well as preparation of large complex reports documenting the results of the seismic event vulnerability study.

Inland Feeder Arrowhead and Badlands Tunnels, Metropolitan Water District of Southern California, San Bernardino and Riverside Counties, California (1989-2013). Mr. Freeman has assisted MWD with the initial planning, environmental permitting, design, and construction of Inland Feeder including the Arrowhead Tunnels and the Badland Tunnels. On this assignment he provided direct assistance to MWD's Inland Feeder Program Management Team and the Arrowhead Tunnel's Project Engineer in the re-design of the Arrowhead Tunnels. His services included assisting with the coordination of MWD's Technical Board of Consultants and Legal Team, interactions with representatives of the San Manuel Indian Tribe, the U.S. Forest Service and the U.S. Geological Survey. His work included: reviews and technical guidance during surface geologic mapping and analysis of rock mass conditions, fault and other discontinuities, and analyses of groundwater conditions along the alignment including reviews and critiques of the U.S. Geological Survey's groundwater modeling efforts. He also assisted in the preparation of the U.S. Forest Service Special Use Permit and prepared the Draft Contingency Plan. Furthermore he assisted with reviews of the design team's contract documents including the GBR, and assisted MWD's staff in the contractor's pre-bid meeting and core reviews. During construction he has assisted MWD in evaluating contractor claims of differing site conditions and in developing models to help forecast future grouting requirements and closing the environmental permit. His staff recently assisted with the decommissioning of the groundwater monitoring wells that were used to document ground water conditions to achieve the final authorization permit for the Arrowhead Tunnels and decommissioning the wells on the Badlands Tunnels.

LADWP On-call Engineering Geology, Seismic Geology Hydrogeology, Geophysics, Geotechnical & Earthquake Engineering Services, Los Angeles, CA (2008 – Current). Mr. Freeman is GeoPentech's lead geoscientist with these on-call assignments, including: the planning and design level seismic hazard assessment of the 1st and 2nd LA Aqueducts in the region around Terminal Hill including a specially designed tunnel and shaft capable of accommodating fault ruptures during future seismic events so that flow through the 2nd LA Aqueduct to the reservoirs in the Department's Van Norman complex would not be cut off, and providing GeoPentech's on-site assignments during the construction of the tunnel and shaft at Terminal Hill; assisting in the evaluation of seismic hazards that could impact their reservoirs, pipelines, and canals in, and leading into, their Van Norman complex. This work included assessing the level of potential activity of faults within the San Fernando Fault System, including design and construction measures on a passing oil pipeline for it to accommodate future fault ruptures and not contaminate the feeder aqueducts to the complex; investigations to characterize the underlying and flanking bedrock, groundwater and seismic conditions and to assess the seismic stability, slope stability and seepage beneath, through and around the City of Los Angeles Department of Water & Power (LADWP) existing embankment dam and reservoir

Department's Elysian Reservoir Water Quality Improvement Project; evaluating the seismic stability of the Bouquet Canyon Reservoir's main dam and saddle dam, including assessing the character and stability of the embankments and their foundations and abutments and developing estimates of potential future ground motions and the level of activity of the Clearwater Fault Zone, which passes near the abutment of the saddle dam; and working through the planning, conceptual design of tunnel alternatives for the pipe line out of the Griffith Park Pump Station and preparing final designs for the Horizontal Direction Drill installation of the final pipeline.

South Orange Coastal Ocean Desalination Project's Open Intake Alternative, Municipal Water District of Orange County, California (2013). Mr. Freeman lead a team of geologist and engineers that assisted the Municipal Water District of Orange County (MWDOC) through Carollo Engineers by providing a conceptual level opinion regarding the feasibility of using either horizontal directional drilling (HDD), a micro-tunneling boring machine (MTBM), or an earth pressure balance tunnel boring machine (EPB TBM) as the construction method for the Open Intake Alternative (OIA) to the well extraction method for MWDOC's South Orange Coastal Ocean Desalination Project (SOCODP). The work included developing a summary of the different possible ground conditions along the OIA alignment based on the currently available subsurface geologic data and information available at that time and the likely affects these different possible ground conditions will have on the feasibility and associated costs of these three different construction methods. He also coordinated with subconsultant engineers in developing planning level opinions as to of the likely construction costs and schedule for the feasible one(s) of these three alternative construction methods.

Delta Habitat Conservation and Conveyance Program (2013). Metropolitan Water District of Southern California (Metropolitan) is evaluating the barge unloading and tunnel launch concept in their planning level feasibility assessment of Pipeline/Tunnel Option for the program. Mr. Freeman helped lead a GeoPentech team of geologist and engineers who were assisting Metropolitan in a preliminary planning level valuation of the geological and geotechnical aspects of designing and constructing the barge unloading facilities as an alternative for transporting the project's Tunnel Boring Machines to their launch shafts. And he lead a team of engineers and contractors who provided Metropolitan independent review of the region planning level studies of the 40-mile+ alternative alignment configurations for the project.

San Onofre Nuclear Generating Station, SCE, San Diego/Orange County (2009-2013). Tom Freeman was the lead geoscientist in SCE's re-evaluation of the seismic hazards at SONGS, particularly leading and coordinating up to 45 leading and internationally recognized academic, government and private sector researchers, including seismic geologist, petroleum geologist, seismologist and terrestrial and marine geophysics. Studies included analysis of old and newly acquired marine geophysics surveys of the faults in the region between Mexico and Palos Verde and offshore as far as San Clemente Island, coastal paleogeomorphology mapping of past seismic ground deformation of the coastal areas between Baja California and Palos Verde Peninsula, past fault activity trench investigation across the Newport-Inglewood Fault in San Diego, assessments of regional seismicity and geodetics data in Southern California, and the preparation and conducting several large workshops and meetings. The work also included the preparation of large complex reports documenting the results of the work.

Upper Chiquita Dam, Santa Margarita Water District, Orange County, California (2011). Principal Engineering Geologist for GeoPentech's involvement in the design and construction management team for the Santa Margarita Water District's new of the 155-ft high Upper Chiquita Dam and Reservoir. GeoPentech was responsible for the seismic and subsurface characterization for the design of the dam and reservoir, identifying onsite borrow areas for construction by reviewing previous studies; completing regional and local seismic source fault and potential ground motion assessments, onsite geologic mapping, CPT's, large diameter borings, surface and downhole geophysical surveys, test pit with in-place density measurements, recovered sample laboratory testing and corresponding seepage and stability analyses and reporting. Selective grading plans for on-site borrow material were developed and we have also coordinated and assisted in the reviews of these investigations and analysis, including observations during construction with the California DSOD. GeoPentech also provided consulting services related to geotechnical input to the EIR. This dam is now fully operational and GeoPentech is providing as-needed assistance with the District's monitoring system.

San Diego Pipeline #6 – South Reach Tunnel Feasibility Study, Metropolitan Water District of Southern California through Jacobs Associates, Riverside and San Diego Counties, California (2006-2009). Mr. Freeman has assisted MWD and Jacobs Associates by managing and conducting the site investigations, including existing information research and analysis, stereo aerial photograph assessments, geologic mapping, terrestrial geophysics. The work also included obtaining all the appropriate permits and completing several deep vertical and angle core holes into the granitic bedrock and across fault and discontinuities that could be sources of heavy volume, high pressure groundwater inflow during future tunnel excavations. Pumping tests were complete on the core holes and piezometers were installed for longer term monitoring. The recovered core was laboratory tested for the rock properties utilized in tunnel design and construction. Using the resulting gathered data, groundwater models of the potential groundwater inflows were prepared and used to assess potential groundwater control measures during the construction of the tunnel and the possible impact to the groundwater regime overlying the tunnel alignment. The results were then used in developing preliminary designs and environmental documentation. Following the completion of the study all the installed groundwater monitoring equipment was decommissioned.

Other MWD Tunnels (1989-2012)

Mr. Freeman has also correlated the characteristics of soil and rock ground conditions into planning, design and construction of other MWD tunnels, including his experience assisting with the planning and site characterization of the ground and groundwater conditions beneath the Santa Ana Mountains and the Cleveland National Forest for the MWD's Central Pool Augmentation Project's tunnel. He also assisted in the subsurface investigations for Lake Mathews's intake structure.

Orange County Reservoir Seismic Assessment (2008). Principal Engineering Geologist on the evaluation of static and seismic stability of the Metropolitan Water District of Southern California's (Metropolitan) Orange County Reservoir and dam, which was built in 1941 to store potable water. Work included investigations of the ground conditions beneath the dam and reservoir and the surrounding area and analysis of the seismic stability of the facilities, their potential for future fault ruptures, the potential for excessive reservoir and embankment seepage, and an evaluation of the reservoirs existing gunite liner. The work included geologic mapping; mud-rotary borings with calibrated SPT testing, hollow-stem auger borings, CPT soundings; downhole seismic shear wave velocity measurements, groundwater level monitoring, laboratory testing. Analyses were completed of distress in the existing gunite lining and measures to mitigate the gunite liner distress. Analyses were also completed for reservoir leakage and embankment settlement, stability, and deformation and the adequacy of the facility in terms of the potential for fault ruptures, liquefaction, deformation and cracking of the embankment and slippage/movement of the surrounding ridge due to future earthquake events.

Hollywood Water Quality Improvement Project, Los Angeles, California (1997-1999). Mr. Freeman was project manager and lead engineering geologist of a team of consulting engineers, geologist, groundwater hydrologists and geophysicist providing technical support and supplementing when requested the staff of the LADWP in the geotechnical investigations, design, preparation of plans and specifications, and construction of two 30 million gallon underground concrete tanks extending 50 feet below grade and a utility tunnel and bypass tunnel. The project involved construction of a tied-back concrete slurry wall and a conventional tied-back shoring wall, design of subsurface drainage system and perimeter slope stabilization. Mr. Freeman and his staff logged boreholes and interpreted packer tests to assess geologic and hydrologic conditions; collected and interpreted dilatometer and pressuremeter data to assess in-situ engineering properties; conducted geophysical refraction and downhole seismic surveys to determine rock rippability and geologic structure; integrated geologic and geophysical results to create geologic maps and profiles. He also assisted LADWP staff in the preparation of the design and construction contract documents and provided geological consultation to the LADWP Construction Manager during the course of the projects construction.

Diamond Valley Reservoir, Metropolitan Water District of Southern California, Hemet, California (1990-1997). Project Engineering Geologist on a series of geotechnical dam site investigations for the MWD of Southern California, including site characterization studies to screen 14 alternative dam sites to one preferred site on which more detailed geotechnical investigations and final designs were completed and construction geological monitoring was done. As



part of the initial site screening studies, Mr. Freeman led the geological elements in the assessment of Perris Reservoir as an alternative to the DVR by increasing its height considering potential constructability and borrow sites as well as static stability, seepage evaluations, and seismic deformation of the dam.

LADWP Dams Seismic Assessment, California (1996). Assisted the LADWP's staff in completing an evaluation and ranking and rating of the 17 existing dams in their reservoir system in terms of potential seismic and other geologic hazard. The results of the study allowed the Department to prioritize their future retrofit efforts on the more critical facilities, such as Bouquet Reservoir.

Other Past Related Assignments (1972-2012). Mr. Freeman has also correlated the characteristics of soil and rock ground conditions into planning, design and construction of other underground structures, including a laketap and tunnel at Bradley Lake Alaska, at Thistle Utah and at the Camp Far West Reservoir in California. More recent experience includes assisting with the characterization of the ground and groundwater conditions beneath the Santa Ana Mountains and the Cleveland National Forest for the Riverside County Transportation Commission's Irvine-Corona Expressway Tunnels. Examples of other tunnels where he lead the effort in planning and executing the investigations, participated in design teams' preparation of the contract documents, was a leader in the construction management team to complete the tunnel construction, and assisted owners in solving seismic hazard , underground stability and excessive groundwater inflow problems include the Second Manapouri Tailrace Tunnel and gold mine tunnels in seismically active New Zealand, the Getty Museum's Drainage Tunnel, the Richmond Tunnel, the Goodwin Tunnel in seismically active California, and the Glenwood Canyon tunnels in Colorado. Mr. Freeman also provided senior geological and tunnel constructability reviews during feasibility studies for MWD's West Valley Conveyance tunnel. He also assisted in the evaluation, design and construction management to repair tunnels, such as the Azusa, Devil's Gate for the City of Pasadena, and the Kern River tunnels for Southern California Edison. Other tunnel projects where Mr. Freeman contributed his geologic engineering and tunneling expertise toward their design and/or construction include Yucca Mountain, South Bay and Point Loma out falls, Cowels Mountain, and Stone Canyon Water Quality Improvement. In the 1970's and early 80's he assisted a variety of tunnel contractors on over 16 projects with their pre-bid assessments and differing site condition claims during construction.

Assisted the Orange County Water District by providing on-site stratigraphic logging and monitoring of the drilling of their Talbert seawater barrier injection wells. Along with Dr. Paul Witherspoon, provided WRD a geological/groundwater hydrogeology analysis of the West Basin and its crossing Newport-Inglewood and other faults and their effectiveness as seawater barriers and to assist in identifying efficient measures to close gaps in the fault barriers. Provided WRD senior geological/hydrogeological review of the subsurface characterization and modeling of the stratigraphy, faulting and groundwater conditions in the Alamitos Gap in the Newport-Inglewood Fault leading to trial-runs of alternative measures permanently close the gap thus eliminative the need for injection wells. Completed complex investigations characterizing the geometry and level of activity of the Newport-Inglewood Fault through the Bolsa Chica and Bixby Knolls areas.

Managed planning-level regional reconnaissance hydrogeologic investigations for groundwater basin storage and resource development studies in eastern California's desert for MWD's Colorado River Aqueduct Groundwater Storage Project including Vidal, Rice, Ward, Cadiz, Fenner, Palen, Chuckwalla, Hayfield, and Shavers valleys. Managed a detailed site investigations for MWD in Hayfield Valley to assess the feasibility of using the valley's groundwater basin, overlying dry lake bed and their CRA Hinds Pumping Station discharge facilities in a groundwater storage and conjunctive use program. The investigations included surface geologic/geomorphic mapping, deep sounding geophysical surveys and borings, fault barrier analyses, ground water monitoring and water quality analysis large scale trial infiltration tests, and groundwater modeling/analysis and report preparation.



Managed a detailed site investigations for MWD in Chuckwalla Valley to assess the feasibility of using the valley's groundwater basin and the bordering CRA canal and syphon in a groundwater storage and conjunctive use program. The investigations included surface geologic/geomorphic mapping, deep sounding geophysical surveys and borings, fault barrier analyses, ground water monitoring and water quality analysis designing and constructing large scale trial infiltration test basins, and groundwater modeling/analysis and report preparation. Providing management of on-call engineering geology and hydrogeological services supporting MWD's portion of the Cadiz Valley Groundwater Conjunctive Use Project, including, geologic/geomorphic mapping along the route between the CRA and the Cadiz Valley, proposed for the water conveyance facility, alternative spreading basin concepts, groundwater modeling and water quality analysis of existing and alternative conjunctive use scenarios. Also assisted by critiquing, other ground water models, such as presented by interveners and regulating agencies and provided presentation in various internal meeting and meetings with regulators and interveners.

Assisted MWD by reviewing PG&E's remediation of Cr+6 contaminated groundwater near the Colorado River and by completing an independent reviews, analyses and models of the stratigraphic and groundwater conditions along and bordering the river leading the development of alternative measures to install a permanent barrier to protect the river from Cr+6 contamination.

Recently, have been assisting MWD by providing on-call geology/hydrogeology services to analysis and assess the impact of the Diamond Valley Reservoir operations on the neighboring groundwater utilizers

PUBLICATIONS

- Arrowhead Tunnels: Assessing Groundwater Control Measures in a Fractured Hard Rock Medium; with E. Fordham, D. Tempelis and S. Duke; Rapid Excavation and Tunneling Conference Proceedings, 2003
- Matahina Dam – Fault Surface Displacement Design Criteria (with Murray Gillon, Paul Somerville, Lelio Mejia, and Yoshiharu Moriwaki), 12th World Conference on Earthquake Engineering, Auckland, New Zealand, 2000
- Planning Southern California Tunnels (with F.W. Horne, and D.C. Mann). Proceedings Rapid Excavation and Tunneling Conference, Boston, MA. 1993.
- Numerical Simulation of Tunnel Ground-Water Inflows with (S.B. Lee and D. Jensen). Association of Engineering Geologist 36th Annual Meeting Pg. 60 Program and Abstracts 1 - 16 October, San Antonio, TX. 1993.
- Seismic Hazard Assessment, Newport-Inglewood Fault Zone in Engineering Geology Practice in southern California, (with E. Heath, P. Guptill, and J. Waggoner), Edition by B. Pipkin and R. Proctor AEG Special Publication No. 4, Pg. 211-231, 1992.
- Late Quaternary Activity Along the Onshore Portion of the Palos Verdes Fault Zone (with P.D. Guptill, T.A. Demere, D.L. Schug) Final Technical Report to U.S. Geological Survey, Contract no. 14-08-0001-21304, 1987.
- Lake Thistle, Evaluation of Lake Tap Alternatives (with J.A. Bischoff and R.J. Essex) Tunneling Technology. Published by the U.S. National Committee on Tunneling Technology. 1984.
- Underground Technology in the Peoples Republic of China (with D.J. Lachel and B.L. Smith) Tunneling Technology. Published by the U.S. National Committee on Tunneling Technology. 1981.



- Potassium argon ages of tertiary volcanic rocks from the eastern Mojave Desert (with S. Kuniyoshi). Geological Society of America Annual Meeting Abstracts with Programs. 1974.
- The Buckskin Mountain tunnel: rock mass properties and their effect on TMB design and performance (with L.L. Oriard). Southern California Section of the Association of Engineering Geologists. 1979.
- Th^{230} - U^{234} dating of pedogenic carbonates in gravelly desert soils of Vidal Valley, southeastern California (with T.K. Ku, W.B. Bull, and K.G. Knauss). Geological Society of American Bulletin 90 (11), 1063-1073. 1979.
- Late Quaternary Slip Rate of the North Branch of the San Andreas Fault at City Creek California (with K. Sieh and L. B. Grant) Geological Society of America 90th Annual Cordilleran Section Meeting Abstracts with Programs. Vol. 26 No. 2 pg. 91. 1994.



EDUCATION

California State University,
Long Beach, California, M.S.,
Geology, 1989

California State University,
Long Beach, California, B.S.,
Geology, 1981

REGISTRATION

Professional Geologist,
California, 1990, No. 4754
expiration 02/28/17

Certified Engineering Geologist,
California, 1991, No. 1665
expiration 02/28/17

Certified Hydrogeologist,
California, 1995, No. 283
expiration 02/28/17

AFFILIATIONS

American Geophysical Union

Association of Engineering
Geologists

Association of Groundwater
Scientists and Engineers

Society for Mining, Metallurgy
and Exploration

AREAS OF EXPERTISE

- Hydrogeology
- Engineering Geology
- Environmental Geology

REPRESENTATIVE EXPERIENCE

Mr. Fordham is a consulting hydrogeologist with over 30 years' experience in the field of hydrogeology, engineering geology and environmental geology. Mr. Fordham's responsibilities have included designing and implementing surface and subsurface investigations to characterize geologic and hydrogeologic conditions for: groundwater control during the construction of subterranean structures; the siting and expansion of dams and waste disposal facilities; development of groundwater monitoring programs; geologic and hydrogeologic support for environmental permitting; management of groundwater basins, including groundwater development, aquifer recharge and groundwater storage; design and evaluation of water supply wells; and the assessment and remediation of soil and groundwater contaminants. Mr. Fordham has provided these services for both private- and public-sector clients.

Mr. Fordham's capabilities include conducting subsurface characterizations using a multitude of investigation methods including downhole and surface geophysics, drilled and direct-push soil borings, soil and rock coring, bucket-auger drilling, trenching, test pits and down-hole logging, Cone Penetration Testing, measurements of groundwater chemistry and sampling from monitoring well networks, discrete-interval groundwater sampling, single well and multiple well pumping tests, slug tests, vertical flowmeter tests, tracer tests and soil-gas testing. Mr. Fordham utilizes collected data to develop a conceptual understanding of the geologic and hydrogeologic conditions which he then tests using both analytical and numerical techniques.

His project experience has involved project management and staff supervision, data collection, compilation, and analysis of geologic and hydrogeologic information, technical review, expert witness testimony, report preparation, database management, geographical information system (GIS) management, statistical analysis, and vadose zone and groundwater flow and pollutant fate and transport modeling. He possesses a thorough knowledge of groundwater-related



Groundwater Supply Wells

regulatory requirements and regularly performs agency liaison on behalf of clients.

A selection of Mr. Fordham's representative experience is highlighted below:

- Mr. Fordham evaluates his client's groundwater supply wells to address well capacity and water quality issues and provides recommendations to mitigate supply and water quality issues. Mr. Fordham has utilized various methods to investigate well issues including downhole video, downhole geophysics, spinner/flow testing, depth specific water quality testing, continuous pumping tests and step-tests for well performance. He has assessed the vulnerability of supply wells to shaking and vibrations from earthquakes, road noise and construction activities. Mr. Fordham has also provided well design and construction services. Clients that Mr. Fordham has provided these services include, Newhall County Water District, City of Downey, City of Chino and the Niagara Water Bottling Company.

Subsidence

- Evaluates causes for subsidence due to groundwater extraction from aquifers and ground loss from subterranean construction. Examples include: excessive groundwater withdrawals from the Chino Basin of Southern California resulted in over 4 feet of permanent ground subsidence with differential subsidence across a previously unknown fault barrier resulting in the occurrence of ground fissures. Investigations included developing understanding of the underlying aquifers and aquitards, groundwater occurrence, groundwater extraction history, evaluating existing land survey data, installing and monitoring piezometric pressures in key zones along with a multi-depth extensometer, use of InSAR and land level surveys to assess ongoing permanent and elastic ground deformations, and installation of a horizontal extensometer to evaluate potential for ground fissures. Also evaluated for the Los Angeles County Metropolitan Transportation Authority, ground subsidence above the Red Line Northern Extension tunnels due to ground loss during construction.

Numerical Modeling

- Integrates geologic, hydrogeologic and geochemical data into groundwater flow models to evaluate groundwater supply and quality, identify potential benefits and disadvantages of proposed water-related projects, evaluate



Groundwater Resource Development

Spreading Grounds

effects of man-made subsurface barriers on seawater intrusion, and assess the fate and transport of chemical contaminants in soil and groundwater. Develops numerical and analytical models to estimate possible groundwater inflows to tunnels during construction and evaluates potential impact to overlying groundwater resources. Applies numerical and analytical techniques to evaluate optimum construction dewatering schemes. Groundwater flow codes applied include MODFLOW, FEMWATER, FRAC3DVS, WinFlow, UTCHEM, and SEEP2D/ SEEP3D. Develops and applies chemical fate and transport models to assess dissolved and free-phase chemical transport of petroleum hydrocarbon compounds, VOCs, metals, nitrate and chloride. Transport codes applied include MT3D, MT3DMS, MODPATH, ParsSim, UTCHEM, FRACTRAN, MOC3D, and SUTRA. Also uses mass balance modeling approach to evaluate perchlorate, manganese, iron, arsenic, nitrate, and chloride impacts to groundwater supply. Also uses the code PHREEQC to model water chemistry resulting from soil interaction and water mixing as a result of groundwater recharge. Key projects include, Metropolitan's Hayfield and Chuckwalla Groundwater Storage projects and Inland Feeder tunnel projects, the Tehachapi Blue Eagle Lode Mine, Kern County's Lake Isabella shallow groundwater issues, Newhall County Water District well fields, Water Replenishment District of Southern California's Alameda Seawater Barrier Project, Xerox VOC remediation, BF Goodrich Aerostructures Facility VOC remediation and Arroyo Trabuco Golf Course water supply.

- Provides hydrogeologic services to municipal water agencies, private water bottling companies and land developers to develop groundwater resources for domestic water supply, bottled water production and irrigation. Key projects have included hydrogeologic characterization of groundwater basins for conjunctive use projects. Clients include Metropolitan Water District of Southern California; City of Chino; Water Replenishment District of Southern California; Newhall County Water District; Rancho Mission Viejo; Arrowhead Springs Water Company; and Niagara Water Bottling Company.
- Lead hydrogeologist responsible for conducting hydrogeologic and geologic investigations for Metropolitan Water District of Southern California to



Seawater Barriers

assess the feasibility of storing surplus Colorado River water in California's desert basins during wet years and recovering water from the basins during drought years. Projects included Hayfield, Chuckwalla, Cadiz, Rice, and Palen valleys. Conducted percolation tests, analyzed results and provided recommendations for the Water Replenishment District of Southern California on groundwater recharge enhancements at the Dominguez Gap Spreading Grounds. Evaluated options for conjunctive use of groundwater and surface water for golf course irrigation, including groundwater storage during wet years.

- Lead hydrogeologist for the Seawater Barrier Alternatives Study for three existing seawater barrier systems in the West Coast Basin of Los Angeles County, California. This work was completed under contract with the U.S. Department of the Interior Bureau of Reclamation with technical support from the Water Replenishment District of So. California, L.A. County Department of Public Works and the Orange County Water District. Responsible for compiling, synthesizing and reporting to a technical advisory committee geologic and hydrogeologic characteristics of the three barriers and identifying potential technologies that could be applied to prevent the intrusion of seawater. Collected geologic, hydrogeologic and geotechnical data, and completed data analysis and groundwater flow and chloride transport modeling to evaluate the effects of a Deep Soil Mix subsurface barrier wall on preventing seawater intrusion at the Los Alamitos gap.

Environmental Geology

- Conducts Phase 2 site assessments to characterize the hydrogeology, the magnitude and extent of chemical and pathogenic contaminants in soil and groundwater, and also implements remediation to reduce the potential for public health and environmental effects. Mr. Fordham also provides legal assistance on issues associated with potential or actual impact of transgressing chemicals released into the environment. Chemical contaminants with which Mr. Fordham has specific experience include perchlorate, nitrate, chromium, arsenic, lead, mercury, thallium, volatile and semi-volatile organic compounds, fuel hydrocarbons and pathogenic microbes. Many of these projects were completed under the authority of either the California Regional Water Quality Control



Technical Review

Board or the Department of Toxic Substances Control. Clients included Fortune 500 companies such as Xerox, Eaton, Amgen, Unocal and BP Amoco; and local, State and Federal agencies such as the City of Malibu, California Department of Parks and Recreation, Metropolitan Water District of Southern California, Los Angeles County Metropolitan Transportation Authority, CalTrans, and the U.S. Bureau of Reclamation.

- Participates on review committees for various government and corporate entities providing hydrogeologic and geologic input, including: Impact Assessment for the New York City Department of Environmental Protection, Aqueduct Connection Environmental Support Project, Roseton, New York (2014 to present); Chino Basin Watermaster Land Subsidence Committee, representing the City of Chino (2003 to present); PG&E Topock Hexavalent Chromium Cleanup Site Technical Work Group, representing the Metropolitan Water District of Southern California (2003 to present); Nevada Environmental Response Trust Perchlorate Cleanup Stakeholder, representing the Metropolitan Water District of Southern California (2004 to present); ARCO Pipeline Environmental Remediation Working Group, (1996 to 1998).



Education

Ph.D., Geotechnical
Engineering, UC Berkeley,
1975
M.S., Engineering Mechanics,
NYU, 1968
B.S., Civil Engineering, MIT,
1966

Registration

Civil Engineering, CA, 1986
(C40972)
Geotechnical Engineering, CA,
2000 (GE2499)

Affiliations

American Society of Civil
Engineers
Earthquake Engineering
Research Institute

QUALIFICATIONS:

Dr. Moriwaki, Principal with GeoPentech, has managed or contributed to various types of small to large, multi-disciplinary civil engineering projects for over 45 years, spanning from field, laboratory, and instrumentation work through analysis and evaluation to project management.

Dr. Moriwaki has extensive experience in comprehensive geotechnical seismic evaluation of dams, reservoirs, pipelines, underground structures, and bridges. Further, he has extensive experience in seismic hazard (earthquake ground motions, liquefaction, soil-structure interaction, mitigation measures, etc.) evaluations for numerous sites and facilities, including dams, underground structures, pipelines, and bridge sites in many parts of the United States (California, Alaska, Utah, Missouri, New York, etc.) and the world (Canada, Japan, Indonesia, Australia, Germany, etc.).

Dr. Moriwaki's expertise also includes static and seismic numerical analysis of soil and soil-structure systems and the geotechnical application of probabilistic methods to various projects including those applied to dams, highway and bridge systems. Dr. Moriwaki has actively contributed to various professional societies and committees, such as having been an ASCE Geotechnical and Geoenvironmental Engineering Journal Editorial Board member, and has taught at the San Jose State University and Caltech. Furthermore, his professional contributions include being a

member of the NCEER experts that compiled the state-of-the-art liquefaction assessment, a contributor to California Division of Mines and Geology (CDMG) Special Publication 117 Guidelines for Evaluating and Mitigating Seismic Hazards in California, and one of the instructors for Seismic Hazards Evaluations seminars sponsored by CDMG (led by Prof. Ray Seed) over several years. Dr. Moriwaki also was a member of the NSF-sponsored USA geotechnical team that visited the Kobe area following the 1995 Kobe earthquake.

His experience includes many ground improvement evaluations including those at Tablachaca, Peru; Costa Oriental Dikes, Venezuela; Jensen Filtration Plant; the Honda testing track in the Mojave Desert, and the CSU site in Long Beach. Methods addressed included many soil improvement methods including excavation and replacement, stone column methods, chemical grouting, dynamic compactions, and others.

SELECTED SPECIFIC PROJECT EXPERIENCE INCLUDES:

Stevens Creek and Lenihan Dams, Santa Clara Valley Water District, Santa Clara, CA (2013)

Principal engineer leading the seismic/earthquake engineering aspects of GeoPentech work on this project focusing on material and ground motion characterization and seismic analysis. The evaluations was required by the Division of Safety of Dams (DSOD) in June 2008 as part of their Phase III screening process of the State's dams located in highly seismic environments. The evaluations of 170-ft Lenihan Dam and 120-ft high Stevens Creek Dams are also a vital part of the Santa Clara Valley Water District's Dam Safety Program (DSP). The project included field investigation, material characterization and seismic deformation analysis to evaluate the potential deformation range in the event of a major earthquake.

San Pablo Dam, East Bay Municipal District, Contra Costa, CA (2010)

Lead seismic/earthquake engineer for the seismic upgrading design work of initially hydraulically built San Pablo Dam located in Contra Costa County, California, completed in 1921 but seismically upgraded twice in the past. In the



previous investigations, the shells of the dam and alluvial foundation soils beneath the embankment were considered to have high liquefaction potential. With the high design earthquake shaking conditions (0.91g peak ground acceleration) developed for the site, the seismic upgrading design focused on deep soil mix downstream of the embankment to be overlain by a significant downstream berm and other associated modifications. Field investigation starting with cone penetration tests and continuing with borings combined with laboratory testing, formed the basis for a revised site and material characterization where the shells of the dam have low liquefaction potential and even alluvial foundation soils have only some potential for liquefaction. Seismic deformation analysis using FLAC was performed to generate inputs to the design of deep soil mixing systems to address some potential for liquefaction in the alluvial foundation soils that cannot be discounted. The FLAC evaluation addressed the "soil-structure interaction" effects as well as spatially varying deformation patterns of the embankment. California Department of Safety of Dams, a review board for the client, and a number of technical consultants were involved.

Walnut Canyon Dam, Anaheim, California

Principal engineer leading the seismic/earthquake engineering aspects of GeoPentech work. The seismic performance evaluation of the Walnut Canyon Dam was performed using FLAC and material properties based on detailed analysis of the construction records, laboratory strength testing, field investigation including in situ testing, and our experience. The input ground motions at about 1 g peak ground acceleration were reviewed and accepted by DSOD. On the basis of the material characterization and FLAC analysis results combined with careful evaluations of seepage conditions, we were able to show to DSOD that initially contemplated significant seismic remediation will not be needed. The results of seismic FLAC analysis addressed not only the seismically induced deformations of the dam, but also potential changes in internal stress conditions as possibly affecting the potential for cracks and piping phenomena.

Bouquet Canyon Dams Seismic Evaluation, Los Angeles Department of Water and Power, Los Angeles, California (ongoing)

Principal engineer leading the seismic/earthquake engineering aspects of GeoPentech work. The two earth dams at the Bouquet Canyon Reservoir dams, located in the Angeles National Forest, north of Los Angeles, are being evaluated for earthquake shaking and faulting. The two dams were identified as those requiring further seismic evaluation based on a screening study performed by GeoPentech professionals while working at Woodward-Clyde Consultants. In particular, the downstream slope of the Bouquet Canyon Dam No. 1 is founded on existing alluvium with potential for liquefaction. Because the site is only 8 km from the San Andreas Fault, the shaking conditions including acceleration time histories had to be developed incorporating near-fault effects. The current phase of the project includes seismic hazard evaluation, field investigation, material characterization, and analysis using FLAC to evaluate the response of the dam in the event of a major earthquake. The work is reviewed by DSOD, as well as an external review board.

Second Narrows Water Supply Tunnel, MetroVancouver, Vancouver, British Columbia (2010 - 2014)

Lead seismic and earthquake engineer for GeoPentech. The project consisting of two new water mains within an approximately 6 meter diameter tunnel crossing below Burrard Inlet at Second Narrows and associated structures involved reviewing site characterization, ground motion evaluation, and seismic deformation analysis performed by another firm. Our work involved independent, but focused material characterization and dynamic analysis addressing significant liquefaction-induced deformations near ground surface extending to depths of about 60 m below the ground surface. Our review identified significant epistemic uncertainty of the seismic displacements computed at depth (up to 60 m), and recommended further evaluating and quantifying this uncertainty.



Cerro Corona Tailings Dams in Peru (2012)

Lead seismic and earthquake engineer for GeoPentech. As a subconsultant to MWH, working on static and seismic deformation and stability evaluations of various tailings dams at the site as the "modified" centerline design concept developed; the work involves evaluations of data, ground motion issues, and advanced static and seismic analyses using FLAC and various soil models over several years involving liquefaction issues.



Education

MS, Geophysics, 1990
BS, Geophysics, 1988

Registration

Registered Geologist:
California, 2001 (7243)
Certified Engineering
Geologist: California, 2002
(2264)
Registered Geophysicist:
California, 1996 (1013)
Registered Hydrogeologist:
California, 2003 (746)

Affiliations

Environmental and
Engineering Geophysical
Society
Society of Exploration
Geophysicists
American Geophysical Union

QUALIFICATIONS:

Mr. Duke has over 23 years of experience in the fields of engineering geology, hydrogeology, and engineering geophysics. He has designed, performed, and interpreted geological and geophysical data for numerous small and large scale projects. His experience extends through all phases of project development including planning, design, construction, and post-construction work.

Mr. Duke has been responsible for field operations, data processing, and quality control during geological and geophysical site investigations for numerous projects related to groundwater storage, tunnels, subways, dams, borrows, foundation engineering, slope stability, hydrogeology, seismic geology, and landfills. For projects such as these, he has characterized the soil, rock, and groundwater conditions; and evaluated active faults, landslides, and other geologic structures. Mr. Duke is also extensively involved in soil and rock borehole and core logging, downhole bucket-hole logging, cone penetration testing, geologic and groundwater instrumentation, groundwater modeling, surface seismic, magnetic, and electrical geophysical surveys, marine geophysical surveys, and down-hole geophysical surveys. He has used these investigation techniques for site characterization and monitoring for numerous groundwater, geotechnical, and environmental projects.

SELECTED SPECIFIC PROJECT EXPERIENCE INCLUDES:

Bouquet Reservoir Seismic Evaluation, Los Angeles County, California (2002 – Present). Planned, conducted, and supervised a geologic and geophysical program for the evaluation of the seismic integrity and potential fault rupture hazard of two dam sites containing Bouquet Reservoir. Performed geologic mapping of natural exposures, road cuts, and exploration trenches. Conducted geophysical refraction and downhole seismic surveys to determine soil/rock velocities and geologic structure. Geologic and geophysical data were compiled to produce geologic maps and profiles. The compiled data were used to develop estimates of potential rupture displacements and to map potentially liquefiable layers that might underlie the two dams.

Diemer Filtration Plant, Yorba Linda, CA (1994 – Present). Performed numerous geophysical surveys (including seismic refraction, downhole seismic, electrical resistivity, magnetometer, and magnetic locator) and geotechnical investigations for various site development projects located throughout the MWD Diemer plant. These surveys were used in part to evaluate subsurface geology, faulting, slope stability, and groundwater conditions; corrosivity; location of utilities; material rippability; and the presence of a buried metallic well head.

LADWP On-call Geophysical Services (2011 – Present): Project Manager providing on-call geotechnical and geophysical services to the Geology and Soils Group of the LADWP's Power Engineering Services Division. He has recently completed a geotechnical investigation for the Owens Gorge Flow Restoration Project for improvements of LADWP's at Upper, Middle, and Control Gorge Power Plant Facilities. Additionally, he has recently completed work for the Haskell Canyon site development, Hollywood-Toluca Lake Road Repairs, and Cottonwood Power Plant development. Typical work for these projects included: seismic refraction geophysical surveys, bucket auger borings, rotary wash borings, test-



pits, surface geologic mapping, laboratory testing, and engineering analysis to provide recommendations for slope stability, foundation design.

Mid-and-High-Rise Buildings, Los Angeles, CA (2004 – Present). Provided the engineering geology and geophysical services for several of the mid-and-high-rise buildings in downtown Los Angeles. Typical geotechnical investigation work performed for these structures include deep borings, laboratory testing and extensive engineering analysis to provide recommendations for foundation design, ground motions, excavation and shoring, earthwork and drainage. Example buildings in downtown LA area include: 9th & Figueroa (addition currently being completed), 1027 Wilshire Blvd. (in design phase), LA Convention Hotels (two towers recently opened), 1015 Wilshire Blvd., 12th and Grand, Metropolis, Hollywood/Western, 8th and Grand, and the New San Bernardino Courthouse. Some of these buildings were designed considering performance-based design seismic input. In addition to the engineering and geophysical studies provided for these projects, he also performed the instrumentation and monitoring of the deep excavations such in the case of 9th and Figueroa. Also performed downhole and refraction microtremor (REMI) geophysical measurements to characterize shear-wave velocity structure (V_{s30} , $Z_{1.0}$) for several mid-and-high rise building development sites in the Los Angeles area. In addition to the sites mentioned above, these sites include: California Science Center, Bicycle Casino, 755 S. Figueroa Blvd., 5825 Sunset Blvd., 6121 Sunset Blvd., 225 S. Grand, 848 S Grand Ave., UCLA Health Sciences, 820 Olive Street, 929 S. Broadway, 1212 S. Flower, Metropolis, 400 S. Broadway, and 850 S. Hope.

Santiago Dam, Irvine, California (2011 – 2012). Performed a geotechnical investigation to assess potentially liquefiable materials under the dam. Conducted rotary sonic boreholes, geophysical seismic refraction using a shear-wave source, downhole seismic and ReMi surveys to determine geologic structure and shear-wave velocity characterization. Results were used to assess liquefaction in gravelly soil condition using the results of the sonic boreholes and the measured shear-wave velocities. Analyses were presented to DSOD to show that the materials underlying the dam were not liquefiable.

Walnut Canyon Dam, City of Anaheim, CA (2010 – 2014). Performed a geotechnical investigation for a seismic evaluation of the City of Anaheim's Walnut Canyon Dam that was operating at a restricted low level due to DSOD concerns over its seismic stability and its drain system. Also, installed a groundwater instrumentation system to automatically monitor groundwater levels within boreholes located on the dam and trained City of Anaheim personnel to manage and download automated instrumentation readings.

San Onofre Nuclear Generating Station Seismic Hazard Analysis, San Onofre, California (2009 – 2014). Mr Duke is a Senior Project Geophysicist and Geologist for the seismic hazard analysis for the recently closed San Onofre Nuclear Generating Station. His work for this project included a detailed geologic and seismic characterization using (1) marine seismic reflection data analysis, (2) geodetic data modeling, and (3) geologic and geophysical logging of deep boreholes. He is currently performing a re-analysis of offshore industry seismic reflection data, which have been reprocessed using modern methods to improve seismic image quality. The results are being used to evaluate the center, body, and range of possible fault tectonic models and ground motion parameters that may influence the seismic hazard at the plant, including the fuel handling building.

Elysian Reservoir Water Quality Improvement Project, LADWP, Los Angeles, California (2009 – 2013). Senior Project Geologist and Geophysicist - Performed a geologic and geophysical investigation program to characterize subsurface conditions for the design of a proposed water-conveyance tunnel and reservoir cover development. Conducted geophysical seismic refraction, seismic downhole, and SASW / ReMi surveys to determine geologic structure, shear-wave velocity characterization (V_{s30} and $Z_{1.0}$), and rock rippability. Also, supervised the logging of coreholes, rotary-wash boreholes, and a sonic borehole to



characterize rock conditions along the proposed tunnel alignment and beneath the dam, and soil conditions within the dam and under the reservoir.

Upper Chiquita Reservoir, Orange County, California (2009 – 2011). Planned, conducted, and supervised a geologic and geophysical program for the site characterization and design of a 155-ft high earth fill dam for the Santa Margareta Water District. The subsurface investigations conducted included CPT's, large diameter borings that were downhole logged, surface and downhole geophysical surveys, test pit with in-place density measurements, and geologic mapping. Also, developed Vs30, Z1.0, Z1.5, and Z2.5 for use in Next Generation Attenuation (NGA) models. Reviewed and presented results of field investigations to DSOD in their Sacramento offices. Currently, leading the site geologic mapping and coordination with DSOD during the construction of the dam and reservoir, which has included the evaluation of the activity of a fault that was located through the dam.

Escondido Canal, San Diego County, California (2009 – 2010). Performed a geotechnical feasibility-level evaluation of alternative cut and cover pipeline alignments considered for the undergrounding of the existing Escondido Canal. This evaluation identified possible ground conditions and its influence on pipeline design, construction and operation along the alternative alignments. Reviewed available geological/geotechnical data, including aerial photography and performed a field reconnaissance study, including seismic refraction surveys. Results were used to provide input on constructability, geotechnical issues, and geologic hazards for cataloging and rating of the proposed alternative alignments.

Camanche Reservoir, San Joaquin County, California (2008). Assisted with the characterization of the Camanche Reservoir Main Dam and associated Dikes. The characterization involved assessing main tailings foundation material beneath the main dam and alluvium beneath the dikes. The characterization was used in FLAC seismic analysis to be used for the basis for ground improvement recommendations. Performed downhole seismic measurements and calculated Vs30, Z1.0, Z1.5, and Z2.5 for use in Next Generation Attenuation (NGA) models.

San Pablo Dam, Contra Costa, California (2006 – 2008). Assisted with the characterization and design of the seismic upgrade of the 170-ft high hydraulic fill dam constructed in 1920. The design work involved the seismic nonlinear analysis of the dam to optimize the size, extent, and mix design of deep soil mixing stabilization of the downstream alluvium against seismic deformation. The characterization involved assessing alluvium beneath the dam for use in the nonlinear analysis. Performed geophysical seismic refraction and downhole seismic measurements.

San Diego Pipeline No. 6 Segment 2, Riverside and San Diego Counties, California (2007). Performed a geotechnical feasibility evaluation along the cut-and-cover pipeline portions of 5 alternative alignments for the second segment of San Diego Pipeline 6. Reviewed available geological/geotechnical data, including construction data of existing parallel pipeline alignments and performed a field reconnaissance study. Results were used to provide input on constructability, geotechnical issues, and geologic hazards related to the construction of the pipeline along the alternative alignments.

Arrowhead East and West Tunnels – Inland Feeder Pipeline Project, San Bernardino County, California (2001 – 2009). Performed geologic and hydrologic characterization of the tunnel alignments to assist with geologic and groundwater resource evaluation during tunnel construction. Installed and maintained automated groundwater instrumentation system to monitor pre- and post-construction groundwater levels along 10-mile tunnel alignment. Performed data reduction and interpretation of monitoring data from groundwater resources and developed mitigation criteria for groundwater resource sites. Also, created a probe drill pressure automated monitoring system, and analyzed response of system



during probe drilling ahead of tunnel face to predict ground conditions within the unmined rock ahead of the tunnel.

Riverside Badlands Tunnel – Inland Feeder Pipeline Project, Riverside and San Bernardino Counties (1998 – 2003). Installed and maintained automated groundwater instrumentation system to monitor pre- and post-construction groundwater levels along 8-mile tunnel alignment. Planned, implemented, and interpreted data from numerous hydrologic tests and geologic borings to assess aquifer properties, well production, and groundwater response to tunnel construction activities. Interpreted data were used to assess groundwater impacts to nearby private groundwater resources, the effectiveness of contractor's dewatering systems, design and construction of additional dewatering wells, and groundwater influence from an adjacent landfill.

Chuckwalla Groundwater Storage Basin Project, Riverside County, California (2002 – 2003). Performed and supervised geologic, hydrogeologic, and geophysical investigations for the design of an approximately 1,000,000 acre-ft aquifer storage and recovery project. Installed automated groundwater instrumentation system within the basins to monitor groundwater levels. Interpreted geologic and hydrogeologic conditions to assist with the design of spreading basin layouts, estimate storage volume for different pump field alternatives, and to estimate hydrocompaction.



Education

PhD, Civil Engineering, 2007
Rutgers University
MS, Civil Engineering, 2003
Rutgers University
BS, Civil Engineering, 1999

Registration

Civil Engineering, CA, 2009
(C74338)
Geotechnical Engineering, CA,
2013 (GE3051)

Affiliations

American Society of Civil
Engineers
Earthquake Engineering
Research Institute

numerical analysis of seismically induced soil deformation and constitutive modeling.

QUALIFICATIONS:

Dr. Hadidi has more than 14 years of experience in geotechnical and earthquake engineering and numerical analysis on a wide range of infrastructure projects, for both private and public sectors, locally, nationally, and globally with a wide range of complexity and size. These projects cover a wide range of infrastructure facilities such as dams, reservoirs, bridges, buildings, pipelines, roadways, airports, tunnels, and power plants.

During his career, Dr. Hadidi has performed numerical modeling and analysis in support of evaluation, design, construction, and monitoring of infrastructure using many of the commercially available platforms (e.g. FLAC, PLAXIS, ANSYS, ABAQUS) as well as customized analysis routines developed in various development environments (MATLAB, Visual Basic, FISH, etc.). Specifically, within the past two years, Dr. Hadidi has been part of the team in numerical analysis and seismic evaluation of major dams and tunnels in north and south America.

Dr. Hadidi has several years of research and teaching experience at several universities in United States. He has published many articles on

SELECTED SPECIFIC PROJECT EXPERIENCE INCLUDES:

Stevens Creek Dam, Santa Clara Valley Water District, Santa Clara County, CA (2013)

Senior Engineer for seismic stability evaluation and deformation analysis of 120-ft high Stevens Creek Dam. The evaluations was required by the Division of Safety of Dams (DSOD) in June 2008 as part of their Phase III screening process of the State's dams located in highly seismic environments. The evaluations are also a vital part of the Santa Clara Valley Water District's Dam Safety Program (DSP). Presence of potentially liquefiable alluvial deposits under downstream of the dam and its potential to cause stability concerns were a major factor in evaluation of the dam. The project included field investigation, material characterization and seismic deformation analysis to evaluate the potential deformation range in the event of a major earthquake. The analysis was carried out with a FLAC and using custom developed FISH routines to account for triggering of liquefaction and reduction of the material strength as a results. The analysis has been reviewed by DSOD, and District's review board, and District is evaluating possible remediation measures to address DSOD's concerns.

Lenihan Dam, Santa Clara Valley Water District, Santa Clara County, CA (2013)

Senior Engineer for seismic stability evaluation and deformation analysis of 170-ft high Lenihan Dam. Similar to Stevens Creek Dam, the evaluations was required by the Division of Safety of Dams (DSOD) in June 2008 as part of their Phase III screening process of the State's dams located in highly seismic environments. The evaluations are also a vital part of the Santa Clara Valley Water District's Dam Safety Program (DSP). The dam is constructed of cohesive material with relatively similar properties. The project included field investigation, material characterization, and analysis using FLAC to evaluate the response of the dam in the event of a major earthquake. The analysis has been reviewed by DSOD, and District's review board, and indicates satisfactory performance of the dam in the event of a major earthquake.



Headworks Reservoir, Los Angeles Department of Water and Power, Los Angeles, California (2010)

Senior engineer responsible for performing numerical soil-structure interaction analysis using FLAC and assisting in geologic hazard evaluation. Project includes geotechnical investigation and design recommendations for the proposed buried reinforced concrete water storage reservoir with the capacity of 110 million gallons, hydroelectric generation station, and 3,600 linear feet of piping. The innovative approach to design included evaluation of the performance the reservoir through a soil-structure interaction analysis with simulated structure, allowed the design team to evaluate the response of the structure and attempt to achieve performance goals beyond the conventional code-based design.

Palos Verdes Reservoir, Metropolitan Water District of Southern California (ongoing)

Senior Engineer for seismic stability evaluation and deformation analysis of Palos Verdes reservoir in Southern California. The more than 70 year old reservoir stores drinking water for South Bay and Harbor areas of Southern California and is managed and operated by Metropolitan Water District of Southern California. The evaluations is a part of district's on-going commitment to seismic safety. The project included field investigation, material characterization, and analysis using FLAC to evaluate the response of the dam in the event of a major earthquake. The analysis will be reviewed by DSOD, and District's engineers.

Bouquet Canyon Dams, Los Angeles Department of Water and Power, Los Angeles, California (ongoing)

Senior engineer responsible for performing numerical analysis using FLAC and assisting in investigation and geologic hazard evaluation for Bouquet Canyon Dams. The 200 ft high dam No. 1 and shorter Dam No. 2 are earthfill dams built in 1934 as a replacement for the Failed St. Francis Dam, and they impound one of the a major reservoirs along the Los Angeles Aqueduct, which supplies drinking water to City of Los Angeles. The project includes seismic hazard evaluation, field investigation, material characterization, and analysis using FLAC to evaluate the response of the dam in the event of a major earthquake. The analysis will be reviewed by DSOD, as well as an external review board.

Second Narrows Water Supply Tunnel, MetroVancouver, Vancouver, British Columbia (2012 – 2014)

Senior Project Engineer for the seismic deformation evaluation for the preliminary design of the Second Narrows Water Supply Tunnel Project. The project is to construct two new water mains within an approximately 6 m diameter tunnel crossing below Burrard Inlet at Second Narrows and associated structures. The new crossing is required to withstand and remain operational following the Maximum Credible Earthquake with a return period of 10,000 years. The subsurface materials consist of a stratigraphic column of deltaic deposits with variable susceptibility and resistance to liquefaction triggering. The work undertaken included review of the characterization by others followed by an independent effort to complete data reduction and interpretation, ground motion evaluation, and seismic deformation evaluation for preliminary design phase. This included specific emphasis on characterizing modeling uncertainty through use of different soil models in the analysis (i.e. Mohr Coulomb, UBCSAND, and PM4SAND).

Cerro Corona Tailings Dams, Cajamarca Hualgayoc, Peru (2012)

Senior Engineer for seismic stability evaluation and deformation analysis of three tailing dams on Las Aguilas, Gordas, and La Hiebra valleys (subconsultant to MWH). Increases in the height of the existing dams of various heights are being considered to accommodate the mining operations. The analysis included seismic stability evaluation and deformation analysis using FLAC to evaluate the response of the



dam in the event of a major earthquake. The results are reviewed by a panel of experts and they will guide the design team in implementing the proposed height increases.

Dumbarton Rail Line Corridor Project Geologic and Seismic Studies, San Mateo California (2009).

Senior Engineer for identification and assessment of geologic and seismic impacts for approximately 15 miles of rail line for proposed Dumbarton Rail Corridor project, an effort to transform former Southern Pacific rail line into commuter rail line serving South Bay area and as link in area multi-modal transit system. The project included numerous bridges including Dumbarton rail bridge, a 310 foot long steel truss bridge, and the Newark Slough bridge, A 188 feet long bridge. Responsible for directing and performing geologic, seismic and geotechnical engineering studies in support of project environmental document.



Professional Subconsultant Resumes



Ronald T. Eguchi

Chief Executive Officer and President

ImageCat, Inc.

400 Oceangate, Suite 1050

Long Beach, CA 90802

562 628-1675

rte@imagecatinc.com, <http://imagecatinc.com>

A. PROFESSIONAL PREPARATION

<u>College/University</u>	<u>Major</u>	<u>Degree & Year</u>
University of California, Los Angeles	Engineering	B.S., 1973
University of California, Los Angeles	Engineering	M.S., 1975

B. APPOINTMENTS

2000 - Present	President & CEO, ImageCat, Inc., Long Beach, California
2007 - 2009	Research Associate Professor, Department of Civil, Structural, & Environmental Engineering, University at Buffalo
1991 - 2000	Vice President, EQE International Inc., Irvine, California
1986 - 1991	Associate, Dames & Moore, Los Angeles, California
1984 - 1986	Senior Associate, Engineering Mechanics Associates
1983 - 1984	Principal Engineer, Agbabian Associates, El Segundo, California
1975 - 1983	Department Manager, J.H. Wiggins Company, Redondo Beach, California

C. PRODUCTS

(i) Products/Data Sets/Software/Patents/Copyrights Most Closely Related to Proposal

1. Corbane, C., Saito, K., Dell'Oro, L., Gill, S., Piard, B., Huyck, C., Kemper, T., Lemoine, G., Spence, R., Krishnan, R., Bjorgo, E., Senegas, O., Ghesquiere, F., Lallemant, D., Evans, G., Gartley, R., Toro, J., Ghosh, S., Svekla, W., Adams, B., and R. Eguchi, 2011. A Comprehensive Analysis of Building Damage in the January 12, 2010 Mw7 Haiti Earthquake using High-Resolution Satellite and Aerial Imagery, *Photogrammetric Engineering & Remote Sensing Journal*, American Society for Photogrammetry and Remote Sensing, Special Issue on the Haiti Earthquake, Vol. 77, Number 10, October.
2. Cutter, S.L., Emrich, C.T., Adams, B.J., Huyck, C.K., and R.T. Eguchi, 2007, "New Information Technologies in Emergency Management," *Emergency Management – Principles and Practice for Local Government*, Chapter 14, Second Edition, Editors W.L. Waugh Jr. and K. Tierney, ICMA Press, pp. 279-298.
3. Ghosh, Shubharoop, Huyck, Charles K., Greene, Marjorie, Gill, Stuart P., Bevington, John, Svekla, Walter, DesRoches, Reginald, and Ronald T. Eguchi, 2011. Crowd-sourcing for Rapid Damage Assessment: The Global Earth Observation Catastrophe Assessment Network (GEO-CAN), *Earthquake Spectra*, Special Issue on the Haiti Earthquake, Vol. 27, No. S1, October.
4. Hill, A., Bevington, J., Davidson, R., Chang, S., Eguchi, E., Adams, B., Brink, S., Panjwani, D., Mills, R., Pyatt, S., Honey, M., and Amyx, P., 2011. Community-Scale Damage, Disruption, and Early Recovery in the 2010 Haiti Earthquake, *Earthquake Spectra*. Vol. 27, No. S1, October.
5. Eguchi, R.T. and Mansouri, B., 2005, Use of Remote Sensing Technologies for Building Damage Assessment after the 2003 Bam, Iran, Earthquake – Preface to Remote Sensing Papers, *Earthquake Spectra*, Volume 21, No. S1, December.



(ii) Other Significant Products/Data Sets/Software/Patents/Copyrights (5 total)

1. Huyck, C.K., Adams, B.J., Cho, S, and Eguchi, R.T., 2005, "Towards Rapid City-wide Damage Mapping Using Neighborhood Edge Dissimilarities in Very High Resolution Optical Satellite Imagery – Application to the December 26, 2003 Bam, Iran Earthquake," *Earthquake Spectra Special Edition on the Bam Earthquake*, Volume 21, No. S1, December.
2. Eguchi, R.T., Huyck, C.K., and Adams, B.J., An Urban Damage Scale based on Satellite and Airborne Imagery, *Proceedings of the 1st International Conference on Urban Disaster Reduction*, Kobe, Japan, January 18-20, 2005.
3. Eguchi, R.T., Goltz, J.D., Seligson, H.A., Flores, P.J., Blais, N.C., Heaton, T.H., and E. Bortugno, "Real-Time Loss Estimation as an Emergency Response Decision Support System: The Early Post-Earthquake Damage Assessment Tool (EPEDAT)," *Earthquake Spectra*, Vol. 13, Number 4, November 1997.
4. Eguchi, R.T., Goltz, J.D., Taylor, C.E., Chang, S.E., Flores, P.J., Johnson, L.A., Seligson, H.A. and N.C. Blais (1998), "Direct Economic Losses in the Northridge Earthquake: A Three-Year Post-Event Perspective," *Earthquake Spectra*, Volume 14, No. 2, May 1998.
5. Eguchi, R.T., Goltz, J.D., Seligson, H.A., Heaton, T.H., "Real-Time Earthquake Hazard Assessment in California: The Early Post-Earthquake Damage Assessment Tool and the Caltech-USGS Broadcast of Earthquakes," *Proceedings, Fifth US National Conference on Earthquake Engineering*, Vol. 1, July 1994, p. 55-63.

D. SYNERGISTIC ACTIVITIES

(1) Transfer of research findings on Lifeline Earthquake Engineering into Practice; developed a series of seismic evaluation guidelines for electric power and natural gas and oil systems for the American Lifelines Alliance; (2) Teaching and training on Lifeline Earthquake Engineering – Developed Earthquake Hazard Mitigation Course on Lifelines for the Federal Emergency Management Agency (FEMA) – taught over 50 courses throughout the U.S.; (3) Conducted innovative research on the use of remote sensing technologies for natural disaster assessment; workshop organizer for ten international workshops on remote sensing and disaster response – sponsors include U.S. Geological Survey, MCEER, Earthquake Engineering Research Institute, the University of California at Irvine, and ImageCat; (4) Created a real-time loss estimation tool for the California Governor's Office of Emergency Services – a tool that is still being used by the State and the City of Los Angeles; (5) Created a series of user's guides to update and enhance input databases on building and lifeline inventories for HAZUS-MH; this work is helping local and state organizations in California respond to the requirements of FEMA's Hazard Mitigation program.

E. COLLABORATORS AND OTHER AFFILIATIONS

Collaborators over the Last 48 Months:

Stephanie Chang (University of British Columbia) – NSF Grant on Post-disaster Recovery
 Robert Chen (Columbia University) – NASA Grant on Global Inventory Datasets
 Rachel Davidson (University of Delaware) – NSF Grant on Post-disaster Recovery
 Reginald DesRoches (Georgia Institute of Technology) – World Bank study on Haiti earthquake
 Arleen Hill (Memphis University) – NSF Grant on Post-disaster Recovery
 Albert Lin (University of California, San Diego) – NSF Rapid Grant, Tohoku, Japan earthquake
 Sharad Mehrotra (University of California, Irvine) – NSF ITR: RESCUE project
 Nalini Venkatasubramanian (University of California, Irvine) – DHS: Safire project

Graduate and Postdoctoral Advisors

C. Martin Duke (University of California, Los Angeles)



Brief Capabilities Statement for ImageCat, Inc. – Seismic Risk of Pipeline Systems

Capabilities:

- Seismic hazard map development for ground shaking and ground failure effects (surface fault rupture, liquefaction and landslide)
- Pipeline fragility analyses for seismic effects
- Network studies of post-earthquake system performance
- GIS (geographic information systems) studies to correlate pipeline risk to impacts on communities
- Examination of seismic risk reduction strategies or measures

Example Studies:

- Development of Seismic Risk Action Plan – Subconsultant to CH2MHill – GVS&DD
- GVS&DD Sewage System Seismic Risk Assessment Study – Subconsultant to Sandwell – GVS&DD
- Guideline for Assessing the Performance of Oil & Natural Gas Pipeline Systems in Natural Hazard and Human Threat Events: Part 1 – Guideline; Part 2 – Commentary, prepared for Federal Emergency Management Agency - American Lifelines Alliance.
- Guideline for Assessing the Performance of Electric Power Systems in Natural Hazard and Human Threat Events: Part 1 – Guideline; Part 2 – Commentary, prepared for Federal Emergency Management Agency - American Lifelines Alliance.
- Regional Risk Assessment of Environmental Contamination from Oil Pipelines, prepared for Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo.
- Pipeline Replacement Feasibility Study: A Methodology for Minimizing Seismic and Corrosion Risks to Underground Natural Gas Pipelines, prepared for National Center for Earthquake Engineering Research.
- Seismic Risk Assessment of BC Gas Transmission and Intermediate Pressure Natural Gas Pipeline System in the Lower Mainland Region, prepared for BC Gas Inc.
- Study of Indirect Economic Consequences from a Catastrophic Earthquake: Impact on National Energy Distribution Network, prepared for the Federal Emergency Management Agency.
- Preliminary Seismic Risk Evaluation of Major ARKLA Incorporated Pipeline and Distribution Facilities, prepared for Arkansas Louisiana Gas Company.
- Preliminary Seismic Risk Evaluation of Texas Gas Transmission Pipeline and Distribution Facilities, prepared for Texas Gas Transmission Corporation.
- A Relative Seismic Risk Assessment of Proposed Inland Feeder Alignments, prepared for the Metropolitan Water District of Southern California.
- Seismic Risk Analysis of Southern California Gas Company Pipelines - The Effects of a Large and Moderate Earthquake on the Newport-Inglewood Fault, prepared for the Southern California Gas Company.
- Seismic Risk Analysis of Southern California Gas Company Pipelines - The Effects of a Large Earthquake on the San Andreas Fault in Southern California, prepared for the Southern California Gas Company.
- Earthquake Performance of Water and Natural Gas Supply Systems, prepared for the National Science Foundation.
- U-RAMP, a software package to estimate earthquake-induced damage to water, wastewater, and drainage networks as well as the costs and benefits associated with specific mitigation activities developed for the California Governor's Office of Emergency Services.
- A comprehensive seismic vulnerability and loss evaluation of the State of South Carolina, including lifelines and hazardous materials, prepared of the State of South Carolina.

Key Personnel:



Ronald T. Eguchi is President and CEO of ImageCat, Inc., a risk management company specializing in the development and use of advanced technologies for risk assessment and reduction. Mr. Eguchi has over 30 years of experience in risk analysis and risk management studies. He has directed major research and application studies in these areas for government agencies and private industry. He is a member of the National Research Council's Disaster Roundtable whose mission it is to identify urgent and important issues related to the understanding and mitigation of natural, technological, and other disasters. He is a past member of the Scientific Advisory Committee of the U.S. Geological Survey, a committee that reports to Congress on recommended research directions for the USGS in the area of earthquake hazard reduction. In 1997, he was awarded the ASCE C. Martin Duke Award for his contributions to the area of lifeline earthquake engineering. He still remains active in the ASCE Technical Council on Lifeline Earthquake Engineering serving on several committees and having chaired the Council's Executive Committee in 1991. In 1992, Mr. Eguchi was asked to chair a panel, established jointly by the Federal Emergency Management Agency and the National Institute of Standards and Technology to develop a plan for assembling and adopting seismic design standards for public and private lifelines in the U.S. This effort has led to the formation of the American Lifeline Alliance, currently managed by the National Institute of Building Sciences. In 2006, he accepted an ATC Award of Excellence on behalf of the ATC-61 project team for work on *An Independent Study to Assess Future Savings from Mitigation Activities* that showed that a dollar spent on hazard mitigation saves the nation about \$4 in future benefits. He was recently recognized by EERI as the 2008 Distinguished Lecture where he discussed the topic of *"Earthquakes, Hurricanes, and other Disasters: A View from Space."* He was also invited as a keynote speaker to the 14th World Conference on Earthquake Engineering, held in Beijing, China in 2008. He has authored over 250 publications, many of them dealing with the seismic risk of utility lifeline systems and the use of remote sensing technologies for disaster response.

William P Graf, CE, manages ImageCat's earthquake risk software resources for lenders, building owners and property insurers. He has 30 years of experience in seismic and other natural hazard and risk analyses for individual buildings, building portfolios, and lifeline structures. Mr. Graf also performs analyses of structures subject to earthquake or other loads, and develops seismic strengthening schemes.

Charles K. Huyck is Executive Vice President of ImageCat, Inc. As a founding partner of ImageCat, Mr. Huyck has been instrumental in developing operational strategies for spatial technologies. He directs a team of engineers, scientists, and programmers developing software tools and data processing algorithms for loss estimation and risk assessment. He has 20 years of GIS analysis and application development experience integrating advanced geospatial technologies into disaster simulation tools and CAT modeling programs. He is known for results-oriented and novel solutions to complex spatial modeling problems, including extracting damage estimates and building inventories from satellite imagery, migration of CAT models to an online environment, integration of transportation and lifelines vulnerability into GIS network analysis, and integrating social networking platforms into real time online loss estimation programs.

ImageCat Certifications:

State Minority Business Enterprise, California Department of Transportation
Disadvantaged Business Enterprise, California Unified Certification Program
Small Business, California Department of General Services
Minority Business Enterprise, California Public Utilities Commission, Supplier Clearinghouse



Douglas G. Honegger

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SUMMARY

Mr. Honegger has over 30 years of experience in a broad range of consulting activities related to understanding the response of structures, structural components and equipment to extreme loading resulting from earthquake hazards, blast and impact. Over his career, his clients have included pipeline and utility companies (natural gas, oil, water), the nuclear power industry, the Department of Energy (DOE), and the Department of Defense. Mr. Honegger's project activities have covered experimental investigations, detailed analytic evaluations and engineering assessments. He is experienced in providing defensible results under the high level of scrutiny often associated with critical facilities. He has been the principal author of over 30 professional papers and has been a contributing author to three books related to the subject of seismic design of pipeline systems.

Mr. Honegger is a recognized expert in the evaluation of the impacts of large permanent ground deformation on buried pipelines and conduits and continues to advance the state of practice through active laboratory and field research activities. His expertise also includes assessing the impact of earthquakes on aboveground non-structural components, and establishing rational design criteria for seismic hazards. He was in charge of developing new industry guidelines for the design of natural gas and liquid hydrocarbon transmission pipelines for hazards related to earthquakes, landslides, and subsidence and has been a co-instructor of a continuing education course on the seismic design of buried pipelines, most recently including a co-instructor for an 8-hour pre-conference workshop at the ASCE Pipelines 2013 conference in Fort Worth, TX.

Mr. Honegger was the principal investigator for the American Lifelines Alliance (ALA), a FEMA project focused on promulgating national guidelines and standards to improve utility and transportation system performance when subjected to natural and man-made hazards (www.americanlifelinesalliance.org). During course of the ALA project (1998 through 2009), ALA projects addressed topics related to recommended practice for assessing vulnerability and design of buried pipelines, revised seismic design requirements for aboveground steel storage tanks, and guidelines for determining the appropriate scope of work to support risk management decisions for water, natural gas, and oil pipeline systems. As the principal investigator for ALA, Mr. Honegger was instrumental in adding language to ASCE-7 to explicitly exclude electrical transmission towers, hydraulic structures, buried utility lines and their appurtenances from seismic design requirements primarily intended for buildings and industrial structures.

Mr. Honegger is an active member of the American Society of Civil Engineers (ASCE) where he has chaired the Earthquake Actuated Automatic Gas Shutoff Devices (ASCE 25) standards committee. He is a member of the ASCE 7 seismic task committee, is a past chair of the ASCE Codes and Standards Council that oversees all ASCE standards, and has represented lifelines interests in the development of national standards in the U.S. and Canada. He also currently serves on the Canadian standard committee addressing requirements for field constructed LNG containers and facilities.

NATURAL GAS PIPELINE EXPERIENCE

- Currently responsible for updating industry guidelines for the seismic assessment of new and existing natural gas and liquid hydrocarbon transmission pipelines prepared by D.G. Honegger Consulting in 2004 for the Pipeline Research Council International (PRCI Catalog No. L51927)
- Currently providing (since 2011) assessment of several Pacific Gas & Electric Company gas pipeline fault crossings and identifying pipeline replacement and construction alternatives to improve pipeline response.
- One of three contractors to PRCI and the project technical coordinator for a 3-year project to develop guidelines for assessing the performance of pipelines located in areas subjected to ground movement from landslides and



subsidence that is partially funded by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (<http://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=202&btn=Go>).

- Seismic consultant to Southern California Gas Company providing analysis and design recommendation for numerous pipelines fault crossings including the San Andreas, San Jacinto, Santa Susana, and Whittier faults.
- Since 1995, has served as a seismic consultant to BC Gas Utility Ltd. (now FortisBC Energy) to provided site-specific assessments of critical pipeline river crossings, developed recommendations for changes in pipeline alignments to minimize risk for pipeline rupture from large lateral spread displacements, conduct training courses, and provide guidance on when to perform detailed seismic hazard investigations on new pipeline projects. Recently (2010), he directed a project for FortisBC Energy was to provide a probabilistic assessment the seismic vulnerability of key gas pipelines in the Lower Mainland and on Vancouver Island.
- Seismic consultant to Sempra Energy on a project to build a natural gas transmission pipeline to the President Juarez Power Plant (Tijuana to Rosarito Beach) in northern Baja California, Mexico
- Provided review and recommendations to Pipeline Research Council International regarding proposed 2008 research that was intended to address gaps in the practice of assessing buried pipelines for blast loading. Review resulted in reformulation of research focus with recommendation that more effort be directed at alternate assessment approaches based upon expected zones of explosively-driven block motion.
- Provided an assessment of the proposed Rocky Mountain Pipeline for fault displacement on the Weber segment of the Wasatch fault. Various alignments are being evaluated to account for a large uncertainty in fault location and constraints on available pipeline right-of-way.
- Provided recommendations for Questar Feeder Line 26 crossing of the Wasatch fault near Provo, UT including alternate pipeline alignment configurations and locations for increased pipe wall thickness.
- Provided design recommendations for proposed Porcupine Ridge crude oil pipeline crossing the Weber segment of the Wasatch fault in the City of Centerville, UT. Key challenges in the project revolved around design measures that would accommodate the pipeline alignment within city streets.
- Analyzed standard large PG&E meter set assemblies for seismic ground motions expected in the PG&E service area, compared analysis findings with actual earthquake experience, and provided recommendations for improving PG&E standard specifications.
- Served as the technical lead and coordinator in the preparation of the California Seismic Safety Commission document, *Improving Natural Gas Safety in Earthquakes*, that identifies key risks and mitigation measures related to the use of natural gas in residential applications (www.seismic.ca.gov)
- Served as expert reviewer to Williams for the seismic design of a 16-inch high pressure gas pipeline crossing the Strait of Georgia between Washington and Vancouver Island, British Columbia
- Performed analyses to confirm the seismic adequacy of preliminary designs for key gas components of the BHP Billiton Cabrillo LNG facility. These analyses examined pipeline response to ground displacements resulting from fault movement, liquefaction, and wave propagation as well as the loads placed on portions of the pipelines, risers and mooring system as a result of turbidity currents generated by seismically triggered slope failure.
- Worked with D.J. Nyman & Associates on a variety of pipeline projects:
 - ♦ Fault crossing design for the Papua New Guinea LNG gas and liquids pipelines
 - ♦ Performed analyses to confirm gas pipeline design requirements for British Petroleum's Baku-Tbilisi-Ceyhan project through Azerbaijan, Georgia, and Turkey
 - ♦ Assess the response of the Rockies Express to potential subsidence induced by coal mining.
 - ♦ Assess the response of buried product and process pipelines within a common pipe corridor to subsidence induced by salt mining.



- ♦ Perform analyses to simulate the dislocation of offshore pipelines from hurricane surge for the purposes of estimating pipeline axial and bending strains.
- ♦ Analytically simulate construction of a pipeline installed by winching sections of pipeline up a steep slope to determine required winch capacity and residual pipeline stresses following construction and hydrotesting

LIQUID PRODUCT PIPELINE EXPERIENCE

- Provided analytical support to Trans Mountain Pipe Line Company (now Kinder-Morgan Canada) to confirm the ability of a proposed horizontal directionally drilled replacement of portion of a 24-inch liquid products line crossing the Fraser River to withstand lateral spread displacements
- Provided expert review for Sakhalin Energy Investment Company related to design approaches for fault crossings for the Sakhalin II project developed by their contractor Snamprogetti as a consultant to D.J. Nyman & Associates
- Provided guidance to UNOCAL for a proposed replacement alignment for a crude oil pipeline in Huntington Beach, California to minimize the risk of fires related to pipeline leakage as a result of earthquake-related ground deformations.
- Provided assistance to SPEC Services Inc. for several Kinder-Morgan projects including pipeline response analyses and design recommendations for ground displacement hazards associated with earthquake fault movement and ground settlement for the Concord-to-Sacramento pipeline, assessment of pipeline performance for a new alignment across the Hayward fault, and developing strategies to determine the influence of ground subsidence cracking in the vicinity of two products pipelines in Arizona.

WATER/WASTEWATER RELATED EXPERIENCE

- Consultant to URS Corporation to provide design recommendations for the seismic design of a proposed new low-level outlet pipeline for Anderson Dam.
- Consultant to URS Corporation providing pipeline analysis and design support for key Alameda County Water District pipelines at several Hayward fault crossings.
- Consultant to the San Francisco Public Utilities Commission providing seismic expertise related to acceptable construction alternatives to resolve issues related to non-compliant welded slip joints on Bay Division Pipeline 5.
- Consultant to URS Corporation providing analytical support for the seismic upgrade of the San Francisco Public Utilities Commission Bay Division Pipelines 3 and 4 to survive fault displacement along the Hayward fault. Analysis requires dynamic simulation of the seismic response of a 72-in pipeline installed in a segmented vault with custom designed slip joints and ball joints.
- Provided assessment of likely damage and service outage durations for the natural gas and water systems operated by Memphis Light Gas & Water for several earthquake scenarios as part of an overall MLGW seismic risk assessment project.
- Member of MMI Engineering project team that provided assessment and risk mitigation strategies to Contra Costa Water District for prioritizing capital improvement funds to reduce the severity of service interruption that may result from an earthquake on the Concord fault.
- Member of MMI Engineering project team that evaluated risks to the water system operated by the Sonoma County Water Agency to support preparation of the Agency's Local Hazard Mitigation Plan. Subsequently, was a consultant to MMI Engineering providing analytical assessment of proposed pipeline mitigation options.
- Subconsultant to Golder Associates on five major projects since 2005 for the Greater Vancouver Regional District in British Columbia, Canada (now Metro Vancouver) to assess the seismic adequacy of water pipelines ranging in size from 18 to 54 inches at key river crossings in the Vancouver region.



- Provided consulting services to MMI Engineering related to recommendations to the City of Hayward, CA to reduce potential damage and service interruptions to key water and wastewater pipelines in the event of a rupture of the Hayward fault

HIGH-VOLTAGE BURIED ELECTRICAL CABLE EXPERIENCE

- Provided analytical assessment of 230kV subsea cable response to earthquake-triggered slope instability for BC Hydro as part of the risk assessment process for installing new power transmission lines across the Georgia Strait
- Provided summary of mitigation alternatives to San Diego Gas and Electric Company for placing buried 230kV duct banks within zones of potential surface fault displacement to assist in responding to regulatory inquiries regarding electric power reliability

RESEARCH AND TESTING EXPERIENCE

- Project director and contributor on a research project for PRCI at the University of British Columbia investigating the use of geosynthetic fabrics to improve pipeline performance under large ground movement.
- Providing on-going testing services to Southern California Gas Company for a field testing program to systematically measure axial soil friction forces on existing pipelines.
- Primary technical consultant for a 3-year research program aimed at understanding the earthquake generated the ground motions that occurred in the 1994 Northridge, California earthquake and the mode of failure in gas transmission pipelines. The research, funded by US and Japanese gas utilities, included field testing, subsurface exploration, geotechnical studies, pipeline testing, and analytical studies of pipeline response.
- Performed an investigation of fire ignition characteristics and ground motion from the 1994 Northridge earthquake to support development of new actuation criteria for a revision to the standard governing earthquake actuated automatic gas shutoff devices

PROFESSIONAL HISTORY

President, D.G. Honegger Consulting, 1995-present

EOE International, Irvine, California, Technical Manager, 1989-1995

National Technical Systems, Long Beach, California, Project Engineer, 1985-1989

Structural Mechanics Associates, Houston, Texas, Staff Engineer, 1982-1985

EDUCATION

University of Illinois, M.S. Civil Engineering, 1981

University of Illinois, B.S. Civil Engineering, 1980

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers

Earthquake Engineering Research Institute

Seismological Society of America

SELECTED PUBLICATIONS

Books and Guidelines

Contributor to Seismic Risk Analysis and Management of Civil Infrastructure Systems, edited by S. Tesfamariam (UBC, Canada) and K. Goda (Bristol, UK), to be published by Woodhead Publishing Ltd. 2013.

Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines Through Areas Prone to Landslide and Subsidence Hazards, final report to Pipeline Research Council International, Inc., with C-CORE and SSD, Inc., Catalog No. L52292, 2009.

Guidelines for the Seismic Design and Assessment of Natural Gas and Liquid Hydrocarbon Pipelines, with D.J. Nyman, Pipeline Research Council International, Inc., Catalog No. L51927, 2004

Fire Following Earthquake, TCLEE Monograph 26, contributing author, American Society of Civil Engineers, 2005.



Guidelines for the Design of Buried Steel Pipe, project manager and contributor, www.americanlifelinesalliance.com, 2001.

Guide to Post-Earthquake Investigation of Lifelines, contributing author, American Society of Civil Engineers, 1997
Guidelines for the Seismic Design of Natural Gas Distribution Systems, TCLEE Monograph No. 9, contributing author, American Society of Civil Engineers, 1995

Recent Papers

"Regional Pipeline Vulnerability Assessment Based Upon Probabilistic Lateral Spread Hazard Characterization," with D. Wijewickreme and T.L. Youd, 10th National Conference on Earthquake Engineering, 2014.

"Response Of Buried Pipelines Subjected To Ground Displacements Under Different Trench Backfill Conditions," with D. Wijewickreme, M. Monroy, and D. Nyman, 10th National Conference on Earthquake Engineering, 2014.

"Design of Welded Steel Pipeline Crossings of Thrust Faults," with D. Nyman and G.A. Carver, 10th National Conference on Earthquake Engineering, 2014.

"Effectiveness of Geotextile-Lined Pipeline Trenches Subjected To Relative Lateral Seismic Fault Ground Displacements," with M. Monroy and D. Wijewickreme, 15th World Conference on Earthquake Engineering, Lisbon, Portugal, 2012.

"Challenges in Assessing the Seismic Vulnerability of Two Water Main River Crossings in British Columbia, Canada," with Upul Atukorala, Humberto Puebla, Roberto Olivera, Jusheng (Mark) Qian, and Murray Gant, 15th World Conference on Earthquake Engineering, Lisbon, Portugal, 2012.

"Recent PRCI Guidelines for Pipelines Exposed to Landslide and Ground Subsidence Hazards," with R. Phillips, J. Hart, C. Popelar, and R. Gailing, 8th ASME International Pipeline Conference, September, 2010.

"Definition of Lateral Spread Displacement for Regional Risk Assessments of Pipeline Vulnerability," with H. Puebla, D. Wijewickreme, A. Augello, and M. Rahman, 8th ASME International Pipeline Conference, September, 2010.

Guidelines for Managing Risks to Pipelines Through Landslide and Subsidence Hazard Areas," with R. Gailing, J. Hart, R. Phillips, and C. Popelar, 17th Joint Technical Meeting on Pipeline Research, Milan, Italy, May, 2009.

"Geotechnical Challenges for Design of a Crude Oil Pipeline Across an Active Normal Fault in an Urban Area," with Jeffery Keaton, 6th ASME International Pipeline Conference, September, 2008.

"Considerations for Selecting Approaches to Estimate Lateral Spread Displacements for Assessing Pipeline Performance," 4th ASME International Pipeline Conference, September, 2006.

"Buried Pipelines Subjected to Transverse Ground Movement: Comparison Between Full-Scale Testing and Numerical Modeling," with H. Karimian and D. Wijewickreme, Proceedings of OMAE2006 25th International Conference on Offshore Mechanics and Arctic Engineering, June 4-9, 2006.

"Liquefaction Hazard Mitigation for Oil and Gas Pipelines," with D.J. Nyman and T.L. Youd, Proceedings of the 8th National Conference on Earthquake Engineering, April, 2006.

"Seismic Vulnerability Assessment and Retrofit of a Major Natural Gas Pipeline System: A Case History," with D. Wijewickreme, T. Fitzell, and A. Mitchell, EERI SPECTRA, Vol. 21, No. 2, 2005.

"Numerical Modeling of Permanent Ground Deformation Hazard to a Natural Gas Pipeline In California," with Y. Prashar, R. Stauber, and Z. Zafir, Proceedings of Geo-Frontiers 2005 Conference, American Society of Civil Engineers, January, 2005.

"Trans-Alaska Pipeline System Performance in the M7.9 Denali Fault Earthquake," with D.J. Nyman, E.R. Johnson, L.S. Cluff, and S.P. Sorensen, EERI SPECTRA, Vol. 20, No. 3, 2004.

"Improving Natural Gas Safety in Earthquakes – California Recommendations," with F. Turner, Proceedings of the 6th U.S. Conference on Lifeline Earthquake Engineering, August, 2003.



Thomas K. Rockwell

Professor
Department of Geological Sciences
San Diego State University
5500 Campanile Dr.
San Diego, CA 92182-1020

Curriculum Vitae

Dr. Thomas Rockwell is a nationally and internationally renowned paleoseismologist and geomorphologist who has published over 120 articles in major international journals, coauthored a number of book chapters, published 40 papers in conference proceedings and guidebooks, and coauthored over 300 papers presented at professional meetings. Having served as Geology Group Leader for the Southern California Earthquake Center for many years, he is an expert on the tectonics and earthquake hazards of southern California and Baja California, has conducted extensive trenching programs to date earthquakes on faults in the western U.S., South and Central America, the Middle East and Asia, and routinely uses soil stratigraphy and geomorphology combined with various radiometric dating techniques to assess rates of fault activity, determine recency of faulting, and date past earthquakes. His research focuses on understanding earthquake occurrence in time and space. Current projects include the characterization of fault systems behavior by understanding patterns of past recurrence of large earthquakes on faults in southern California, northern Mexico, Panama, Argentina, Portugal, Turkey, India, and Israel. This work includes resolving information on slip per event, as it relates to understanding the controls on segmentation and rupture termination. He has also worked extensively on the affects of tectonism on the landscape, and using geomorphology to constrain rates and timing of tectonic events. Included in this latter aspect is detailed mapping and dating of marine terraces along the west coast of North America and assessment of paleosea level during the late Quaternary.

Education

B.S. Univ. of Nevada, Reno - December 1976 (Geology)
Ph.D Univ. of Calif., Santa Barbara - December, 1983 (Geology)

Positions

9/76-6/82	Research and teaching assistant at the University of Nevada (9/76-12/76), the University of California at Santa Barbara (9/77-6/82 with two absences), and the University of Illinois (9/80-12/80)
3/80-8/80	Geologist, Dames and Moore, Los Angeles, California
9/82-12/82	Lecturer, California Inst. of Technology, Pasadena
1/83-7/86	Assistant Professor, San Diego State University
7/86-7/89	Associate Professor, San Diego State University
7/89-present	Professor, San Diego State University

Professional Affiliations and Societies

Sigma Xi
Seismological Society of America – Board of Directors, 2002-2004
Southern California Earthquake Center (SCEC)
Geological Society of America - Fellow
Soc. of Economic Paleontologists and Mineralogists, Pac. Section
San Diego Association of Geologists
American Geophysical Union
Association of Engineering Geologists



REFEREED PUBLICATIONS

Published Refereed Papers Related to Neotectonics and Paleoseismology of the southern San Andreas fault system (including the San Jacinto and Elsinore faults), past 4 years

- Onderdonk, N., McGill, S., and **T.K. Rockwell**, 2015 in press, Variations in slip rate and size of pre-historic earthquakes during the past 2000 years on the northern San Jacinto fault zone, a major plate boundary structure in southern California. Accepted in *Lithosphere*, 12/2014
- Haaker, E. C., **Rockwell, T.K.**, Kennedy, G.L., Grant-Ludwig, L., Freeman, S.T., Zumbro, J.A., Mueller, K.J., and Edwards, R. L., (2015 in press) Long – Term Uplift of the Southern California Coast Between San Diego and Newport Beach Resolved with New dGPS Survey Data: Testing Blind Thrust Models in the Offshore California Borderland: *in* Anderson, R. L., and Ferriz, H., *Applied Geology in California: Association of Environmental and Engineering Geologists Special Publication 26*.
- Rockwell, T.K.**, T.E. Dawson, J. Young-Ben Horton, and G. Seitz, 2015, A 21 event, 4,000-year history of surface ruptures in the Anza Seismic Gap, San Jacinto Fault and implications for long-term earthquake production on a major plate boundary fault. *Pure and Applied Geophysics*, published on-line, November, 2014.
- Rockwell, T.K.**, K.M. Scharer, T.E. Dawson, 2014 in press, Paleoseismology of the San Andreas Fault Zone. *in* Anderson, R. L., and Ferriz, H., *Applied Geology in California: Association of Environmental and Engineering Geologists Special Publication 26*.
- Scharer, K.M., Salisbury, J.B., Arrowsmith, J.R., and **Rockwell, T.K.**, 2014, Southern San Andreas Fault Evaluation field activity: Approaches to measuring small geomorphic offsets - challenges and recommendations for active fault studies, accepted, *Seismological Research Letters*, v. 85, p. 68-76, doi:10.1785/0220130108.
- Blisnuik, K., M. Oskin, A-S. Mériaux, **T. Rockwell**, R. Finkel, and F. J. Ryerson, 2013, Stable, Rapid Rate of Slip Since Inception of the San Jacinto Fault, California, *Geophys. Res. Lttrs.* , v. 40, 4209–4213, doi:10.1002/grl.50819.
- Rockwell, T.K.** and Klinger, Y., 2013, Surface rupture and slip distribution of the 1940 Imperial Valley earthquake, Imperial Fault, southern California: Implications for rupture segmentation and dynamics. *Bulletin of the Seismological Society of America*, Vol. 103, No. 2A, pp. 629-640, April 2013, doi: 10.1785/0120120192.
- Onderdonk, N., **Rockwell, T.K.**, McGill, S., and Marliyani*, G., 2013, Evidence for seven surface ruptures in the past 1600 years on the Claremont fault at Mystic Lake, northern San Jacinto fault, California. *Bulletin of the Seismological Society of America*, v. 103, no. 1, p. 519-541. doi: 10.1785/0120120060
- Kimberly Blisniuk, Michael Oskin, Kathryn Fletcher, **Thomas Rockwell**, Warren Sharp, 2012, Assessing the Reliability of U-series and ¹⁰Be dating techniques on Alluvial Fans in the Anza Borrego Desert, California, *Quaternary Geochronology*, doi.org/10.1016/j.quageo.2012.08.004
- Salisbury, J.B., **Rockwell, T.K.**, Middleton, T.J., and Hudnut, K.W., 2012, LiDAR and Field Observations of Slip Distribution for the Most Recent Surface Ruptures Along the Central San Jacinto Fault. *Bulletin of the Seismological Society of America*, v. 102, no. 2, p. 598-619. doi: 10.1785/0120110068.
- Fletcher, K.E.K., **Rockwell, T.K.**, and Sharp, W.D., 2011, Late Quaternary slip rate of the southern Elsinore fault, southern California: Dating offset landforms via ²³⁰Th/U on pedogenic carbonate. *J. Geophysical Research*, 116, F02006, doi:10.1029/2010JF001701.
- Blisniuk, K., **Rockwell, T.**, Owen, L., Oskin, M., Lippincott, C., Caffee, M., and Dortch, J., 2010, Late Quaternary slip rate gradient defined using high-resolution topography and ¹⁰Be dating of offset landforms on the southern San Jacinto Fault zone, California: *J. Geophysical Research* v. 115, B08401, doi:10.1029/2009JB006346, 2010.
- Gingery, James R., Rugg, Scott H., Hilton, Bruce, and **Rockwell, Thomas K.**, 2010, Fault hazard characterization for a transportation tunnel project in Coronado, California. Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, May 24-29, 2010, San Diego, California, Paper No. 7.02C, 13 pgs. <http://5geoeqconf2010.mst.edu>
- Rockwell, T.K.**, 2010, The Rose Canyon Fault in San Diego. Proceedings of the Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, May 24-29, 2010, San Diego, California, Paper No. 7.06C, 9pgs. <http://5geoeqconf2010.mst.edu>



Other Candidate Professional Subconsultant Resumes



Lisa Grant Ludwig, Ph.D. (a.k.a. Lisa B. Grant)

Professor, Public Health
University of California, Irvine
Phone: (949) 824-2889 / 5491
e-mail: lgrant@uci.edu

Education

B.S. with distinction, 1985, Stanford University, Applied Environmental Earth Science
M.S. 1989, California Institute of Technology, Environmental Engineering and Science
M.S. 1990, California Institute of Technology, Geology
Ph.D. 1993, California Institute of Technology, Geology with Geophysics minor

Selected Academic Positions:

Professor, 2013 - present; Associate Professor, 2006 -2013 Program in Public Health, UC Irvine
Graduate Director, 2009 – 2014, Program in Public Health , University of California, Irvine Associate Director,
California Institute for Hazards Research, University of California, 2006-11
Assistant Professor, 1998-2006, Environmental Health, Science and Policy School of Social Ecology, UC Irvine,
Assistant Professor of Environmental Science and Geology and Program Director for Environmental Science, 1995-
1998; Chapman University, Orange, CA,
Graduate Research and Teaching Assistant 1989-1992, Caltech Division of Geological & Planetary Sciences; and
Keck Hydraulics Lab

Selected Professional Positions:

Independent Consultant for GeoPentech Consultants, Santa Ana CA, 2009 - 2013
Senior Staff to Assistant Project Scientist, 1993 - 95 (part-time to 1998) Woodward-Clyde Consultants,
GeoEngineering Group, Santa Ana, CA
Research Scientist, 1985-1987, California Research & Technology / Titan Systems, Chatsworth, CA
Hydrologic Technician, 1983-4 (part-time) U.S. Geological Survey, Menlo Park, CA

Selected Professional Leadership or Service Positions:

Member, Advisory Committee on Earthquake Hazard Reduction, Federal Advisory Committee reporting to Director of
National Institute of Standards and Technology (NIST), 2014-17
Member, Committee on Seismology and Geodynamics, standing committee of the National Research Council, Board
on Earth Sciences and Resources, 1/01/2015 – 12/31/2017
President, President-Elect, Seismological Society of America, April 2013 - present
Member, Board of Directors, Seismological Society of America, 2010 – present
Member, Board on International Scientific Organizations, National Academies, Policy and Global Affairs, 2012 – 2015
Leader, Earthquake Geology Group, Southern California Earthquake Center, 2012 - 2014
Vice Chair, Board of Directors, Southern California Earthquake Center, 2007 - 2011 At-Large Elected Member of the
Board of Directors, 2002 - 2011
Member, National Academy of Sciences U. S. National Committee to the International Union of Geodesy and
Geophysics (IUGG). 2003 -2011.
National Correspondent, International Association for Seismology and Physics of the Earth's Interior (IASPEI) 2008 –
2011.
Member, Community Executive Committee, Orange County Essential Facilities Risk Assessment (OCEFRA) Project,
FEMA Region IX Floodplain Mapping Program, 2007- 2008



Selected Awards and Fellowships:

NASA 2012 Software of the Year Co-Winner QuakeSim 2.0 (Sept. 11, 2012)
Outstanding Outreach Certificate, Southern California Earthquake Center, 1999
Award for Excellence, Chapman University 1997

Selected publications

1. Akciz, S. O., **Grant Ludwig, L.**, Zielke*, O., and Arrowsmith, J R. (2014). Post-1857 fracturing and deflection of an apparent offset channel along the San Andreas fault in the Carrizo Plain. *Bull. Seismol. Soc. Amer.* vol 104, no 6, doi: 10.1785/0120120172
2. Donnellan, A, J Parker, M Glasscoe, E De Jong, M Pierce, G Fox, D McLeod, J Rundle, **L. Grant Ludwig** (2012). A Distributed Approach to Computational Earthquake Science: Opportunities and Challenges, *Computing In Science & Engineering*, v. 14, no 5, 1521-9615/12, IEEE, Sept/Oct 2012, p31-42.
3. Noriega*, G. R. and **Grant Ludwig, L.** (2012). Social vulnerability assessment for mitigation of local earthquake risk in Los Angeles County, *Natural Hazards*, Accepted July 11, 2012. doi: 10.1007/s11069-012-0301-7, published online August 24, 2012
4. Vidale, J., Atkinson, G., Green, R., Hetland, E., **Grant Ludwig, L.**, Mazzoti, S., Nishenko, S. and L. Sykes (2011). Report of the Independent Expert Panel on New Madrid Seismic Zone Earthquake Hazards to the National Earthquake Prediction Evaluation Council (NEPEC) and Dr. Marcia McNutt, Director of the U.S. Geological Survey, April 16, 2011. <http://earthquake.usgs.gov/aboutus/nepec/reports/index.php>
5. **L. Grant Ludwig**, S. O. Akciz, G. R. Noriega, O. Zielke and J R. Arrowsmith (2010). Climate-modulated channel incision and rupture history of the San Andreas fault in the Carrizo Plain. Published 21 January 2010 on *Science Express*, DOI: 10.1126/science.1182837; print version featured on cover; v. 327, 26 Feb 2010, 1117-1119.
6. O. Zielke*, J R. Arrowsmith, **L. Grant Ludwig**, and S. O. Akciz (2010). Slip in the 1857 and earlier large earthquakes along the Carrizo Plain, San Andreas fault, Published 21 Jan 2010 *Science Express*, DOI: 10.1126/science.1182781; prin v. 327, 26 Feb 2010, 1119-1122.
7. Plesch, A., Shaw, J. H., Bensen, C., Bryant, W. A., Carena, S., Cooke, M., Dolan, J., Fuis, G., Gath, E., **Grant, L.**, Hauksson, E., Jordan, T., Kamerling, M., Legg, M., Lindvall, S., Magistrale, H., Nicholson, C., Niemi, N., Oskin, M., Perry, S., Planasky, G., Rockwell, T., Shearer, P., Sorlien, C., Suss, M. P., Suppe, J., Treiman, J., and R. Yeats. Community fault model (CFM) for Southern California. . *Bull. Seism. Soc. Amer.*, v. 97, no. 6, 1793-1802, December 2007. doi:10.1785/0120050211
8. **Grant, L. B.**, Gould, M. M., Donnellan, A., McLeod, D., Chen*, A. Y., Sung, S., Pierce, M., Fox, G. C., and Rundle, P. (2005). A Web-service based universal approach to heterogeneous fault databases, *Computing in Science & Engineering*, July/Aug. 2005, 51- 57. 10.1109/MCSE.2005.63
9. **Grant, L. B.** and P. M. Shearer (2004). Activity of the offshore Newport-Inglewood Rose Canyon fault zone, coastal southern California, from relocated microseismicity. *Bull. Seism. Soc. Amer.*, 94, 747-752.
10. **Grant, L. B.** L. J. Ballenger, and E. E. Runnerstrom (2002). Coastal uplift of the San Joaquin Hills, Southern Los Angeles basin, California, by a large earthquake since 1635 A.D. *Bull. Seism. Soc. Amer.*, v. 92, no. 2, p.590-599, 2002.
11. **Grant, L. B.**, K. J. Mueller, E. M. Gath, H. Cheng, R. L. Edwards, R. Munro and G. L. Kennedy (1999). Late Quaternary Uplift and Earthquake Potential of the San Joaquin Hills, southern Los Angeles Basin, California, *Geology*, v. 27, no. 11, p. 1031-1034.
12. **Grant, L. B.**, J. T. Waggoner, C. von Stein and T. Rockwell (1997) Paleoseismicity of the North Branch of the Newport-Inglewood Fault Zone in Huntington Beach , California, from Cone Penetrometer Test Data. *Bull. Seism. Soc. Amer.*, v. 87, no. 2, p.277 - 293, 1997.
13. **Grant, L. B.** (1996) Uncharacteristic Earthquakes on the San Andreas Fault, *Science*, 272, 826 - 827, 1996.



THOMAS D. O'ROURKE

Thomas R Briggs Professor of Engineering,
Civil and Environmental Engineering,
Cornell University,
273 Hollister Hall
Ithaca, NY 14853-3501

Education

Ph D, University of Illinois at Urbana-Champaign, 1975

MSCE, University of Illinois at Urbana-Champaign, 1973

BSCE, Cornell University, 1970

Experience

Professor O'Rourke has been a member of the teaching and research staffs at Cornell University and the University of Illinois at Urbana-Champaign. His teaching and professional practice have covered many aspects of geotechnical engineering including foundations, earth retaining structures, slope stability, soil/structure interaction, underground construction, laboratory testing, and elements of earthquake engineering. He has authored or co-authored over 300 publications on geotechnical, underground, and earthquake engineering.

He was elected a member of the National Academy of Engineering in 1993 and a Fellow of the American Association for the Advancement of Science in 2000. He was awarded the C.A. Hogentogler Award from ASTM in 1976 for his work on the field monitoring of large construction projects. In 1983 and 1988, Prof. O'Rourke received the Collingwood and Huber Research Prizes, respectively, from ASCE for his studies of soil and rock mechanics applied to underground works and excavation technologies. In 1995 he received the C. Martin Duke Award from ASCE for his contributions to lifeline earthquake engineering, and in 1997 he received the Stephen D Bechtel Pipeline Engineering Award from ASCE for his contributions to the profession of pipeline engineering. In 2002 he received the Trevithick Prize from the British Institution of Civil Engineers and was designated as an NSF Distinguished Lecturer. He received the 2003 Japan Gas Association Best Paper Award and the 1996 EERI Outstanding Paper Award. In 2005 he received the Ralph B Peck Award from ASCE. In 1998, he was elected to the EERI Board of Directors and served as President from 2003-2005. In 1998 and 2003, Prof O'Rourke received Cornell University's College of Engineering Daniel Lazar and Kenneth Goldman Excellence in Teaching Awards, respectively. He received both the College of Engineering Distinguished Service Award and the CEE Distinguished Alumnus Award from the University of Illinois in 2005 and 2000, respectively. He testified before the US House of Representatives Science Committee in 1999 on engineering implications of the 1999 Turkey and Taiwan earthquakes and in 2003 on the reauthorization of the National Earthquake Hazards Reduction Program. He has served on numerous earthquake reconnaissance missions, and holds a US patent for innovative pipeline design. He was elected as an Overseas Fellow of Churchill College, University of Cambridge, in 2006 and awarded a Fulbright Senior Specialist grant to work with the New Zealand Department of the Prime Minister and Cabinet to develop policy on critical infrastructure and natural hazards in 2007.

Professor O'Rourke has developed engineering solutions for problems concerning foundation performance, ground movement effects on structures earth retaining structures, pipelines, earthquake engineering tunneling and infrastructure rehabilitation, both on a research and consulting basis. He has served as chair or member of the consulting boards of many large underground construction projects, as well as the peer reviews for projects associated with highway, rapid transit, water supply, and energy distribution systems. Such projects include the NYC Second Avenue Subway, Boston CA/T, Third NYC Water Tunnel, Tren Urbano Rapid Transit, NYC Fulton St Transit Center, soft and hard rock tunneling for the Massachusetts Water Resources Authority, Dulles Airport underground expansion, San Francisco TJPA Downtown Extension Project involving hard and soft ground tunneling, seismic design of tunnels in Turkey, Trans-bay Tube Seismic Retrofit, seismic design for the San Francisco water supply (including the SFPUC Crystal Springs By-pass Tunnel, Bay Tunnel, Irvington Tunnel and Bay Division Pipelines),



underground stations for BART in San Jose, CA, geotechnical and seismic criteria for The Alaskan Way Viaduct in Seattle, WA, and many others. He has assisted in the development and application of advanced polymer and composite materials for the in-situ rehabilitation of water supply and gas distribution facilities. He has developed techniques for evaluating ground movement patterns and stability for a variety of excavation, tunneling, micro-tunneling, and mining conditions. He has developed analytical methods and siting strategies to mitigate pipeline and tunnel damage during earthquakes, analyze and design high pressure pipelines, and established full-scale testing facilities for transmission and distribution pipelines and tunnel facilities. He has developed geographical information systems (GIS) and network analysis procedures for water supply systems in areas vulnerable to earthquakes and other natural disasters. He and his co-workers have developed a computer model for the Los Angeles water supply, including all 12,000 km of pipelines and related facilities, which has been adopted by the Los Angeles Department of Water and Power as its decision support system for seismic planning and design.

He is a member of the ASCE, ASME, ASTM, AAAS, ISSMEE, EERI, and IAEG. He was a member of the NSF Engineering Directorate Advisory Committee, and serves on the Executive Committee of the Multidisciplinary Center for Earthquake Engineering Research and he was chair of the U.S. National Committee on Tunneling Technology and co-chair of the Institute for Civil Infrastructure Systems. He was a member of the NRC Geotechnical Board and Board on Energy and Environmental Systems. He is a past chair of the UTRC Executive Committee and both the ASCE TCLEE Executive Committee and Technical Committee on Gas and Liquid Fuel Lifelines. He is a past chair of the ASCE Earth Retaining Structures Committee, as well as past president of the ASCE Ithaca Section, and was a member of the intermunicipal water commission in his home town.



Attachment B Cost Estimates

GeoPentech Estimated Cost

GeoPentech 2014 Schedule of Fees and ODC Contract Fee Schedule

Professional Subconsultant Hourly Rates

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY
NORTH ORANGE COUNTY WATER SUPPLY SYSTEM RELIABILITY PLAN
PART A. SEISMIC HAZARD ASSESSMENT
GEOPENTECH, INC. ESTIMATED COST

	Labor Rate (\$/hr):	Total Consultant Hours	Subtotal Consultant Cost	Total Subconsultant Hours	Subtotal Subconsultant Cost ¹	Consultant Reimbursable Expenses ⁴	Total Task Item Cost
	Personnel Title:						
Task Item Description							
Task A.1: Identify and Characterize Faults of Interest							
Subtask A.1-1: Prepare Maps of Faults Relative to Critical Water Supply Facilities in NOC (on Appropriate Base Maps)		41	\$4,320	2	\$500	\$100	\$4,920
Subtask A.1-2: Prepare Map of Historic Earthquakes and Instrumentally-Recorded Earthquakes in Southern California		25	\$2,880	0	\$0	\$0	\$2,880
Subtask A.1-3: Identify Recency of Activity of the Faults and Timing of Past Ruptures		23	\$2,850	4	\$1,000	\$100	\$3,950
Subtask A.1-4: Report Fault Slip Rate Estimates		11	\$2,850	0	\$0	\$0	\$2,850
Subtask A.1-5: Estimate the Maximum Credible Earthquake (MCE; i.e., the 2,475-year average return period earthquake) for the Faults		0	\$2,090	8	\$2,000	\$100	\$4,190
Subtask A.1-6: Additional Evaluation of Faults outside NOC Relative to Major Aqueducts		15	\$2,090	4	\$1,000	\$500	\$3,590
Total Tasks A.1		115	\$17,080	18	\$4,500	\$800	\$22,380
Task A.2: Identify Broad-Scale Ground Shaking Hazard							
Subtask A.2-1: Prepare Map of 2014 NSHM Regional-Scale Hazard Corresponding to 2% in 50 Years (the 2,475-yr Return Period) Relative to Critical Water Supply Facilities in NOC		27	\$3,515	0	\$0	\$0	\$3,515
Total Tasks A.2		27	\$3,515	0	\$0	\$0	\$3,515
Task A.3: Identify Potential Primary Fault Rupture Hazard Areas							
Subtask A.3-1: Prepare Maps of California AP Zones Relative to Critical Water Supply Facilities in NOC (on Appropriate Base Maps)		27	\$3,010	0	\$0	\$0	\$3,010
Subtask A.3-2: Estimate Primary Fault Offsets Using Common Empirical Magnitude-Area-Displacement Regressions		14	\$2,020	8	\$2,000	\$100	\$4,120
Total Task A.3		41	\$5,030	8	\$2,000	\$100	\$7,130
Task A.4: Identify Potential Secondary Earthquake Hazard Areas							
Subtask A.4-1: Prepare Maps of California Seismic Hazard (Liquefaction and Landslide) Zones Relative to Critical Water Supply Facilities in NOC (on Appropriate Base Maps)		30	\$3,435	0	\$0	\$0	\$3,435
Subtask A.4-2: Identify Generalized Areas of Potential Coseismic Uplift and Subsidence		36	\$4,680	8	\$2,000	\$200	\$6,880
Total Task A.4		66	\$8,115	8	\$2,000	\$200	\$10,315
Task A.5: Reporting and Presentations							
Subtask A.5-1: Prepare One Draft Technical Memorandum Summarizing the Findings of the "Part A. Seismic Hazard Assessment"		40	\$6,000	4	\$1,000	\$0	\$7,000
Subtask A.5-2: Prepare One Final Technical Memorandum Summarizing the Findings of the "Part A. Seismic Hazard Assessment"		36	\$5,360	0	\$0	\$0	\$5,360
Subtask A.5-3: Prepare and Participate in Four Presentations		96	\$16,400	20	\$5,000	\$500	\$21,900
Total Task A.5		172	\$27,760	24	\$6,000	\$500	\$34,260
Total Tasks A.1 through A.5							
		421	\$61,500	58	\$14,500	\$1,600	\$77,600

Optional Task A.O.1: Scenario-Specific Ground Shaking Hazard							
Subtask A.O.1-1: Selection of One Scenario Earthquake (MCE) for One Fault		7	\$1,090	0	\$0	\$0	\$1,090
Subtask A.O.1-2: Compute Ground Shaking at Two Spectral Periods for NOC Area for Scneario		25	\$3,640	0	\$0	\$0	\$3,640
Subtask A.O.1-3: Prepare Maps of Ground Shaking at Two Spectral Periods for NOC Area for Scenario		31	\$3,775	0	\$0	\$0	\$3,775
Total for One Run of Optional Task A.O.1		63	\$8,505	0	\$0	\$0	\$8,505
Optional Task A.O.2: Scenario-Specific Ground Deformation							
Subtask A.O.2-1: Selection of One Scenario Earthquake (MCE) for One Fault		14	\$2,380	0	\$0	\$0	\$2,380
Subtask A.O.2-2: Compute Regional (NOC Area) Ground Deformation for Scenario		36	\$5,760	0	\$0	\$0	\$5,760
Subtask A.O.2-3: Prepare Maps and Profiles of Ground Deformation for Scenario		36	\$4,185	0	\$0	\$0	\$4,185
Total for One Run of Optional Task A.O.2		86	\$12,325	0	\$0	\$0	\$12,325
Total Tasks A.O.1 and A.O.2		149	\$20,830	0	\$0	\$0	\$20,830

Optional Task B.1: Workshops							
Subtask B.1-1: Coordination of Two Workshops		56	\$9,700	8	\$2,000	\$0	\$11,700
Subtask B.1-2: Conduct Workshop 1		62	\$10,550	64	\$16,500	\$1,000	\$28,050
Subtask B.1-3: Conduct Workshop 2		62	\$10,550	64	\$16,500	\$1,000	\$28,050
Total Tasks B.1		180	\$30,800	136	\$35,000	\$2,000	\$67,800
Optional Task B.2: Documentation of Workshops							
Subtask B.2-1: Prepare One Draft Technical Memorandum Documenting Workshop 1		31	\$4,725	16	\$3,500	\$0	\$8,225
Subtask B.2-2: Prepare One Final Technical Memorandum Documenting Workshop 1		15	\$2,075	0	\$0	\$0	\$2,075
Subtask B.2-3: Prepare One Draft Technical Memorandum Documenting Workshop 2		31	\$4,725	16	\$3,500	\$0	\$8,225
Subtask B.2-3: Prepare One Final Technical Memorandum Documenting Workshop 2		15	\$2,075	0	\$0	\$0	\$2,075
Total Tasks B.2		92	\$13,600	32	\$7,000	\$0	\$20,600
Total Tasks B.1 through B.2		272	\$44,400	168	\$42,000	\$2,000	\$88,400

Notes:
1. Hours and costs for Lisa Grant not included in Subconsultant costs based on understanding that she will not charge fees for this project.
2. Subconsultant reimbursable expenses included in subconsultant total costs.

Summary

Total - Tasks A.1 Through A.5	\$77,600
Total - Optional Tasks B.1 and B.2	\$88,400
Total - Tasks A.1 through A.5 and Optional Tasks B.1 and B.2	\$166,000



GeoPentech, Inc.

2014 SCHEDULE OF FEES

<i>Position</i>	<i>Rate (\$/hr)</i>
Principal	240
Associate	210
Senior Project Professional	175
Project Professional	150
Assistant Project Professional	125
Senior Staff Professional	115
Staff Professional	110
Technician	95
Administrative Support	75

Legal and Expert Witness Fees

Time for staff assigned as expert witness at court trials, mediation, arbitration hearings, and depositions will be charged at \$350/hour.

Subcontracts, Equipment Rental and Document Reproduction

The costs of outside services subcontracted by GeoPentech to others such as drilling subcontractors, laboratory testing, equipment rentals, consultants, document reproduction will be charged at cost plus 10%.

Mileage

The mileage charge for personal autos will be at the current IRS reimbursement rate.



GeoPentech ODC CONTRACT FEE SCHEDULE

<u>Item Description</u>	<u>Billing Unit</u>	<u>Amount</u>
Mileage charge – Automobiles ¹	Miles	IRS rate
Truck Usage	\$ per day	\$100
Subcontractor Services		Cost
Outside Service/Rental Expenses (including reproduction, plots, postage, handling and delivery service, messenger services, transportation, lodging and other expenses) ¹		Cost
Refraction Geophysical Equipment	\$ per day	\$1,000
Downhole Geophysical Equipment (1-inch + diameter cased hole)	\$ per day	\$1,000
Rental of specialized geophysical equipment (ground penetrating radar, field resistivity, swept frequency hammer for reflection seismic, and other)	\$ per day	Cost
Vibration Monitoring Geophones and readout	\$ per day	\$600
Generator	\$ per day	\$50
Ground Water Test Equipment:		
Laptop	\$ per day	\$75
Instrumentation NW DL-2 Data Logger	\$ per day	\$75
15 PSI Transducer	\$ per day	\$75
Water Level Indicator	\$ per day	\$25
Slug test Kit	\$ per day	\$15
Slope Inclinator	\$ per day	\$200



Professional Subconsultant Hourly Rates

Ronald T. Eguchi, (ImageCat, Inc.) – \$200/hr.
Douglas G. Honegger, (D.G. Honegger Consulting) – \$200/hr.
Tom O'Rourke, (Cornell University) – \$275/hr.
Tom Rockwell, (San Diego State University) – \$250/hr.
Lisa Grant, (UC Irvine) – No Fees*

*Lisa Grant will not charge consulting fees to this project unless further involvement beyond the current scope of work is requested and it meets her schedule requirements.



DISCUSSION ITEM

March 2, 2015

**TO: Planning & Operations Committee
(Directors Osborne, Barbre, Hinman)**

FROM: Robert Hunter, General Manager

Staff Contact: Joe Berg, Melissa Baum-Haley

SUBJECT: Presentation regarding Smart Timer Program water savings evaluation

STAFF RECOMMENDATION

Staff recommends the Planning & Operations Committee receive and file the staff report.

COMMITTEE RECOMMENDATION

Committee recommends (To be determined at Committee Meeting)

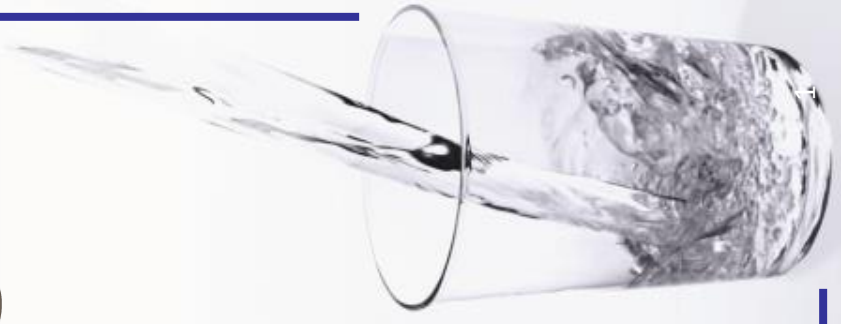
SUMMARY

Staff will provide a Power Point presentation summarizing the results of a recent Smart Timer Program process and water savings impact evaluation. This presentation will compare the current results to past smart timer evaluations as well plans for future program evaluations.

Budgeted (Y/N):	Budgeted amount:	Core ____	Choice ____
Action item amount:		Line item:	
Fiscal Impact (explain if unbudgeted):			

Smart Timer Rebate Program Water Savings Evaluation Results

March 2, 2015
Water Use Efficiency
Municipal Water District of Orange County



Why we Perform Program Evaluations

- **Impact Evaluation**
 - Assess the actual water saving as a result of the program
 - Evaluate the cost effectiveness of the program
 - Potential for future savings
 - Participant satisfaction and water savings perception
- **Process Evaluation**
 - Program participation trends
 - Adaptive management approach to program administration
- **Grand funding deliverable**



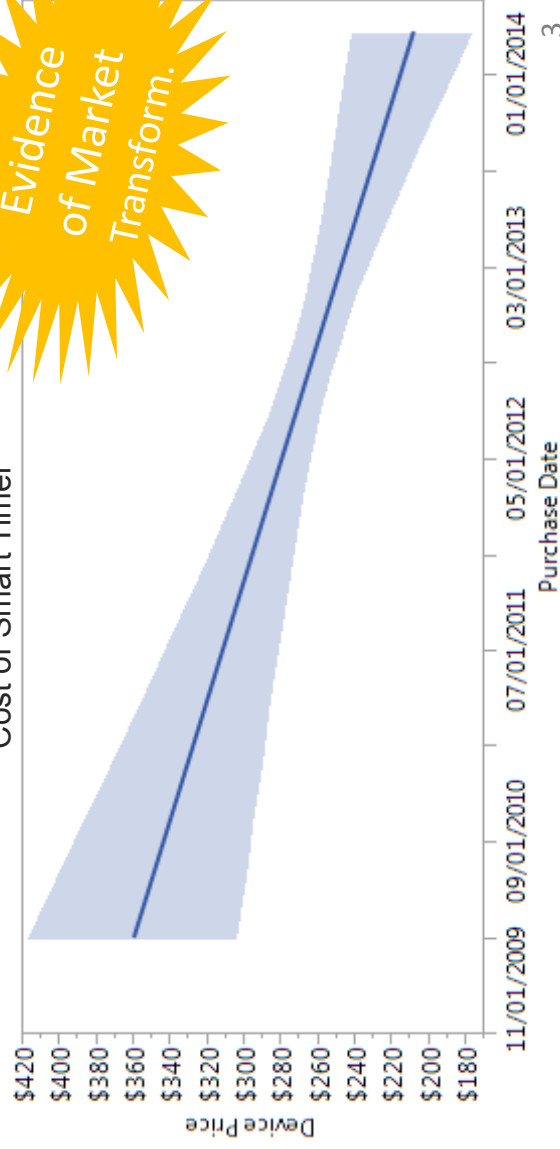
Smart Timer Program Funding

- Commercial Rebate Level (per station)
 - \$25 to \$35 from Metropolitan Water District
- Residential Rebate Level (per device)
 - \$80 from Metropolitan Water District
 - \$75 from Retail Agency Contribution
 - \$155 to \$270 from Bureau of Reclamation Grant

Note: Rebates are only provided UP TO DEVICE COST and are confirmed by invoices



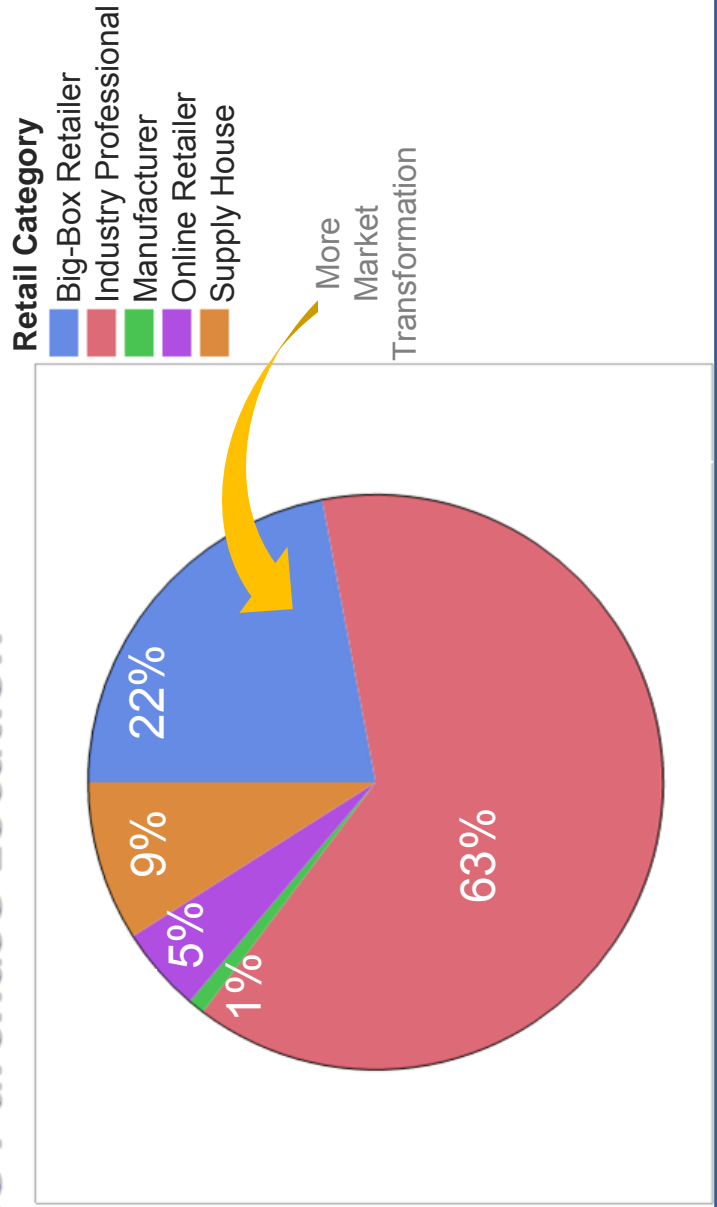
Cost of Smart Timer



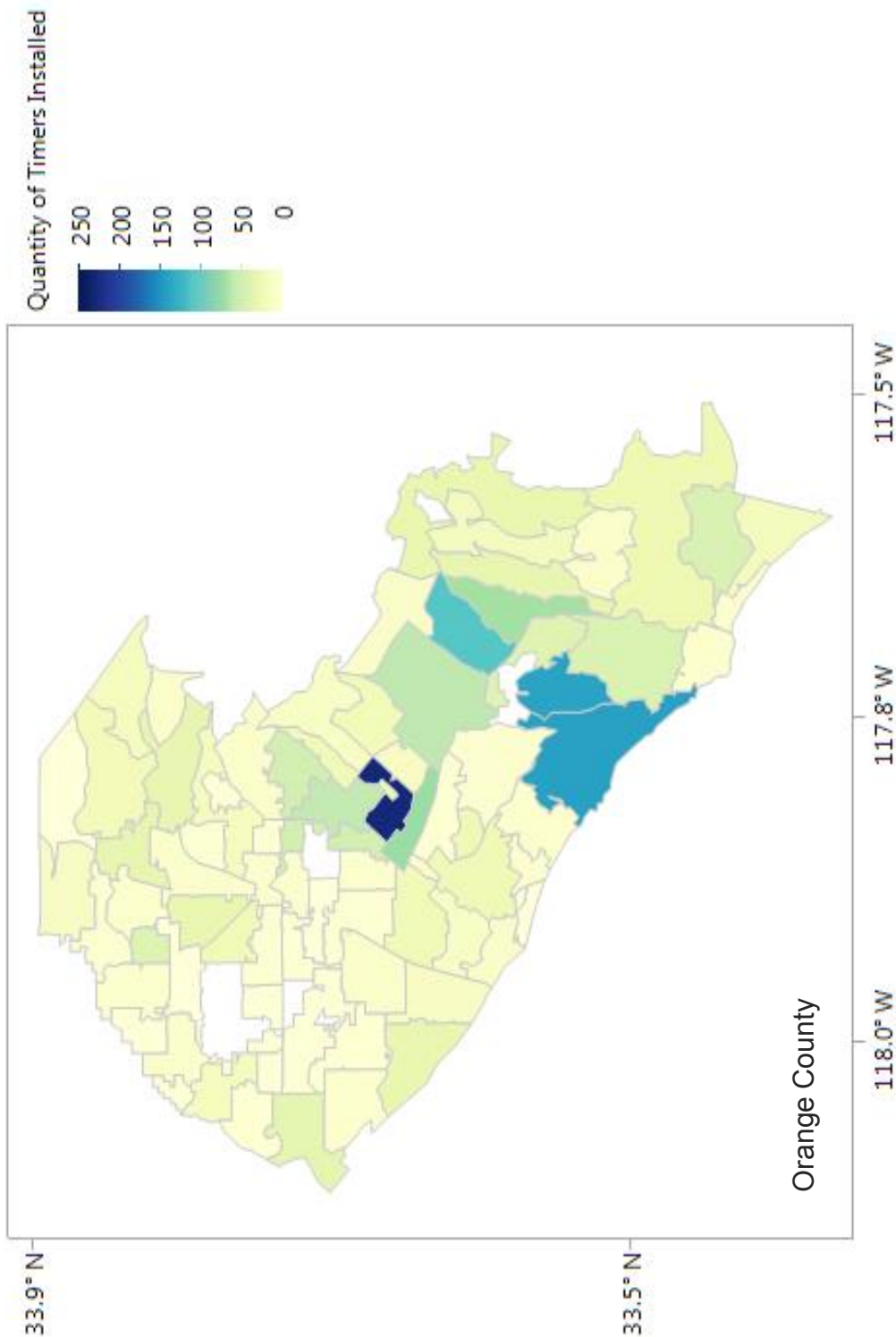
Smart Timer Program Activity

- Current Evaluation Program Term
 - September 2011 thru December 2014
- Total Smart Timer Installations
 - Residential = 2,072 (20% insp. rate)
 - Commercial = 1,176 (8.5% Insp. rate)
- Device Purchase Location

Exceeded
goals by
over 400%



Geographic Representation of Program Activity



Water Savings Trends

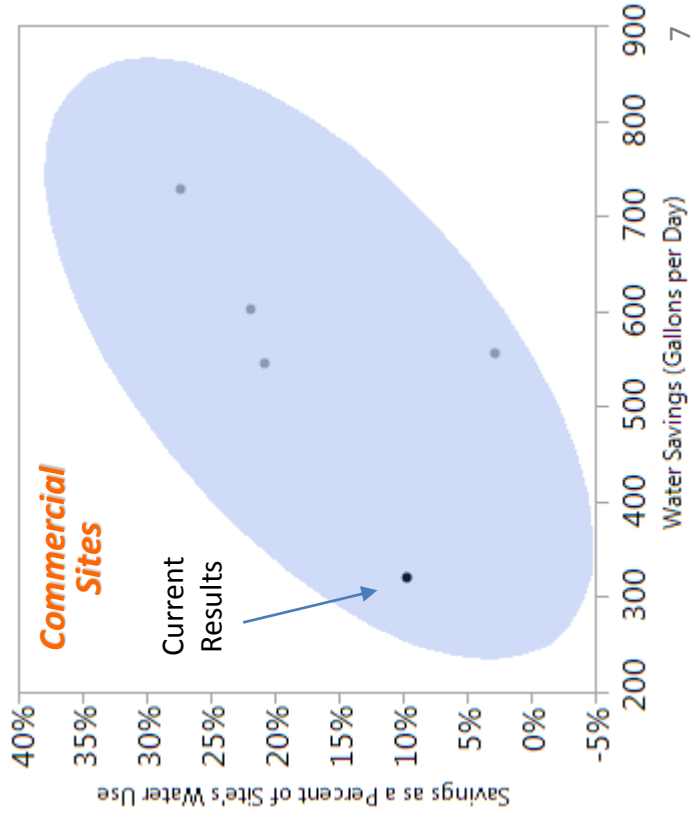
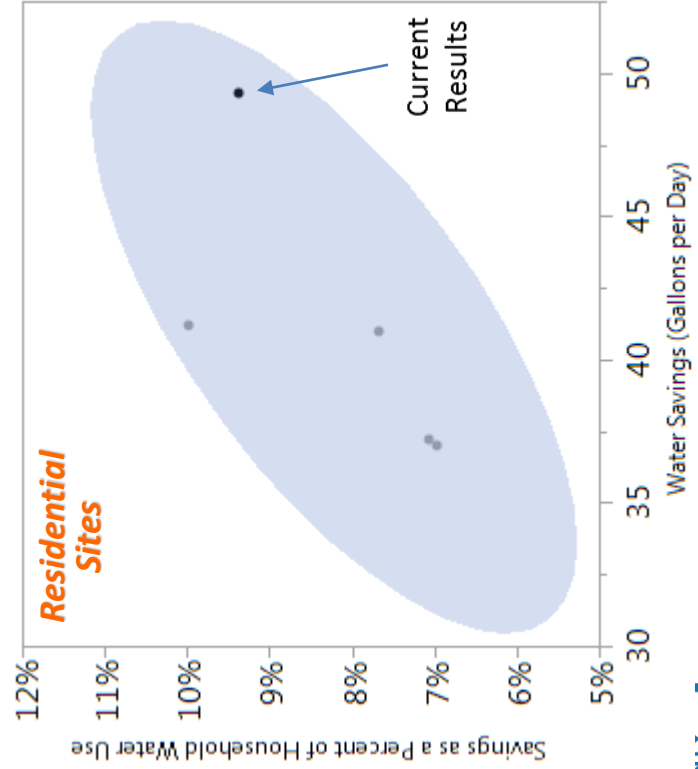
- Participant Perception
 - 66% felt that the device had a positive influence on their water bill (saved them money/water)
 - Noteworthy correlations
 - Ease of use with perception of functionality
 - Ease of installation with perception of functionality
 - Device functionality with perception of water savings
- Actual Water Use Impact:

Water Use Category	Overall	Residential	Commercial
Decreased Use (-)	45%	47%	44%
No Significant Deviation	37%	36%	38%
Increased Use (+)	18%	17%	18%

Evaluation Results

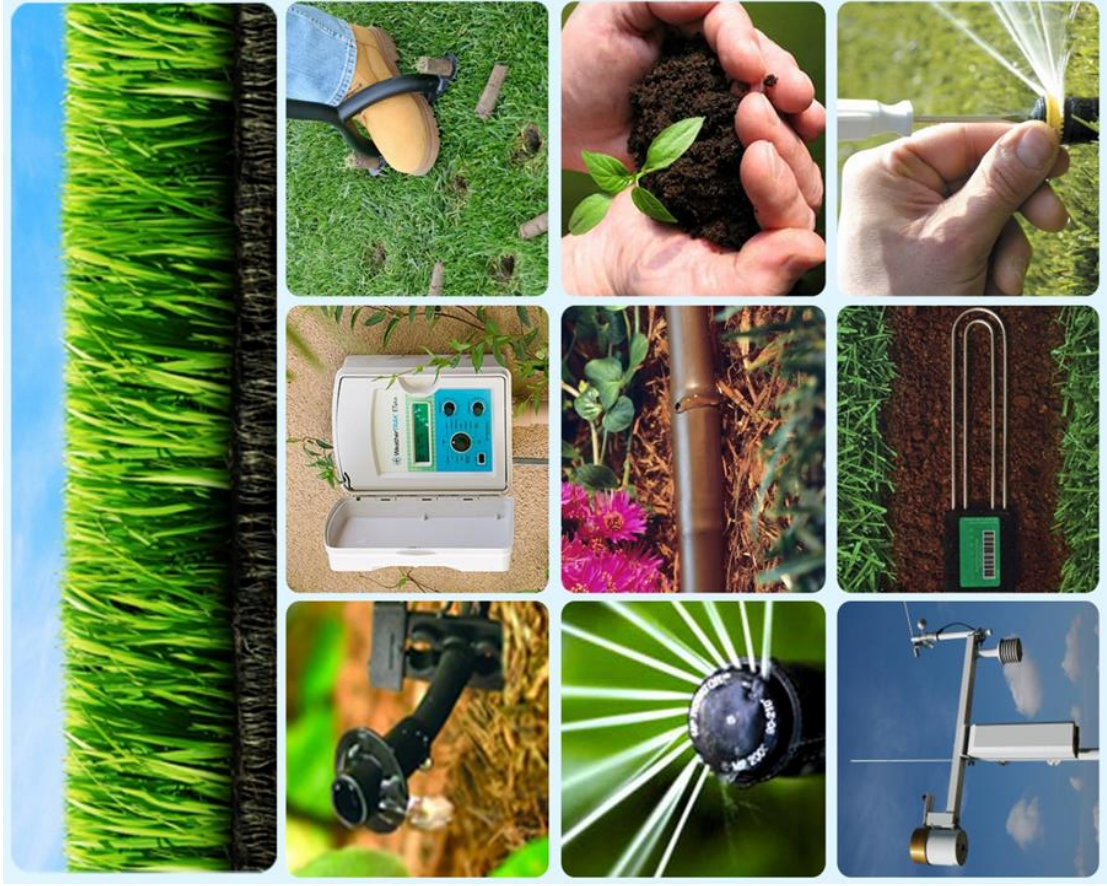
- Net Water Savings:

	Sector	
	Residential	Commercial
Normalized Mean Savings	59 GPD	320 GPD
Mean Savings	10.6%	9.8%
Statistically Significant	yes	yes



Future Evaluations

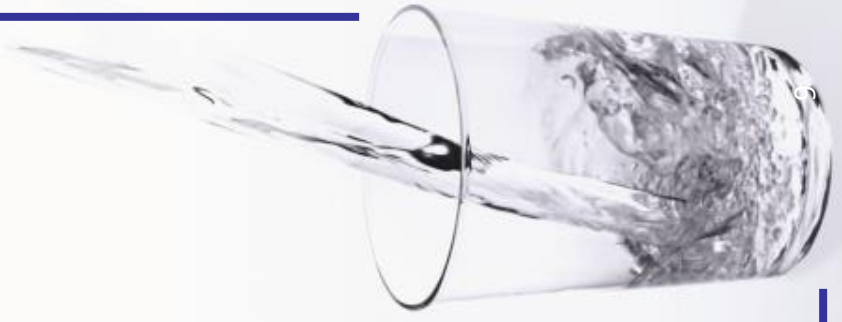
- **In Progress**
 - **Spray to Drip Pilot Program**
 - **Turf Removal Program**
 - **Device Retention Study**
- **Long Term**
 - **Savings Persistence Study**
 - **Flow Sensing Technology**
 - **Soil Moisture Sensors**
 - **Comprehensive Landscape Diminishing Return Study**



Questions?

Dr. Melissa Baum-Haley
Water Use Efficiency Programs Specialist
714-593-5016

mbaum-haley@mwdoc.com



Status of Ongoing MWDOC Reliability and Engineering and Planning Projects

February 24, 2015

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
Baker Treatment Plant or Expansion of Baker Water Treatment Plant	IRWD, MNWD, SMWD, ETWD Trabuco CWD		On line date is early 2016	MWDOC has been asked to help secure MET's concurrence on the quality of water being introduced into the South County Pipeline from the Baker Treatment Plant project. A number of discussions have been held with MET on this issue. MWDOC received a letter from MET dated February 18, 2015 that summarizes MET's position in a number of areas and indicates that MET has "no comments" with respect to the SCP Tie-in. The letter is attached to this report. Karl Seckel and Kevin Hostert participated in a shutdown meeting to plan for the March 2015 connection of the Baker Treatment Plant Pipeline to the South County Pipeline.
Doheny Desalination Project	MWDOC			<p>On Friday February 13, Karl Seckel, Heather Baez and MWDOC Director Susan Hinman in conjunction with South Coast WD Directors Bill Green and Rick Erkeneff hosted a Doheny Desal Tour. There were a total of 18 attendees, including:</p> <ul style="list-style-type: none"> • OC Supervisor Lisa Bartlett • Victor Cao, staff to Supervisor Bartlett • Duane Cave, MNWD Director • Renae Hinchey, GM of LBCWD • Chris Regan, AGM of LBCWD • Marvin Johnson, Commissioner for LBCWD

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				<ul style="list-style-type: none"> • Debbie Neev, Commissioner for LBCWD • Cheryl Kinsman, Commissioner for LBCWD and her son • Kathy Ward, Councilmember for San Clemente • Barbara Szemenyer, applicant for SJC Water Commissioner • Richard Hartl, SJC Water Commissioner • Dick Dietmeier, South Coast WD Director <p>Richard Bell participated in the Kick-Off meeting with South Coast WD and the Consultant Team from Chambers and Merkel to begin the baseline environmental monitoring work that will provide the baseline for future CEQA work. This is great news that this work is beginning.</p>
Poseidon Resources Ocean Desalination Project in Huntington Beach				<p>In January, the OCWD Board authorized their staff to enter into negotiations with Poseidon on the terms and conditions for the Huntington Beach Project. One meeting was held so far. Staff is to report back at their March Board meeting. OCWD is also establishing a Citizen's Advisory Committee on the Project.</p> <p>MWDOC is working on securing the ability to convey either groundwater or Poseidon water in the EOCF#2. Securing the ability to do so will open up a number of opportunities in OC.</p>
Orange County Water Reliability Study				<p>Karl Seckel and Richard Bell hosted the February Workgroup meeting for the OC Water Reliability Study following the Manager's meeting. The bulk of discussions were held regarding proposals obtained by MWDOC to update the</p>

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				<p>Seismic Assessment Mapping and Facility Vulnerability Review. MWDOC was successful in securing proposals from four firms to provide assistance in better understanding the risks to water facilities, particularly wells. Additional work is proposed as part of the OC Water Reliability Study. A report is included in the P&O Packet.</p> <p>IRWD provided a preliminary review of the economic and reliability issues associated with the Poseidon Project that was beneficial in generating quite a bit of discussion among the workgroup.</p>
Other Meetings/Work				
				<p>Karl Seckel and Joe Berg participated in the South Orange County IRWMP Management Group discussions on:</p> <ul style="list-style-type: none"> • Water supplies, including recycled supplies, stormwater capture and groundwater quality • Flood • Water Use Efficiency • Watershed Management • Water Quality <p>Follow-up discussions will occur with the workgroup in preparation for a March 12 meeting for the Executive Committee for all of South OC.</p>
				Richard Bell attended the San Juan Basin Authority meeting in

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				February where discussions continued on basin monitoring and management. Cathrene Glick reported on the status of the basin activities related to the Groundwater Management Plan.
				Karl Seckel and Harvey De La Torre met with Dan Ferons & Don Bunts from SMWD (SMWD missed the meeting due to being detained in a Regional Water Board meeting) and Paul Weghorst and Mark Tettemer from IRWD and the MET staff in charge of the Local Resources Program (LRP), James Bodnar and Ray Moktari to discuss how recycled projects, including seasonal storage reservoirs, might be better formulated in seeking funding under MET's LRP Program. The meeting was helpful in understanding how MET views the various components of recycled water systems.
				Karl Seckel and Kevin Hostert attended the February 9 meeting of the Center for Demographic Research Management Oversight Committee. The directors may be interested that the Center for Demographic Research is hosted in facilities owned by Cal State Fullerton. A new Dean is conducting work related to campus space and is considering relocating CDR to an alternate location. CDR would like to stay where they are and may request that support members participate in future discussions regarding the value and exposure brought to Cal State Fullerton by the work conducted by CDR. Stay tuned. CDR provided background information on the history of the County's Forecast and Analysis Center and how the services were transferred to CDR during the County's bankruptcy.

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				Keith Lyon participated in the discussions for the upcoming shutdown of the Orange County Feeder in the City of Fullerton for relocating a portion of the pipeline. The shutdown was pushed out into the April timeframe.
				Karl Seckel, Keith Lyon and Kevin Hostert participated in a shutdown planning meeting to test the ability of the City of Newport Beach to provide emergency water to Laguna Beach CWD. MET staff were involved as they will be required to shut down the lower portion of the Orange County Feeder at service connection CM-1 to simulate an outage and they will need to take their CM-1A meter totalization off-line to eliminate double billing for LBCWD during the test. The operational test will take several hours to conduct and is being targeted for March 10. The test will help to better understand future emergency operations options.
				Keith Lyon and Kevin Hostert are working with MET and the City of La Habra to test the shutoff valve at OC-45; La Habra is preparing to rebuild the flow control facility and needs to know if the MET valve will hold tight during the 6 month construction process.
				Karl Seckel met with Duane Cave, MNWD director and External Relations Manager for SDG&E. SDG&E has a \$475 million electrical reliability program they are now starting with the release of the Environmental Documents. They will be holding hearings in March in San Clemente and San Juan Capistrano and would like support from the water industry.

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				They are investing to provide multiple paths for electricity to be distributed in South OC compared to how it is organized today where the entire area flows through a single substation. Similar to the flow of water, having alternative delivery options is good for electrical reliability planning.
				Richard Bell attended the recent Independent Science Technical Advisory Panel (ISTAP) Meeting with the Coastal Commission, Concur (the meeting convener) and the Science Panel. This was the second workshop in Phase 2 to further discuss Seabed Infiltration Galleries (SIG's). At the meeting, the shoreline alternative was determined to be "not feasible" and will not be considered in further deliberations. The further offshore seabed option is still under consideration; an alternative construction methodology was discussed for this option. The ISTAP group will be preparing a final report on their findings.
				Karl Seckel, Kevin Hostert and Director Susan Hinman attended the OCWA Luncheon where Deven Upadhyay from MET spoke about the drought and the potential for MET to impose allocations later this year. Deven characterized the current drought as the 8 th year out of the past 9 years where water supplies and precipitation have been below the long term average with the exception of only one year. When asked about important "take aways" from the current situation we are in, Deven indicated the need to operate groundwater basins in Southern California differently than we have been operating them as over 1 MAF of water has been pulled out of the basins

Description	Lead Agency	Status % Complete	Scheduled Completion Date	Comments
				in recent years, leaving them in a less than desirable position at this time. Deven also noted the need for more recycling, indirect potable reuse and potable reuse. When pressed, he indicated that ocean desalination investments by MET beyond the LRP contributions may come up in the IRP update.
				Karl Seckel met with Anona Dutton from EKI, a consulting firm that works on Urban Water Management Plans, as MWDOC is preparing an RFP to prepare plans for MWDOC and a number of our agencies.
				Karl Seckel and Cathy Harris met with Mike Markus and John Kennedy to discuss building budget issues for preparation of MWDOC's Budget.



THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

February 18, 2015

Mr. Robert Hunter
General Manager
Municipal Water District of Orange County
P.O. Box 20895
Fountain Valley, CA 92728

Dear Mr. Hunter:

South County Pipeline Projects

This letter is in reference to the Municipal Water District of Orange County's (MWDOC's) projects on the South County Pipeline. Specifically, the two projects are the Baker Plant Tie-in to the South County Pipeline (SCP Tie-in), and a proposed new service connection referred to as SC-06.

For the SCP Tie-in project, MWDOC submitted plans and specifications as well as a surge analysis report. The Metropolitan Water District of Southern California (Metropolitan) has reviewed the project plans and specifications, and the surge analysis report, and we have no comments. Provided that MWDOC follows the submitted plans and specifications, and complies with the recommendations in the surge analysis report, Metropolitan is satisfied that the SCP Tie-in project will not cause damaging hydraulic transients to our facilities.

To date, MWDOC has submitted funds totaling \$95,200 for the SCP Tie-in project and Metropolitan has expended \$30,200. A shutdown of the South County Pipeline and an outage of Metropolitan's OC-88 and OC-88A service connections will be required when you are ready to make the tie-in. We understand from discussions with your staff that the pipeline shutdown will occur in March 2015, and that the shutdown will last approximately seven days. Metropolitan's only remaining involvement for the SCP Tie-in project will be coordination of activities related to the outage.

For the SC-06 project, Metropolitan requires that a surge analysis be performed to ensure that the new facility does not cause damaging surges to our system. Metropolitan will review the surge analyses on a reimbursable basis. Once the service connection outage and the surge analysis review are completed, Metropolitan will reconcile the costs for both projects and return any remaining funds to MWDOC.

If you have any questions, please contact Ms. Patricia Bonaparte at (213) 217-6661. If Ms. Bonaparte is not available, please call Mr. Cash Spradling at (213) 217-6504.

Mr. Robert Hunter

Page 2

February 18, 2015

Very truly yours,

A handwritten signature in black ink, appearing to read "James F. Green", followed by a long horizontal flourish.

James F. Green

Manager, Water System Operations

PLB/

O:\opsexec\OPSCON\MWDOC\SCP Ltr.docx

cc: Mr. Karl Seckel
kseckel@mwdoc.com

**Status of Ongoing WEROC Projects
February 2015**

Description	Comments
General Activities	<p>Kelly Hubbard has been asked to speak at the American Water Works Association 2015 Annual Conference and Exposition (ACE) in June at the Anaheim Convention Center. She has been asked to be a speaker at three different sessions on water utility coordination and response. The sessions are largely similar with slightly different target audiences. She is working with a group of water security and emergency managers to host her sessions and a series of sessions on emergency management at the conference. These sessions will be promoted to WEROC member agencies.</p> <p>Kelly was asked to tape a Cox OC Civic Connection segment in which she was interviewed by Lacy Kelly on water emergency preparedness and response coordination. It was taped on February 2 and is currently available online.</p> <p>Kelly attended the Independent Special Districts of Orange County (ISDOC) Executive Committee meeting to confirm her representation of ISDOC to the Operational Area Executive Board.</p> <p>Kelly assisted with check-in for the MWDOC Quarterly Policy Dinner featuring Dr. Lucy Jones.</p> <p>Kelly participated in the management staff retreat on February 6, 2015.</p> <p>Kelly, Karl Seckel, Cathy Harris and Katie Davanaugh coordinated the interview and hiring process for WEROC Coordinator position.</p> <p>Kelly went on the State Water Project Tour with Director McKenney on February 20th and 21st.</p> <p>Kelly has been working on the WEROC budget for Fiscal Year 2015-2016.</p>

Description	Comments
<p>Coordination with Member Agencies</p>	<p>Kelly attended a lunch meeting with Santa Margarita Water District's Director Gibson, Joyce Crosthwaite (Assistant to the General Manager), and Dan Ferons (General Manager). The lunch was requested by Director Gibson (new board member) to learn more about the WEROC program, what water utilities should do to be prepared and how he could support his own district's efforts.</p> <p>WEROC held its Quarterly Emergency Coordinator Meeting on February 3rd. The meeting included a great presentation by Sprint on their disaster response programs that are available to local government. Additionally, the group had good discussions in regards to a WEROC Radio System Assessment, WebEOC Forms review for the newest update, Member Agency section of In Case of Crisis, water utility Alert OC Live Drill, Orange County Intelligence Assessment Center Water System Assessment and the May disaster exercise for planning purposes.</p> <p>Kelly started to work with MWDOC Public Affairs staff and County Emergency Management staff for the planning of the Alert OC live drill. Because of the timeline (live drill is April 7th), political sensitivity and training needed, WEROC will be hosting 3 trainings, 3 coordination meetings, and a hotline at the County EOC for the actual drill. Materials for the exercise, training dates and drill information has been provided to the general managers, emergency coordinators and public affairs staff of the utilities, as well as the city staff with responsibility for Alert OC and emergency management. This is the first time the water utilities have been provided the opportunity to use the "test" slot for AlertOC. A water conservation message will be conveyed to registered participants.</p> <p>Kelly provided 12 member agency staff with a 2 hour training called "Bare Bones of Response." The training covered what is the bare minimum information that is needed from member agencies during emergencies and the various communication methods that can be utilized. Overall the message to the agencies was to keep their response concepts simple, as long as WEROC receives critical pieces of information. The training was well received and has been requested again.</p> <p>MESA Water District has been working with a consultant to update their emergency operations</p>

Description	Comments
	<p>plan and provide emergency response training. Kelly worked with MESA Water staff and the consultant to provide resources for the process and to provide review and comment on the draft plan.</p>
<p><i>Coordination with the County of Orange</i></p>	<p>Kelly attended the Urban Area Working Group (UAWG) Meeting February 11 at the County emergency operations center. UAWG is one of the approval bodies for the Urban Area Security Initiative grant funds. At the meeting Kelly requested more funding for emergency manager specific training and to allow the water and wastewater utility staff to participate in fire services training that the water utilities also conduct (trench rescue, confined space rescue, hazardous materials response, etc.) Kelly advised the group that the water and wastewater utilities train and staff their own rescue and response teams to provide greater likelihood of rescue during high risk operations, but would appreciate the opportunity to train with fire officials to build common understanding of processes and familiarity with one another's equipment. Battalion Chief Black, Orange County Fire Authority Emergency Coordinator, liked the idea of including the water utilities in the training and assured that he would open up OCFA assigned seats to water utilities.</p> <p>Kelly attended the Operational Area (OA) Executive Board Meeting on February 11th in Santa Ana as the voting representative of ISDOC. The meeting was attended by several members of the Grand Jury and a representative of the OC Vector Control District in addition to its voting representatives. Kelly provided input into the Operational Area Power Outage Annex to include lessons and planning concepts that have been developed by WEROC and the Cal WARN working group. This plan was approved at the meeting.</p>
<p><i>Coordination with Outside Agencies</i></p>	<p>Kelly participated in the California Office of Emergency Services (Cal OES) Southern Region Drought Conference Call. These conference calls are now once a month and new information has slowed considerably within Southern California as small storms and temporary measures have relieved pressure on the counties hardest hit by the drought.</p> <p>Kelly facilitated the February California Emergency Services Association (CESA) Southern</p>

Description	Comments
	<p>Chapter Board Meeting in Norwalk as the chapter President.</p> <p>Kelly participated in the Cal WARN State Steering Committee as Region 1 Chair. Cal WARN is largely working on several emergency response plans in coordination with the state in regards to water planning and response, as well as recruitment of water utilities to sign the agreement prior to a disaster occurring.</p> <p>The Public Water Agency Group (PWAG) is a group of small utilities in LA County that use agreements to share costs for selected common interest projects and issues. The PWAG agencies are familiar with WEROC, and would eventually would like a similar organization for their member agencies (recognizing that WEROC is decades in the making). They have hired a consultant to perform an assessment of where PWAG agencies are now with respect to emergency preparedness and mutual aid, and then develop a “roadmap” that identifies options, opportunities, constraints and general costs to plan and develop a PWAG mutual aid program. The report will include identification of desired program elements, prioritization of elements, a phased implementation schedule, preliminary budgets, and funding models. Kelly met with their consultant to provide guidance in how WEROC developed over time and what she considers to be essential elements for an effective program.</p> <p>The PAWG agencies include: Three Valleys Municipal Water District, South Montebello Irrigation District, La Puente Valley County Water District, Orchard Dale Water District, Pico Water District, Crescenta Valley Water District, San Gabriel County Water District, Newhall County Water District, Valley County Water District, Rowland Water District, Walnut Valley Water District, and Palmdale Water District.</p>
<p>WEROC Emergency Operations Center (EOC) Readiness</p>	<p>WEROC successfully participated in the MARS and Operational Area radio tests for February.</p> <p>Air conditioning maintenance and pest control were coordinated at the WEROC North EOC.</p> <p>UPDATE - Both EOC's still have significant construction onsite. The North EOC site has the IRWD Baker Raw Water Pump Station construction in process and the South EOC has a</p>

Description	Comments
	communications infrastructure construction project onsite for El Toro Water District. Both sites are still accessible and in working order, but because the North EOC is physically a smaller site, the South EOC will continue as the primary EOC at this time.

Status of Water Use Efficiency Projects

March 2015

Description	Lead Agency	Status % Complete	Scheduled Completion or Renewal Date	Comments
Smart Timer Rebate Program	MWDSC	Ongoing	September 2015	For January 2015, 8 smart timers were installed in the residential sector and 35 in the commercial sector. For program water savings and implementation information, please see MWDSC Water Use Efficiency Program Savings and Implementation Report.
Rotating Nozzles Rebate Program	MWDSC	Ongoing	Ongoing	For January 2015, 107 residential and 2,748 commercial rotating nozzles were installed in Orange County. For program savings and implementation information, please see MWDSC Water Use Efficiency Program Savings and Implementation Report.
Water Smart Landscape Program	MWDSC	Ongoing	November 2015	In December 2014, a total of 12,437 meters received monthly irrigation performance reports comparing actual water use to a landscape irrigation budget customized to each meter. For program savings and implementation information, please see MWDSC Water Use Efficiency Program Savings and Implementation Report.
SoCal Water\$mart Residential Indoor Rebate Program	MWDSC	Ongoing	Ongoing	In January 2015, 356 high efficiency clothes washers and 650 high efficiency toilets were installed through this program. For program savings and implementation information, please see MWDSC Water Use Efficiency Program Savings and Implementation Report.
SoCal Water\$mart Commercial Rebate Program	MWDSC	Ongoing	Ongoing	In January 2015, 537 high efficiency toilets were installed through this program.

Description	Lead Agency	Status % Complete	Scheduled Completion or Renewal Date	Comments
SoCal Water\$mart Commercial Rebate Program (cont.)				For program savings and implementation information, please see MWDOC Water Use Efficiency Program Savings and Implementation Report.
Industrial Process Water Use Reduction Program	MWDOC	90%	December 2015	A total of 41 Focused Surveys and 19 Comprehensive Surveys have been completed or are in progress. To date, 12 companies have signed Incentive Agreements. Updated discharger lists have been obtained, and outreach is continuing to sites with feasible water savings potential. As a result of this program, 346 AFY of water savings is being achieved.
MWDOC Conservation Meeting	MWDOC	On-going	Monthly	This month's meeting was held on February 5, 2015 and was hosted by the City of Santa Ana. The next meeting will be on March 5, 2015 at the City of Orange.
Metropolitan Conservation Meeting	MWDSC	On-going	Monthly	This month's meeting was held on February 19, 2015. The next meeting will be March 19, 2015 at Metropolitan.
Water Smart Hotel Program	MWDOC	85%	June 2015	MWDOC was awarded a Bureau of Reclamation grant, to be matched with Metropolitan funds, to conduct up to 30 commercial and landscape audits of hotels. Enhanced financial incentives will be provided to augment the current SoCal Water\$mart rebates. All grant funding for this program has all been reserved, and a wait list for has been created. In the event that any of the sites with reserved funding are unable to complete their projects, wait list sites would then become eligible on a first-come, first-served basis.
Turf Removal Program	MWDOC	On-going	Ongoing	In January 2015, 290 rebates were paid, representing 313,411 square feet of turf removed in Orange County. To date, the Turf Removal Program has removed approximately 3,512,681 square feet of turf.

Description	Lead Agency	Status % Complete	Scheduled Completion or Renewal Date	Comments
Turf Removal Program (cont.)				For program savings and implementation information, please see MWDOC Water Use Efficiency Program Savings and Implementation Report.
California Sprinkler Adjustment Notification System – Base Irrigation Schedule Calculator	MWDOC	5%	December 2015	<p>MWDOC was awarded another grant from the Bureau of Reclamation to develop the Base Irrigation Schedule Calculator in support of the California Sprinkler Adjustment Notification System (CSANS). This system will e-mail or “push” an irrigation index to assist property owners with making global irrigation scheduling adjustments. Participants will voluntarily register to receive this e-mail and can unsubscribe at any time.</p> <p>Staff is now in the process of preparing a Request for Proposals for the development of the Base Irrigation Schedule Calculator. The RFP should be complete by the end of February. Proposals will be due by the end of March, and staff anticipates a Board action in April.</p>
Public Spaces Program	MWDOC	20%	December 2015	<p>This program targets publicly-owned landscape properties located in the South Orange County IRWM Plan area and encourages the removal of non-functional turfgrass, the upgrade of antiquated irrigation timers, and the conversion of high-precipitation-rate fixed spray irrigation to low-precipitation-rate rotating nozzles and/or drip irrigation.</p> <p>To date, 10 cities, water districts, or other special districts (i.e., school districts) have applied for funding through this program, six cities have worked with MWDOC on completing their project funding calculation worksheet, and four complete project proposals have been received.</p>

Description	Lead Agency	Status % Complete	Scheduled Completion or Renewal Date	Comments
Home Certification Program	MWDOC	17%	July 2015	<p>This program provides single-family sites with indoor and outdoor audits to identify areas for water savings improvements and opportunities and offers rebates for the installation of residential water efficiency devices, including smart timers and high efficiency rotating nozzles.</p> <p>In January 2015, MWDOC received eleven (11) applications for the Home Certification Program. Fourteen (14) surveys were conducted, and survey results are pending.</p> <p>Through this program, Metropolitan offers, at no cost, the services of a certified landscape irrigation auditor who will survey and provide written recommendations for qualifying non-residential properties within Metropolitan's service area.</p> <p>To date, 124 sites in the MWDOC service area have contacted Metropolitan to request surveys.</p>
Landscape Irrigation Survey Program	MWDSC	Ongoing	June 2016	<p>This is a pilot program designed to test the efficacy of replacing conventional spray heads in shrub beds with low-volume, low-precipitation drip technology. Through a rebate program format, residential sites will be encouraged to convert their existing spray nozzles to drip.</p> <p>To date, 76 residential applications and 23 commercial applications have received a Notice to Proceed. Of these, 54 residential sites and 12 commercial sites have been completed.</p>
Spray to Drip Conversion Pilot Program	MWDOC	28%	April 2016	<p>This program will provide enhanced rebate incentives to commercial, industrial, and institutional sites and large-landscape properties (landscapes ≥ 1 acre).</p> <p>The program is scheduled to launch during the first Quarter of 2015.</p>
CII Performance-Based Water Use Efficiency Program	MWDOC	2%	December 2017	

Description	Lead Agency	Status % Complete	Scheduled Completion or Renewal Date	Comments
Landscape Training and Outreach	MWD OC & County Stormwater	Ongoing	Ongoing	<p>The Orange County Garden Friendly (OCGF) Pilot Program promotes the use of climate appropriate plants and water efficient irrigation practices, with the overall goals of reducing water runoff and improving outdoor water use efficiency. The OCGF Pilot Program is a collaborative effort of the Orange County Stormwater Program (OCSP) and the University of California Cooperative Extension (UCCE). Each partner plays a role in planning and implementing the Program.</p> <p>After the completion of the Pilot Program, the steering committee met to review the Program's successes and lessons learned. The OCGF program held two events during Fall 2014 (October 12th and October 18th), and four more events are scheduled for Spring 2015.</p>

Orange County

Water Use Efficiency Programs Savings and Implementation Report

Retrofits and Acre-Feet Water Savings for Program Activity

Program	Program Start Date	Retrofits Installed in	Month Indicated		Current Fiscal Year		Overall Program		
			Interventions	Water Savings	Interventions	Water Savings	Interventions	Annual Water Savings[4]	Cumulative Water Savings[4]
High Efficiency Clothes Washer Program	2001	January-15	356	0.82	3,615	35.09	100,342	2,772	17,618
Smart Timer Program - Irrigation Timers	2004	January-15	43	1.91	1,197	227.36	12,429	4,349	24,051
Rotating Nozzles Rebate Program	2007	January-15	2,855	0.95	32,719	583.88	405,121	2,127	8,534
SoCal WaterSmart Commercial Plumbing Fixture Rebate Program	2002	January-15	537	1.90	1,386	12.18	46,745	3,455	30,435
Water Smart Landscape Program [1]	1997	December-14	12,437	887.50	12,437	5,299.29	12,437	10,420	63,125
Industrial Process Water Use Reduction Program	2006	January-14	0	7.75	2	7.75	13.00	346	1,104
Turf Removal Program[3]	2010	January-15	313,411	3.65	1,882,705	527	3,512,681	492	1,459
High Efficiency Toilet (HET) Program	2005	January-15	650	2.30	5,725	142.05	37,905	1,401	8,770
Home Water Certification Program	2013	January-15	14	0.027	118	0.635	196	4,610	1,835
Synthetic Turf Rebate Program	2007		0	0	0	0	685,438	96	469
Ultra-Low-Flush-Toilet Programs [2]	1992		0	0	0	0	363,926	13,452	162,561
Home Water Surveys [2]	1995		0	0	0	0	11,867	160	1,708
Showerhead Replacements [2]	1991		0	0	0	0	270,604	1,667	19,083
Total Water Savings All Programs									
			907		1,939,904	6,836	5,459,704	40,740	338,919

[1] Water Smart Landscape Program participation is based on the number of water meters receiving monthly Irrigation Performance Reports.

[2] Cumulative Water Savings Program To Date totals are from a previous Water Use Efficiency Program Effort.

[3] Turf Removal Interventions are listed as square feet.

[4] Cumulative & annual water savings represents both active program savings and passive savings that continues to be realized due to plumbing code changes over time.

HIGH EFFICIENCY CLOTHES WASHERS INSTALLED BY AGENCY through MWDOC and Local Agency Conservation Programs

Agency	FY 01/02	FY 02/03	FY 03/04	FY 04/05	FY 05/06	FY 06/07	FY 07/08	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY13/14	FY14/15	Total	Current FY Water Savings Ac/Ft (Cumulative)	Cumulative Water Savings across all Fiscal Years
Brea	17	107	178	132	143	132	175	156	42	186	144	93	115	57	1,677	0.62	293.91
Buena Park	9	45	88	81	84	85	114	146	59	230	145	105	106	59	1,356	0.57	218.85
East Orange CWD RZ	3	8	20	20	11	18	22	17	3	23	10	10	8	6	179	0.06	32.92
El Toro WD	21	88	108	103	83	91	113	130	32	162	112	134	121	64	1,362	0.63	221.75
Fountain Valley	36	127	209	196	178	205	219	243	72	289	158	115	102	57	2,206	0.57	401.12
Garden Grove	39	173	278	243	243	238	304	332	101	481	236	190	162	80	3,100	0.78	546.55
Golden State WC	37	195	339	374	342	339	401	447	168	583	485	265	283	195	4,453	1.85	763.98
Huntington Beach	114	486	857	738	680	739	750	751	211	963	582	334	295	158	7,680	1.59	1,427.04
Irvine Ranch WD	159	626	1,087	1,093	1,445	1,972	2,052	1,844	1,394	2,621	2,170	1,763	1,664	1,067	20,957	10.60	3,432.83
La Habra	8	40	86	81	66	96	136	83	22	179	128	82	114	49	1,170	0.48	191.18
La Palma	3	5	13	21	18	33	35	51	25	76	46	34	25	15	400	0.14	64.87
Laguna Beach CWD	17	88	119	84	68	57	77	77	27	96	57	38	37	17	859	0.16	156.25
Mesa Water	24	117	228	240	212	239	249	246	73	232	176	114	86	40	2,276	0.39	431.48
Moulton Niguel WD	158	630	841	640	570	652	716	742	250	1,127	679	442	421	383	8,251	3.12	1,422.06
Newport Beach	17	144	343	277	243	243	270	259	57	197	142	116	92	52	2,454	0.53	470.55
Orange	58	247	304	358	330	366	365	403	111	349	262	218	163	86	3,620	0.84	673.21
Orange Park Acres	-	-	-	-	-	4	8	-	-	-	-	-	-	-	12	0.00	2.76
San Juan Capistrano	16	95	120	107	102	109	103	127	43	190	110	76	73	53	1,324	0.55	229.73
San Clemente	32	182	235	170	136	204	261	278	63	333	206	140	94	74	2,408	0.72	421.91
Santa Margarita WD	140	510	743	573	592	654	683	740	257	1,105	679	553	662	452	8,343	4.54	1,384.65
Seal Beach	13	28	57	39	46	47	46	57	7	81	51	31	29	17	549	0.16	95.88
Serrano WD	9	16	54	39	39	30	31	23	7	21	20	13	10	18	330	0.15	62.42
South Coast WD	35	138	165	97	103	107	130	148	43	183	112	89	79	41	1,470	0.39	254.41
Trabuco Canyon WD	10	63	76	58	44	69	60	62	28	82	62	30	45	31	720	0.30	124.91
Tustin	21	89	152	138	127	152	146	144	45	174	97	78	59	38	1,460	0.33	270.03
Westminster	37	159	235	196	186	213	171	233	74	329	208	121	82	60	2,304	0.62	413.19
Yorba Linda	36	214	342	355	333	288	350	367	117	394	273	181	167	89	3,506	0.91	645.51
MWDOC Totals	1,069	4,620	7,277	6,453	6,424	7,406	7,987	8,106	3,331	10,686	7,350	5,365	5,094	3,258	84,426	31.58	14,653.95

Anaheim	917	677	904	1,364	701	854	847	781	860	910	477	331	285	165	10,073	1.68	1,911.82
Fullerton	40	196	369	289	263	269	334	330	69	397	270	200	186	124	3,336	1.24	568.59
Santa Ana	15	69	188	269	244	236	235	257	87	355	190	163	131	68	2,507	0.59	484.05
Non-MWDOC Totals	972	942	1,461	1,922	1,208	1,359	1,416	1,368	1,016	1,662	937	694	602	357	15,916	3.51	2,964.46

Orange County Totals	2,041	5,562	8,738	8,375	7,632	8,765	9,403	9,474	4,347	12,348	8,287	6,059	5,696	3,615	100,342	35.09	17,618.41
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SMART TIMERS INSTALLED BY AGENCY

through MWDOC and Local Agency Conservation Programs

Agency	FY 08/09		FY 09/10		FY 10/11		FY 11/12		FY 12/13		FY 13/14		FY 14/15		Total Program		Cumulative Water Savings across all Fiscal Years
	Res	Comm	Res	Comm	Res	Comm	Res	Comm	Res	Comm	Res	Comm	Res	Comm	Res	Comm.	
Brea	3	9	0	0	2	0	8	0	9	8	4	0	35	5	72	71	344.80
Buena Park	3	1	0	0	0	0	4	19	3	0	0	0	3	10	13	30	64.86
East Orange CWD RZ	0	0	0	0	1	0	5	0	2	0	0	0	2	0	13	0	2.95
El Toro WD	0	25	2	18	5	5	26	2	7	2	11	0	4	5	69	326	1,747.48
Fountain Valley	1	0	0	6	2	2	8	2	3	2	4	0	5	6	43	23	91.87
Garden Grove	2	1	6	0	5	4	7	0	5	2	9	0	8	13	58	26	82.59
Golden State WC	1	2	9	9	22	7	4	13	3	9	49	9	25	30	125	132	415.15
Huntington Beach	13	1	6	27	6	36	15	4	18	33	20	35	13	0	136	160	547.65
Irvine Ranch WD	29	56	14	145	28	153	267	71	414	135	71	59	42	169	1,161	1,518	6,655.85
La Habra	0	0	0	21	0	0	3	0	4	7	2	0	3	7	20	36	114.42
La Palma	0	0	0	0	0	0	1	0	1	0	2	0	0	0	4	0	0.51
Laguna Beach CWD	2	0	2	14	4	1	109	2	76	2	71	0	3	0	301	19	123.18
Mesa Water	6	7	13	7	7	22	21	0	10	2	15	2	12	14	128	87	402.67
Moulton Niguel WD	21	23	17	162	36	60	179	31	51	74	40	45	30	77	499	554	1,915.38
Newport Beach	10	27	7	58	6	0	275	12	242	26	168	75	9	7	978	352	1,653.61
Orange	5	2	2	13	5	8	25	0	20	24	13	9	12	28	159	139	562.30
San Juan Capistrano	10	0	7	49	13	1	103	2	14	18	6	11	2	10	176	100	359.28
San Clemente	81	20	13	209	46	11	212	17	26	7	28	2	22	12	982	346	1,756.69
Santa Margarita WD	25	44	10	152	61	53	262	7	53	171	64	93	28	302	614	996	2,836.97
Santiago CWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Seal Beach	0	0	0	1	0	0	0	3	1	0	1	36	0	11	2	51	68.21
Serrano WD	0	0	11	0	4	0	3	0	1	0	0	0	0	0	19	0	4.66
South Coast WD	11	6	3	10	13	3	78	10	13	16	8	4	25	18	183	146	640.65
Trabuco Canyon WD	1	0	2	0	2	10	12	0	6	0	2	0	3	1	71	104	621.43
Tustin	7	9	10	14	10	0	11	0	8	4	9	1	11	14	70	49	174.39
Westminster	3	0	3	0	1	1	2	0	1	1	2	0	13	16	41	30	107.31
Yorba Linda	8	5	5	21	25	0	22	0	20	0	12	5	24	2	197	85	460.78
MWDOC Totals	242	238	142	949	289	374	1,671	185	1,017	583	571	402	339	732	6,134	5,380	21,755.63

Anaheim	9	59	5	46	12	11	23	60	19	10	9	26	4	52	124	413	1,660.07
Fullerton	2	2	2	39	9	33	22	51	9	29	8	0	34	3	108	157	495.54
Santa Ana	2	4	1	8	8	0	6	5	8	19	7	8	6	27	42	71	139.36
Non-MWDOC Totals	13	65	8	93	29	44	51	116	36	58	24	34	44	82	274	641	2,294.97
Orange County Totals	255	303	150	1,042	318	418	1,722	301	1,053	641	595	436	383	814	6,408	6,021	24,051

ROTATING NOZZLES INSTALLED BY AGENCY
through MWDOC and Local Agency Conservation Programs

Agency	FY 09/10				FY 10/11				FY 11/12				FY 12/13				FY 13/14				FY 14/15				Total Program				Cumulative Water Savings across all Fiscal Years
	Small		Large		Small		Large		Small		Large		Small		Large		Small		Large		Small		Large		Small		Large		
	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.	Res	Comm.	Comm.		
Brea	8	100	0	32	0	0	130	0	0	65	120	0	84	0	0	157	0	0	498	220	0	0	0	0	0	0	0	8.28	
Buena Park	0	0	2,535	29	0	0	32	0	0	65	0	0	53	0	0	188	0	0	404	75	2,535	0	0	0	0	0	0	449.10	
East Orange	0	0	0	0	0	0	340	0	0	55	0	0	30	0	0	221	0	0	751	0	0	0	0	0	0	0	8.38		
El Toro	145	2,874	890	174	0	0	357	76	0	23	6,281	0	56	3,288	0	1,741	8,684	0	2,584	21,493	890	0	0	0	0	0	377.19		
Fountain Valley	21	0	0	83	0	0	108	0	0	35	0	0	0	0	0	107	0	0	488	0	0	0	0	0	0	0	7.31		
Garden Grove	151	45	0	38	0	0	119	0	0	95	0	0	80	0	0	62	0	0	742	151	0	0	0	0	0	0	15.43		
Golden State	280	29	0	303	943	0	294	0	0	257	2,595	0	192	0	0	426	1,741	0	1,996	5,308	0	0	0	0	0	0	80.54		
Huntington Beach	39	3,420	305	203	625	0	458	0	0	270	0	0	120	0	0	745	0	0	2,250	4,909	2,681	0	0	0	0	0	723.89		
Irvine Ranch	1,034	54,441	1,479	2,411	2,861	0	1,715	4,255	0	25,018	1,014	0	11,010	4,257	0	1,208	55	0	44,600	79,426	2,004	0	0	0	0	0	2,474.76		
La Habra	0	273	0	0	0	0	33	90	0	0	0	0	15	0	0	109	338	0	181	1,236	900	0	0	0	0	0	215.56		
La Palma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0.24		
Laguna Beach	191	0	0	156	0	0	763	0	0	3,596	0	0	2,948	878	0	35	1,971	0	7,905	2,896	0	0	0	0	0	0	103.98		
Mesa Water	195	83	0	118	0	0	297	277	0	270	0	0	361	0	0	143	0	0	1,665	385	343	0	0	0	0	0	113.16		
Moulton Niguel	234	0	959	1,578	0	0	1,225	0	0	512	1,385	0	361	227	0	1,364	3,508	0	5,997	12,123	2,945	0	0	0	0	0	863.43		
Newport Beach	92	4,781	0	337	1,208	0	640	3,273	0	25,365	50	0	19,349	6,835	0	253	668	0	46,123	17,554	0	0	0	0	0	0	709.16		
Orange	129	0	0	135	30	0	343	0	0	264	0	0	245	120	0	227	668	0	2,462	981	0	0	0	0	0	0	50.38		
San Clemente	729	1,299	0	2,612	851	0	4,266	117	1,343	631	172	0	415	5,074	0	252	0	0	9,489	7,538	1,343	0	0	0	0	0	359.13		
San Juan Capistrano	656	5,709	0	1,452	0	0	949	0	0	684	30	0	370	0	0	290	732	0	4,905	8,131	0	0	0	0	0	0	229.66		
Santa Margarita	1,731	937	611	3,959	3,566	0	4,817	0	0	983	0	0	389	0	0	1,053	1,513	0	14,176	6,084	611	0	0	0	0	0	395.68		
Seal Beach	0	291	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	155	291	0	0	0	0	0	0	8.74		
Serrano	1,498	0	0	364	0	0	58	0	0	190	0	0	105	0	0	41	0	0	2,374	0	0	0	0	0	0	0	42.95		
South Coast	0	0	0	318	1,772	0	688	359	0	435	0	0	70	0	0	706	1,155	0	2,406	3,419	0	0	0	0	0	0	67.76		
Trabuco Canyon	1,357	791	0	0	0	0	379	0	0	34	0	0	0	0	0	56	0	0	1,956	791	0	0	0	0	0	0	51.76		
Tustin	314	0	0	512	0	0	476	1,013	0	378	0	0	329	0	0	278	0	0	2,859	1,013	0	0	0	0	0	0	54.42		
Westminster	80	0	0	0	0	0	26	0	0	15	0	0	0	0	0	54	0	0	286	0	0	0	0	0	0	0	4.97		
Yorba Linda	371	3,256	0	529	0	0	559	0	0	730	0	0	40	990	0	638	0	0	3,870	4,359	500	0	0	0	0	0	241.24		
MWDOC Totals	9,255	78,329	6,779	15,343	11,856	0	19,072	9,460	1,343	59,970	11,647	0	36,622	21,669	0	10,394	21,033	0	161,132	178,383	14,752	0	0	0	0	0	7,657.09		

Anaheim	273	164	105	372	382	0	742	38,554	0	459	813	0	338	0	0	463	0	0	3,044	39,913	105	0	0	0	0	0	0	0	0	540.13
Fullerton	48	0	1,484	416	0	0	409	0	0	119	0	0	107	0	0	519	0	0	2,159	64	1,484	0	0	0	0	0	0	0	0	291.46
Santa Ana	48	572	0	53	0	0	22	65	0	99	0	0	86	2,533	0	310	0	0	859	3,226	0	0	0	0	0	0	0	0	0	45.36
Non-MWDOC Totals	369	736	1,589	841	382	0	1,173	38,619	0	677	813	0	531	2,533	0	1,292	0	0	6,062	43,203	1,589	0	0	0	0	0	0	0	0	876.96
Orange County Totals	9,624	79,065	8,368	16,184	12,238	0	20,245	48,079	1,343	60,647	12,460	0	37,153	24,202	0	11,686	21,033	0	167,194	221,586	16,341	0	0	0	0	0	0	0	0	8,534.04

SOCAL WATER\$MART COMMERCIAL PLUMBING FIXTURES REBATE PROGRAM^[1]

INSTALLED BY AGENCY

through MWDOC and Local Agency Conservation Programs

Agency	FY 02/03	FY 03/04	FY 04/05	FY 05/06	FY 06/07	FY 07/08	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	Totals	Cumulative Water Savings across all Fiscal Years
Brea	51	0	22	52	2	27	113	24	4	1	234	0	2	532	300
Buena Park	83	28	55	64	65	153	432	122	379	290	5	23	53	1,762	797
East Orange CWD RZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
El Toro WD	23	73	42	5	2	0	92	143	1	137	0	212	6	759	452
Fountain Valley	94	2	59	35	63	17	35	0	2	314	0	0	1	623	463
Garden Grove	199	51	297	34	136	5	298	130	22	0	4	1	0	1,198	1,171
Golden State WC	197	34	232	80	531	46	414	55	68	135	0	1	0	1,804	1,522
Huntington Beach	191	73	185	82	209	48	104	126	96	156	104	144	3	1,526	1,213
Irvin Ranch WD	1,085	87	325	1,044	429	121	789	2,708	1,002	646	1,090	451	118	10,201	5,156
La Habra	37	52	45	60	16	191	75	53	4	0	0	0	0	543	429
La Palma	0	0	0	5	0	0	140	21	0	0	0	0	0	166	65
Laguna Beach CWD	30	2	18	9	12	20	137	189	0	0	0	27	0	446	250
Mesa Water	155	22	130	241	141	141	543	219	669	41	6	0	79	2,811	1,622
Moulton Niguel WD	74	65	172	3	0	9	69	151	6	0	0	0	0	580	659
Newport Beach	230	9	77	24	94	98	27	245	425	35	0	0	535	1,803	1,007
Orange	144	22	553	127	88	18	374	67	1	73	1	271	0	1,823	1,400
San Juan Capistrano	34	21	181	0	6	2	1	1	0	0	0	14	0	260	337
San Clemente	36	5	95	40	173	2	18	43	0	19	0	0	1	432	318
Santa Margarita WD	16	3	56	0	0	6	23	11	0	0	0	0	2	117	166
Santiago CWD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seal Beach	34	44	40	61	45	1	2	124	0	0	0	0	0	354	346
Serrano WD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Coast WD	31	8	54	8	4	9	114	56	422	84	148	0	4	942	356
Triabuco Canyon WD	1	0	6	0	0	0	4	0	0	0	0	0	0	11	13
Tustin	114	16	82	14	7	115	145	25	230	0	0	0	75	832	647
Westminster	109	32	153	57	104	40	161	16	63	35	1	28	0	815	814
Yorba Linda	36	12	42	4	118	10	24	8	30	0	1	0	0	285	447
MWDOC Totals	3,004	661	2,921	2,049	2,245	1,079	4,134	4,537	3,424	1,966	1,594	1,172	879	30,625	19,951
Anaheim	400	947	362	1,113	780	766	3,298	582	64	48	165	342	454	10,363	5,456
Fullerton	41	138	270	91	96	133	579	29	4	0	94	0	53	1,556	1,277
Santa Ana	153	589	227	624	373	493	815	728	39	12	16	17	0	4,201	3,750
Non-MWDOC Totals	594	1,674	859	1,828	1,249	1,392	4,692	1,339	107	60	275	359	507	16,120	10,484
Orange County Totals	3,598	2,335	3,780	3,877	3,494	2,471	8,826	5,876	3,531	2,026	1,869	1,531	1,386	46,745	30,435

[1] Retrofit devices include ULF Toilets and Urinals, High Efficiency Toilets and Urinals, Zero Water Urinals, High Efficiency Clothes Washers, Cooling Tower Conductivity Controllers, Ph Cooling Tower Conductivity Controllers, Flush Valve Retrofit Kits, Pre-rinse Spray heads, Hospital X-Ray Processor Recirculating Systems, Steam Sterilizers, Food Steamers, Water Pressurized Brooms, Laminar Flow Restrictors, and Ice Making Machines.

Water Smart Landscape Program

Total Number of Meters
in Program by Agency

Agency	FY 05-06	FY 06-07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	FY 11-12	FY 12/13	FY 13/14	FY 14/15	Overall Water Savings To Date (AF)
Brea	0	0	0	0	0	0	22	22	22	22	48.67
Buena Park	0	0	0	0	17	103	101	101	101	101	390.62
East Orange CWD RZ	0	0	0	0	0	0	0	0	0	0	0.00
El Toro WD	109	227	352	384	371	820	810	812	812	812	4,277.49
Fountain Valley	0	0	0	0	0	0	0	0	0	0	0.00
Garden Grove	0	0	0	0	0	0	0	0	0	0	0.00
Golden State WC	0	0	14	34	32	34	32	32	32	32	177.76
Huntington Beach	0	0	0	0	31	33	31	31	31	31	126.31
Irvine Ranch WD	638	646	708	1,008	6,297	6,347	6,368	6,795	6,797	6,759	33,474.72
Laguna Beach CWD	0	0	0	57	141	143	141	124	124	124	644.59
La Habra	0	0	0	23	22	24	22	22	22	22	121.03
La Palma	0	0	0	0	0	0	0	0	0	0	0.00
Mesa Water	170	138	165	286	285	288	450	504	511	511	2,577.14
Moulton Niguel WD	57	113	180	473	571	595	643	640	675	675	3,638.33
Newport Beach	27	23	58	142	171	191	226	262	300	300	1,287.11
Orange	0	0	0	0	0	0	0	0	0	0	0.00
San Clemente	165	204	227	233	247	271	269	269	299	342	2,077.84
San Juan Capistrano	0	0	0	0	0	0	0	0	0	0	0.00
Santa Margarita WD	619	618	945	1,571	1,666	1,746	1,962	1,956	2,274	2,274	12,513.64
Seal Beach	0	0	0	0	0	0	0	0	0	0	0.00
Serrano WD	0	0	0	0	0	0	0	0	0	0	0.00
South Coast WD	0	0	62	117	108	110	118	118	118	164	712.88
Trabuco Canyon WD	0	0	12	49	48	62	60	60	60	60	307.70
Tustin	0	0	0	0	0	0	0	0	0	0	0.00
Westminster	0	0	10	18	18	20	18	18	18	18	103.61
Yorba Linda WD	0	0	0	0	0	0	0	0	0	0	0.00
MWDOC Totals	1,785	1,969	2,733	4,395	10,025	10,787	11,273	11,766	12,196	12,247	62,479.4
Anaheim	0	0	0	0	142	146	144	190	190	190	645.94
Fullerton	0	0	0	0	0	0	0	0	0	0	0.00
Santa Ana	0	0	0	0	0	0	0	0	0	0	0.00
Non-MWDOC Totals	0	0	0	0	142	146	144	190	190	190	645.94
Orange Co. Totals	1,785	1,969	2,733	4,395	10,167	10,933	11,417	11,956	12,386	12,437	63,125.38

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INDUSTRIAL PROCESS WATER USE REDUCTION PROGRAM

Number of Process Changes by Agency

Agency	FY 07/08	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	Overall Program Interventions	Annual Water Savings[1]	Cumulative Water Savings across all Fiscal Years[1]
Brea	0	0	0	0	0	0	0	0	0	0	0
Buena Park	0	1	0	0	0	0	0	0	1	54	329
East Orange	0	0	0	0	0	0	0	0	0	0	0
El Toro	0	0	0	0	0	0	0	0	0	0	0
Fountain Valley	0	0	0	0	0	0	0	0	0	0	0
Garden Grove	0	0	0	0	0	0	0	0	0	0	0
Golden State	1	0	0	0	0	0	0	0	1	3	20
Huntington Beach	0	0	0	0	0	2	0	1	3	127	150
Irvine Ranch	0	0	2	1	1	1	1	0	6	98	301
La Habra	0	0	0	0	0	0	0	0	0	0	0
La Palma	0	0	0	0	0	0	0	0	0	0	0
Laguna Beach	0	0	0	0	0	0	0	0	0	0	0
Mesa Water	0	0	0	0	0	0	0	0	0	0	0
Moulton Niguel	0	0	0	0	0	0	0	0	0	0	0
Newport Beach	0	0	0	0	0	0	0	1	1	21	4
Orange	1	0	0	0	0	0	0	0	1	43	301
San Juan Capistrano	0	0	0	0	0	0	0	0	0	0	0
San Clemente	0	0	0	0	0	0	0	0	0	0	0
Santa Margarita	0	0	0	0	0	0	0	0	0	0	0
Seal Beach	0	0	0	0	0	0	0	0	0	0	0
Serrano	0	0	0	0	0	0	0	0	0	0	0
South Coast	0	0	0	0	0	0	0	0	0	0	0
Trabuco Canyon	0	0	0	0	0	0	0	0	0	0	0
Tustin	0	0	0	0	0	0	0	0	0	0	0
Westminster	0	0	0	0	0	0	0	0	0	0	0
Yorba Linda	0	0	0	0	0	0	0	0	0	0	0
MWDOC Totals	2	1	2	1	1	3	1	2	13	346	1104

[1] Acre feet of savings determined during a one year monitoring period.

If monitoring data is not available, the savings estimated in agreement is used.

TURF REMOVAL BY AGENCY^[1]

through MWD OC and Local Agency Conservation Programs

Agency	FY 10/11		FY 11/12		FY 12/13		FY 13/14		FY 14/15		Total Program		Cumulative Water Savings across all Fiscal Years
	Res	Comm.	Res	Comm.	Res	Comm.	Res	Comm.	Res	Comm.	Res	Comm.	
Brea	0	0	3,397	9,466	0	0	5,697	0	22,920	10,010	39,619	19,476	24.88
Buena Park	0	0	0	0	0	0	0	0	0	0	0	0	-
East Orange	0	0	0	0	0	0	1,964	0	7,788	0	9,752	0	3.01
El Toro	0	0	4,723	0	4,680	72,718	4,582	0	8,288	2,975	22,273	75,693	51.73
Fountain Valley	0	0	1,300	0	682	7,524	4,252	0	17,485	0	23,719	7,524	12.19
Garden Grove	0	46,177	14,013	0	4,534	0	8,274	0	8,195	15,503	35,016	61,680	61.25
Golden State	0	0	42,593	30,973	31,813	3,200	32,725	8,424	51,688	34,109	158,819	76,706	112.41
Huntington Beach	801	3,651	27,630	48,838	9,219	12,437	20,642	0	63,611	37,650	121,903	102,576	106.41
Irvine Ranch	5,423	12,794	6,450	1,666	32,884	32,384	36,584	76,400	113,213	67,268	194,554	190,512	155.52
La Habra	0	7,775	0	8,262	0	0	0	0	4,186	0	4,186	16,037	13.49
La Palma	0	0	0	0	0	0	0	0	1,981	0	1,981	0	0.55
Laguna Beach	978	0	2,533	0	2,664	1,712	4,586	226	6,819	1,189	17,580	3,127	9.31
Mesa Water	0	0	6,777	0	10,667	0	22,246	0	37,554	0	77,244	0	30.58
Moulton Niguel	956	16,139	4,483	26,927	11,538	84,123	14,739	40,741	108,064	551,682	139,780	719,612	297.94
Newport Beach	0	0	3,454	0	3,548	2,346	894	0	6,427	0	14,323	2,346	7.89
Orange	0	0	12,971	0	15,951	8,723	11,244	0	34,349	214,796	74,515	223,519	97.38
San Clemente	0	0	21,502	0	16,062	13,165	18,471	13,908	35,549	0	91,584	27,073	54.97
San Juan Capistrano	0	0	22,656	103,692	29,544	27,156	12,106	0	37,544	832	101,850	131,680	136.02
Santa Margarita	4,483	5,561	1,964	11,400	10,151	11,600	17,778	48,180	90,752	154,270	125,128	231,011	126.28
Seal Beach	0	0	0	0	3,611	0	0	0	4,791	189	8,402	189	3.42
Serrano	0	0	0	0	0	0	2,971	0	12,662	0	15,633	0	4.79
South Coast	0	16,324	6,806	0	9,429	4,395	15,162	116,719	30,575	10,772	61,972	148,210	93.18
Trabuco Canyon	0	0	272	0	1,542	22,440	2,651	0	4,916	0	9,381	22,440	16.11
Tustin	0	0	0	0	9,980	0	1,410	0	16,475	0	27,865	0	10.79
Westminster	0	0	0	0	0	0	0	0	2,667	736	2,667	736	0.95
Yorba Linda	11,349	0	0	0	0	0	0	0	39,523	12,702	50,872	12,702	24.16
MWD OC Totals	23,990	108,421	183,524	241,224	216,104	303,923	238,978	304,598	768,022	1,114,683	1,430,618	2,072,849	1,455.19

Orange	0	0	0	0	0	0	0	0	0	0	0	0	-
Anaheim	0	0	0	0	0	0	0	0	0	0	0	0	-
Ft. Merion	0	0	0	0	0	0	0	9,214	0	0	0	9,214	3.87
Santa Ana	0	0	0	0	0	0	0	0	0	0	0	0	-
Non-MWD OC Totals	0	0	0	0	0	0	0	9,214	0	0	0	9,214	3.87

Orange County Totals	23,990	108,421	183,524	241,224	216,104	303,923	238,978	313,812	768,022	1,114,683	1,430,618	2,082,063	1,459.06
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[1] Installed device numbers are listed as square feet

HIGH EFFICIENCY TOILETS (HETs) INSTALLED BY AGENCY

through MWDOC and Local Agency Conservation Programs

Agency	FY05-06	FY 06-07	FY 07-08	FY 08-09	FY 09-10	FY 10-11	FY 11-12	FY 12-13	FY 13-14	FY 14-15	Total	Cumulative Water Savings across all Fiscal Years
Brea	0	2	7	43	48	8	0	0	38	72	218	36.22
Buena Park	0	1	2	124	176	7	0	0	96	88	494	96.35
East Orange CWD RZ	0	0	10	12	1	0	0	0	13	10	46	8.77
El Toro WD	0	392	18	75	38	18	0	133	218	157	1,049	234.37
Fountain Valley	0	69	21	262	54	17	0	0	41	51	515	134.70
Garden Grove	0	14	39	443	181	24	0	0	63	170	934	214.54
Golden State WC	2	16	36	444	716	37	80	2	142	182	1,657	375.92
Huntington Beach	2	13	59	607	159	76	0	0	163	378	1,457	293.49
Irvine Ranch WD	29	1,055	826	5,088	2,114	325	0	1,449	810	910	12,606	3,115.11
Laguna Beach CWD	0	2	17	91	28	11	0	0	45	71	265	50.01
La Habra	0	3	18	296	34	20	0	0	37	61	469	114.14
La Palma	0	1	10	36	26	13	0	0	21	29	136	26.94
Mesa Water	0	247	19	736	131	7	0	0	174	82	1,396	373.58
Moulton Niguel WD	0	20	104	447	188	46	0	0	400	935	2,140	307.87
Newport Beach	0	5	19	163	54	13	0	0	49	79	382	81.03
Orange	1	20	62	423	79	40	0	1	142	233	1,001	206.03
San Juan Capistrano	0	10	7	76	39	11	0	0	35	73	251	47.24
San Clemente	0	7	22	202	66	21	0	0	72	123	513	103.04
Santa Margarita WD	0	5	14	304	151	44	0	0	528	516	1,562	212.07
Seal Beach	0	678	8	21	12	1	0	2	17	26	765	274.76
Serrano WD	2	0	1	13	5	0	0	0	2	17	40	7.24
South Coast WD	2	2	29	102	41	12	23	64	102	159	536	82.44
Trabuco Canyon WD	0	0	4	23	23	0	0	0	10	49	109	17.02
Tustin	0	186	28	387	479	17	0	0	64	48	1,209	329.49
Westminster	0	17	25	541	167	23	0	0	35	64	872	229.44
Yorba Linda WD	0	14	89	323	96	18	0	0	40	110	690	168.32
MWDOC Totals	38	2,779	1,494	11,282	5,106	809	103	1,651	3,357	4,693	31,312	7,140.13

Anaheim	0	255	78	2,771	619	114	0	0	156	729	4,722	1,176.38
Fullerton	0	4	28	286	60	23	0	0	61	108	570	126.27
Santa Ana	0	11	25	925	89	23	0	0	33	195	1,301	327.02
Non-MWDOC Totals	0	270	131	3,982	768	160	0	0	250	1,032	6,593	1,629.67

Orange County Totals	38	3,049	1,625	15,264	5,874	969	103	1,651	3,607	5,725	37,905	8,769.81
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HOME WATER SURVEYS PERFORMED BY AGENCY

through MWDOC and Local Agency Conservation Programs

Agency	FY 13/14		FY 14/15		Total		Cumulative Water Savings
	Surveys	Cert Homes	Surveys	Cert Homes	Surveys	Cert Homes	
Brea	1	0	1	0	2	0	0.02
Buena Park	0	0	0	0	0	0	0.00
East Orange	19	0	1	0	20	0	0.45
El Toro	0	0	3	0	3	0	0.00
Fountain Valley	3	0	3	0	6	0	0.07
Garden Grove	0	0	6	0	6	0	0.00
Golden State	0	0	0	0	0	0	0.00
Huntington Beach	2	0	2	0	4	0	0.05
Irvine Ranch	1	0	0	0	1	0	0.02
La Habra	0	0	1	0	1	0	0.00
La Palma	0	0	0	0	0	0	0.00
Laguna Beach	4	0	6	0	10	0	0.09
Mesa Water	0	0	0	0	0	0	0.00
Moulton Niguel	4	0	4	0	8	0	0.09
Newport Beach	2	0	7	0	9	0	0.05
Orange	2	0	13	0	15	0	0.05
San Clemente	15	0	7	0	22	0	0.35
San Juan Capistrano	4	0	12	0	16	0	0.09
Santa Margarita	15	0	16	1	31	1	0.35
Serrano	0	0	2	0	2	0	0.00
South Coast	6	0	3	0	9	0	0.14
Trabuco Canyon	0	0	3	0	3	0	0.00
Tustin	0	0	7	0	7	0	0.00
Westminster	0	0	0	0	0	0	0.00
Yorba Linda	0	0	8	0	8	0	0.00
MWDOC Totals	78	0	105	1	183	1	1.83

Anaheim	0	0	0	0	0	0	0.00
Fullerton	0	0	13	0	13	0	0.00
Santa Ana	0	0	0	0	0	0	0.00
Non-MWDOC Totals	0	0	13	0	13	0	0.00

Orange County Totals	78	0	118	1	196	1	1.835
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SYNTHETIC TURF INSTALLED BY AGENCY^[1] through MWDOC and Local Agency Conservation Programs

Agency	FY 07/08		FY 08/09		FY 09/10		FY 10/11		Total Program		Cumulative Water Savings across all Fiscal Years
	Res	Comm.	Res	Comm.	Res	Comm.	Res	Comm.	Res	Comm.	
Brea	0	0	2,153	2,160	500	0	0	0	2,653	2,160	3.30
Buena Park	0	0	1,566	5,850	0	0	0	0	1,566	5,850	5.19
East Orange	0	0	0	0	983	0	0	0	983	0	0.55
El Toro	3,183	0	2,974	0	3,308	0	895	0	10,360	0	6.98
Fountain Valley	11,674	0	1,163	0	2,767	0	684	0	16,288	0	12.46
Garden Grove	1,860	0	0	0	3,197	0	274	0	5,331	0	3.47
Golden State	6,786	0	13,990	0	15,215	0	2,056	0	38,047	0	24.88
Huntington Beach	15,192	591	12,512	0	4,343	1,504	0	0	32,047	2,095	25.29
Irvine Ranch	11,009	876	13,669	0	2,585	0	0	0	27,263	876	21.00
La Habra	0	0	0	0	0	0	0	0	0	0	-
La Palma	429	0	0	0	0	0	0	0	429	0	0.36
Laguna Beach	3,950	0	3,026	0	725	0	0	0	7,701	0	5.84
Mesa Water	4,114	0	3,005	78,118	4,106	0	2,198	0	13,423	78,118	63.46
Moulton Niguel	14,151	0	25,635	2,420	7,432	0	0	0	47,218	2,420	35.69
Newport Beach	2,530	0	6,628	0	270	0	0	0	9,428	0	6.92
Orange	4,169	0	7,191	0	635	0	0	0	11,995	0	8.89
San Clemente	9,328	0	11,250	455	2,514	1,285	500	0	23,592	1,740	18.37
San Juan Capistrano	0	0	7,297	639	2,730	0	4,607	0	14,634	639	9.02
Santa Margarita	12,922	0	26,069	0	21,875	0	7,926	0	68,792	0	44.68
Seal Beach	0	0	817	0	0	0	0	0	817	0	0.57
Serrano	7,347	0	1,145	0	0	0	0	0	8,492	0	6.97
South Coast	2,311	0	6,316	0	17,200	0	1,044	0	26,871	0	16.43
Trabuco Canyon	1,202	0	9,827	0	0	0	0	0	11,029	0	7.89
Tustin	6,123	0	4,717	0	2,190	0	0	0	13,030	0	9.67
Westminster	2,748	16,566	8,215	0	890	0	0	0	11,853	16,566	22.47
Yorba Linda	11,792	0	12,683	0	4,341	5,835	0	0	28,816	5,835	24.48
MWDOC Totals	132,820	18,033	181,848	89,642	97,806	8,624	20,184	0	432,658	116,299	384.83

Anaheim	4,535	0	7,735	20,093	13,555	65,300	4,122	0	29,947	85,393	69.18
Fullerton	4,865	876	5,727	0	6,223	0	105	0	16,920	876	12.36
Santa Ana	0	0	2,820	0	525	0	0	0	3,345	0	2.27
Non-MWDOC Totals	9,400	876	16,282	20,093	20,303	65,300	4,227	0	50,212	86,269	83.81

Orange County Totals	142,220	18,909	198,130	109,735	118,109	73,924	24,411	0	482,870	202,568	468.63
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[1] Installed device numbers are calculated in square feet

ULF TOILETS INSTALLED BY AGENCY
through MWDOC and Local Agency Conservation Programs

Agency	Previous Years	FY 95-96	FY 96-97	FY 97-98	FY 98-99	FY 99-00	FY 00-01	FY 01-02	FY 02-03	FY 03-04	FY 04-05	FY 05-06	FY 06-07	FY 07-08	FY 08-09	Total	Cumulative Water Savings across all Fiscal Years
Brea	378	189	299	299	122	144	867	585	341	401	26	48	17	4	0	3,720	1,692.64
Buena Park	361	147	331	802	520	469	524	1,229	2,325	1,522	50	40	18	9	0	8,347	3,498.37
East Orange CWD RZ	2	0	33	63	15	17	15	50	41	44	19	18	13	2	0	332	138.23
El Toro WD	1,169	511	678	889	711	171	310	564	472	324	176	205	61	40	0	6,281	3,091.16
Fountain Valley	638	454	635	858	1,289	2,355	1,697	1,406	1,400	802	176	111	58	32	0	11,911	5,383.10
Garden Grove	1,563	1,871	1,956	2,620	2,801	3,556	2,423	3,855	3,148	2,117	176	106	67	39	0	26,298	12,155.41
Golden State WC	3,535	1,396	3,141	1,113	3,024	2,957	1,379	2,143	3,222	1,870	167	116	501	43	0	24,607	11,731.47
Huntington Beach	3,963	1,779	2,600	2,522	2,319	3,492	3,281	2,698	3,752	1,901	367	308	143	121	0	29,246	13,854.70
Irvine Ranch WD	4,016	841	1,674	1,726	1,089	3,256	1,534	1,902	2,263	6,741	593	626	310	129	0	26,700	11,849.23
La Jolla Beach CWD	283	93	118	74	149	306	220	85	271	118	32	26	29	6	0	1,810	845.69
La Habra	594	146	254	775	703	105	582	645	1,697	1,225	12	31	6	7	0	6,782	2,957.73
La Palma	65	180	222	125	44	132	518	173	343	193	31	27	20	17	0	2,090	927.52
Mesa Water	1,610	851	1,052	2,046	2,114	1,956	1,393	1,505	2,387	988	192	124	56	14	0	16,288	7,654.27
Moulton Niguel WD	744	309	761	698	523	475	716	891	728	684	410	381	187	100	0	7,607	3,371.14
Newport Beach	369	293	390	571	912	1,223	438	463	396	1,883	153	76	36	16	0	7,219	3,166.77
Orange	683	1,252	1,155	1,355	533	2,263	1,778	2,444	2,682	1,899	193	218	88	53	4	16,600	7,347.93
San Juan Capistrano	1,234	284	193	168	323	1,319	347	152	201	151	85	125	42	39	0	4,663	2,324.42
San Clemente	225	113	191	65	158	198	667	483	201	547	91	66	37	34	0	3,076	1,314.64
Santa Margarita WD	577	324	553	843	345	456	1,258	790	664	260	179	143	101	29	0	6,522	3,001.01
Seal Beach	74	66	312	609	47	155	132	81	134	729	29	10	6	12	0	2,396	1,073.80
Serrano WD	81	56	68	41	19	52	95	73	123	98	20	15	14	2	0	757	338.66
South Coast WD	110	176	177	114	182	181	133	358	191	469	88	72	32	22	0	2,305	990.05
Trabuco Canyon WD	10	78	42	42	25	21	40	181	102	30	17	20	12	14	0	634	273.02
Tustin	968	668	557	824	429	1,292	1,508	1,206	1,096	827	69	89	26	12	0	9,571	4,423.88
Westminster	747	493	969	1,066	2,336	2,291	2,304	1,523	2,492	1,118	145	105	70	24	0	15,683	7,064.28
Yorba Linda WD	257	309	417	457	404	1,400	759	1,690	1,155	627	158	136	81	41	0	7,891	3,409.49
MWDOC Totals	24,256	12,879	18,778	20,765	21,136	30,242	24,918	27,175	31,827	27,568	3,654	3,242	2,031	861	4	249,336	113,878.61

Anaheim	447	1,054	1,788	3,661	1,755	7,551	4,593	6,346	9,707	5,075	473	371	462	341	1	43,625	18,359.52
Fullerton	1,453	1,143	694	1,193	1,364	2,138	1,926	2,130	2,213	1,749	172	77	44	23	2	16,321	7,435.23
Santa Ana	1,111	1,964	1,205	2,729	2,088	8,788	5,614	10,822	10,716	9,164	279	134	25	5	0	54,644	22,887.95
Non-MWDOC Totals	3,011	4,161	3,687	7,583	5,207	18,477	12,133	19,298	22,636	15,988	924	582	531	369	3	114,590	48,682.70

Orange County Totals	27,267	17,040	22,465	28,348	26,343	48,719	37,051	46,473	54,463	43,556	4,578	3,824	2,562	1,230	7	363,926	162,561.30
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