2016 – Groundwater Supply, Quality and Sustainability: the Challenges Ahead

GRA’s 25th Annual Conference & Meeting

By Jim Strandberg, Chair; Co-Chairs Adam Hutchinson, Alyx Karpowicz, Steven Phillips, and Emily Vavricka; and Moderators Michael Burns, Lisa Campbell, Leslie Dumas, Murray Einarson, Thomas Harter, Jean Moran, Lisa O’Boyle, Chris Petersen, and Matt Zidar

For 25 years, GRA’s annual groundwater conference, along with other offerings, have provided policymakers, practitioners, researchers, and educators the opportunity to learn about the current policies, regulations, and technical challenges affecting the use and management of groundwater in CA. This year’s conference focused on key aspects of the Sustainable Groundwater Management Act (SGMA), and a wide range of water-quality issues.

GRA’s 25th Annual Conference and Meeting had targeted SGMA sessions on charting the course forward; associated legislation, policy and legal issues; technical issues for Groundwater Sustainability Plans; and next steps. Additional sessions covered a broad range of groundwater-quality and other topics, including the cleanup approaches, better site assessments, remediation technologies, groundwater replenishment, surface-water/groundwater interaction, and modeling and visualization tools. The conference also included GRA’s 2016 David Keith Todd Distinguished Lecturers; the popular Collegiate Colloquium, which showcased cutting-edge science being conducted by CA’s college students; and a poster session. A summary of these sessions follows.

GRA would like to thank the Chair, Co-Chairs and Moderators listed above for their contributions toward the success of this event, and the many sponsors shown here that make such events possible.

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President’s Message

Thankful for GRA!
By Chris Petersen

Hello Again!

It’s the Sunday before Thanksgiving and for several days now, I’ve been reflecting on all I have to be thankful for this year. Family is always at the top of my list, but I’m also truly grateful for good health, a great job, wonderful friends and my 1967 VW Karman Ghia. This year I have another thing to be thankful for: GRA! We had our November Board meeting in Southern California yesterday and I left the meeting with a strong sense of gratitude for our Directors and all we have accomplished together in 2016. I also walked away excited in anticipation of 2017. Regarding GRA, the thing I am most thankful for are our members and the opportunity to serve together with such fantastic and hardworking volunteer Executive Officers and Directors. Phil Jackson, the legendary basketball coach, once said:

“The strength of the team is each individual member. The strength of each member is the team.”

I like this quotation because I’ve experienced it to be true in my career and in my work with GRA. Yes, we have gifted and distinguished GRA members and Directors, but when we focus on promoting ourselves, we fall short of our full team potential. When we instead rally behind our organizational goals and objectives, wow, great things happen. I was attracted to the GRA Board because of this positive team culture and it remains strong today. We applaud and celebrate individual successes, but also offer support when one of our Directors is feeling down and discouraged, or just overwhelmed with their day job.

We have a lot of content in this winter 2016 issue of HydroVisions, so I will be brief with my Presidents Message, but will highlight a few of GRA’s accomplishments that I am most thankful for in 2016 and list a few of the projects I am most excited about for 2017.

2016 GRA Accomplishments

1. We delivered, and received very positive feedback on, 7 groundwater events, including conferences, symposia, and short courses.
2. We delivered 13 GRACasts, more than 1 per month!
3. We delivered 4 Issues of HydroVisions!
4. We have 1,000 members throughout California.
5. We remain financially strong with a 1-year cash reserve.
6. After 25 years as a 5-Branch organization, we launched a new Northern Sacramento Valley Branch this summer.
7. We have drafted a 2017 Vision to guide the activities of our Legislative Committee in 2017 and beyond in an attempt to give GRA an even greater voice at the Capitol.
8. We are in the process of expanding our Board from a maximum of 15 seats to 19 in recognition of the need for GRA to play a larger role in the successful implementation of the Sustainable Groundwater Management Act and other groundwater regulatory programs, and to facilitate growth of the organization.
9. We have taken positions on multiple groundwater bills.

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President’s Message – Continued

10. We have served on the technical and policy advisory committees for the Water Storage Investment Program and the 2018 Water Plan Update.


12. We hosted the Contemporary Groundwater Issues Council (CGIC) meeting in May. CGIC is composed of a diverse cross-section of groundwater leaders and experts throughout California. This meeting, hosted by GRA in May of each year, helps GRA remain relevant by strategically informing and guiding our programs and activities.

What to Look Forward to in 2017

1. Another strong lineup of Events and GRACasts, including the Legislative Symposium at the end of March, a SGMA event in early May, and a larger (3-day) Annual Meeting in early October; please visit our Event Webpage for more information on these and other events.

2. A drive to increase our membership by 10% in 2017 through focused Branch activity and outreach to growers and irrigation district staff.

3. Launching of two new Branches in Southern California, one in Riverside County and one in San Diego County.

4. Implementing our 2017 Vision within the Legislative Committee, including launching a series of groundwater workshops with legislative staffers.

5. Increasing the number and diversity of technical papers in HydroVisions by initiating a quarterly call for abstracts; for more details on this, please see page 36 of this issue.

6. Addition of groundwater content and improved functionality of our Website.

7. More active engagement with our members through surveys, social media and our events.

8. Recognition of distinguished groundwater leaders and experts through our awards program.

To accomplish these goals in 2017, we need your help and look forward to increased participation by our members in the success of this ambitious list of activities. If you are not already a member of GRA, or have not yet renewed your membership, what are you waiting for? Join or renew today by clicking here, and help us achieve our mission of protecting groundwater quality and quantity through effective education and information.

Wishing you all a safe and enjoyable Holiday Season!!

With Gratitude,

Chris Petersen

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Call for Submissions:

HydroVisions is looking for submissions from students engaged in groundwater research, to highlight in our Student Corner.

Do you know of a student with something to share?

- Articles
- Research Papers
- Summary Blurbs

For further information, please contact:

editor@grac.org, subject “Student Corner”
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Plenary Session: 2016 – Charting the Course to Sustainability

Moderated by Jim Strandberg, West Yost Associates

Gary Bardini, Deputy Director of Integrated Water Management, CA Department of Water Resources (DWR) discussed The Evolution of California Water Management Towards Regional Sustainability. Signed into law by Governor Brown in September 2014, the underpinnings of SGMA were in development for years, most notably through integrated regional water management planning (IRWMP). DWR provided incentives for the IRWMP program with $2.1 billion of support, but lacked the regulatory authority for enforcement. SGMA, with incentives and enforcement authority, will lead to further evolution and re-shaping of water management in CA. The most difficult challenge for SGMA implementation may be the significant changes needed at the state and local levels to forge trusted relationships and partnerships, build capacity, and to continuously innovate. DWR has $90 million of funding for facilitation services to assist in the formation of Groundwater Sustainability Agencies (GSAs), tools (e.g., database access), and technical expertise to support development of Groundwater Sustainability Plans (GSPs).

Karen Ross, Secretary of CA Department of Food & Agriculture, discussed Making the Use of Every Drop for Agricultural Food Production. With Governor Brown’s leadership and incentive programs, CA agriculture has grown from an $18 billion to $54 billion industry through its dedication to innovation, which led to 57% greater yields while the cost of imported water rose from $691/acre-ft (AF) to $1,250/AF. Agriculture needs investment for its renewable resources and partnerships to reduce polarization by closing the urban-environmental-agriculture divide. Innovative partnerships with local agencies for use of recycled water for agricultural purposes is promising. Subject to SGMA and the Irrigated Lands Regulatory Program, the CV-SALTs initiative has helped to build consensus and lead to new partnerships, a critical element for successful SGMA implementation.

Steve Moore, State Water Resources Control Board (SWRCB) Member discussed Sustainable Groundwater Management: Roles and Responsibilities. Water use in CA has shifted from open to a closed system. In 2009, surface-water diversions were first required to be measured. With passage of SB 88, the monitoring frequency and reporting of diversions will increase in 2017 for large diverters; monitoring will be hourly. The state’s estimates of water demand will be based on actual data instead of conservative assumptions. Under SGMA, the State Water Board has no desire to intervene, but if so, will exit after minimum standards are established for sustainable groundwater management. Potential fragmentation of governance will spur the innovation of institutional structures. Local agency’s problem-solving approach is critical to SGMA’s success.

Ellen Hanak, Center Director of the Public Policy Institute of CA, presented Why Water Accounting is SGMA’s (and Groundwater Users’) Best Friend. Good accounting is key to SGMA’s promise and challenge. Many critical water-accounting gaps relate to groundwater, including the understanding of: water availability, including surface-water/groundwater interactions; groundwater rights; water use, primarily groundwater pumping and return flows; and managing and sharing information. Potential solutions include state establishment of standards for data-collection methods, data sharing, and reporting, and state investment in authoritative, fully documented, publicly-available groundwater models for use by local agencies. Associated benefits are more efficient data collection and sharing, and reduced conflict over assumptions on groundwater availability and use. Other potential solutions and benefits are to: incentivize groundwater recharge, including clarifying rights to excess surface flows; establish transparent methods to quantify recharge volume and credit landowners who implement groundwater recharge projects; and establish local markets to trade pumping rights through leases and sales.

SGMA & Legal, Policy, and Compliance

Moderated by Matt Zidar, Independent Consultant

Mark Norberg of DWRs SGMA program led off with a presentation on the status of GSA formation throughout the state, noting that there were a large number of proposed GSAs that needed to resolve issues of overlapping areas in order to move forward; of 123 GSA submissions at the time, Continued on the following page...
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68 were overlapping. Interestingly, 31 basins with approved GSAs are in low- or very-low-priority basins.

Kevin Obrien, attorney at Downey Brand, presented the Pros and Cons of GSAs versus Adjudications. Kevin discussed the adjudication process, including the revised statutes that seek to expedite adjudications, and contrasted a litigation-based process with the planning process for GSP development. He noted that the planning process is likely cheaper and quicker than adjudication, but that adjudication may result in more certainty for overlying groundwater users since GSAs cannot determine or alter surface-water or groundwater rights.

Alisa Moore of ESA examined how SGMA may interact with the current framework of land-use and water-planning integration, including its relationship to General Plans, CEQA, and SB610/221 Water Supply Assessments and Written Verifications. She also described practical approaches for coordinating land-use and groundwater-management plans and the planning process.

Eric Garner, attorney at Kronick, Moskovitz, Tiedemann & Girard, gave an overview of the key provisions of CA surface-water and groundwater law, explaining the similarities between surface-water riparian rights and overlying correlative groundwater rights; he also made the clear distinction between adjudicated senior surface-water rights and overlying groundwater rights.

Collegiate Colloquium

Moderated by Jean Moran, California State University East Bay

Four students presented their research findings during the oral portion of the eighth annual Collegiate Groundwater Colloquium. The Collegiate Colloquium offers an opportunity for practicing groundwater professionals to learn about students’ recent research, and gives students an opportunity to present their work to an audience of groundwater professionals. Submissions are solicited from undergraduate and graduate students through their faculty advisors and can be on any topic related to groundwater occurrence, contamination, remediation or management. This year, four graduate students from CA universities gave presentations on topics ranging from a geophysical method that allows delineation of seawater intrusion to a field-scale reactive barrier for nitrate removal at an artificial recharge pond.

Sarah Beganskas, a PhD candidate at UC Santa Cruz working with Professor Andy Fisher, showed the results of a regional surface-hydrology model, Precipitation-Runoff Modeling System (PRMS), to evaluate locations for distributed stormwater collection in the Pajaro Valley Groundwater Basin. Extensive, high-resolution input files of land use and physical characteristics were combined with varying precipitation regimes to assess where adequate runoff is generated to supply stormwater for managed aquifer recharge (MAR) projects (figure 1). The tools developed can be applied to inform the placement and design of stormwater-MAR projects.

Carlos Flores Arenas, a PhD candidate in Hydrologic Sciences at UC Davis working with Professor Graham Fogg, described a unique method for examining change in groundwater storage using change in head data from monitoring wells. He showed the results of a regression analysis that could be applied as a proxy for determining deep percolation (fig. 2), groundwater pumping, and change in storage. The method was applied using a calibrated model for the Davis and Woodland areas of Yolo County and showed that the greatest flows in the groundwater budget could be accounted for by applying equations that use only measured change in head at monitoring wells as input.

GRA’s Dr. David Huntley Student Competition Awards presented by Jean Moran

(l-r) Sarah Raker, former GRA President; students Meredith Goebel, Galen Gorski, Sarah Beganskas, Hannah Waterhouse, Nate Veale, Sarah Fakhreddine, Drew York; and GRA Student Coordinator Dr. Jean Moran.

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Meredith Goebel, a PhD student at Stanford University working under the advisement of Professor Rosemary Knight, presented the results of an electrical resistivity tomography survey in the coastal aquifers along Monterey Bay, which are experiencing seawater intrusion. The method of data acquisition allowed collection of data over 39 km in 14 days, and yielded detailed, 2-dimensional profiles of groundwater salinity over a depth of 280 m (figure 3).

Galen Gorski, a beginning PhD student at UC Santa Cruz, showed the results of experiments aimed at enhancing nitrate removal using reactive barrier technology at a managed aquifer recharge area. The goal of the experiments is to understand the mechanisms controlling denitrification at plots where controlled percolation through a carbon-rich permeable barrier (redwood chips) and different soil types is monitored for nitrate removal (figure 4). One result, that lower infiltration rates yield higher nitrate removal, could lead to a Best Management Practice for managing nitrogen at MAR areas in agricultural settings.

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Keynote Speakers – Day 1

Moderated by Chris Petersen, GEI Consultants

Rita Schmidt Sudman – Groundwater More or Less

Rita is the former Executive Director of the Water Education Foundation (Foundation), is currently the Foundations Senior Advisor and the recipient of GRA’s Lifetime achievement award in 2003. Rita is also an author, having recently completed Water More or Less. Rita opened her speech by describing a recent National Geographic article on the Ogallala Aquifer called “To the Last Drop,” pointing out that Midwest farmers in their drive to meet national and international food production needs are managing the depletion of the regional water supply. Midwest farmers had a permit system and regulations to protect the resource, but these have been given out liberally; at the current rate of extraction, the groundwater resource may be fully depleted by 2028. According to Rita, “managed depletion” is now part of the everyday discussion in those states. “It’s just a race to see who runs out first—truly a race to the pump house resulting in the Tragedy of the Commons.” Rita encouraged GRA to remain a part of the solution in CA, and said “GRA has been a major force in formulating a progressive statewide policy and disseminating scientific and technical information on groundwater. GRA’s work will be even more critical in the coming years. And you can tell your children what you did during this time and what you stood for as part of the solution.”

Christina Babbitt – In-Depth Analysis of Groundwater Best Management Practices Across the Western United States

Christina is the manager of the California Groundwater Program for the Environmental Defense Fund (EDF). She began her presentation by describing the program goals of the EDF’s California Groundwater Strategy, including:

- Work with early adopters to pilot replicable models
- Develop toolkits to help basins achieve healthier ecosystems & drinking-water supplies
- Establish a statewide network of collaborators.

Christina briefly summarized SGMA and pointed out that groundwater overdraft is a problem in many food-growing regions around the world, as shown in Figure 1. EDF is in the process of documenting case studies of sustainable groundwater management throughout the Midwest and western states. Orange County Water District is 1 of 13 case studies being documented by EDF in a report to be finalized in November 2017. Following completion of the case studies, EDF will begin developing a Groundwater Design Manual as the first in a series of tools to help locals plan for, and ultimately achieve, sustainable groundwater management.

SGMA Planning & Considerations

Moderated by Leslie Dumas, RMC Water and Environment

Tom Barnes of Environmental Science Associates presented CEQA and Groundwater Management Planning. Although SGMA does not require that GSPs be evaluated under CEQA, the projects to be implemented under the GSP will. GSPs will be developed to avoid or minimize six SGMA-defined undesirable results. Tom demonstrated how these undesirable results compare with CEQA Thresholds, providing examples of how CEQA analysis of groundwater management projects can evaluate the potential for undesirable results, and potential management actions that could be implemented to mitigate these SGMA sustainability criteria.
Ruth Langridge of the University of California, Santa Cruz presented Managing Groundwater to Reduce Vulnerability to Drought. Ruth presented recent findings of two new reports for the SWRCB evaluating CA’s adjudicated groundwater basins and special-act groundwater districts. The evaluated areas underlie major urban and agricultural centers, and are of interest because groundwater basins adjudicated prior to SGMA are exempt from the act’s requirements, and have the option to be the GSA in their service area. Key findings include that for many of these basins there is (1) a heavy reliance on imported water, (2) limited use of approaches to reduce withdrawals, (3) limited attention to addressing accumulated overdraft, and (4) the use of controlled overdraft in some basins to provide both additional supplies and potential storage space for recharge during wet cycles. Do these management approaches contribute to future drought vulnerability? Challenges to managing drought impacts include determining the level of drought protection needed, how to recover an overdrafted aquifer to the desired ‘protective’ level; and increasing the focus on planning for extreme drought events.

Richard Booth of the Lahontan Regional Water Quality Control Board (Retired) presented Innovative Groundwater Management in the Mojave Desert: A Case Study. In this case study of the Naval Air Weapons Station (NAWS) China Lake, Richard described the Indian Wells Valley groundwater basin as having naturally-degraded groundwater quality (TDS, arsenic, and other naturally-occurring inorganic compounds) that is infeasible to treat. As a result, the Navy has not been required to clean-up contaminated groundwater to drinking-water standards. Given the high-priority basin designation under SGMA, and the general agreement that remediation to drinking-water standards is infeasible, the question became how to sustainably manage the basin. Part of the solution proposed was to de-designate the degraded portion of the basin as a municipal or potable drinking water supply, enabling the Navy to establish a risk-based approach to determine groundwater remediation goals, versus requiring cleanup to drinking-water standards everywhere.

Matt Zidar, Independent Consultant, presented Considerations and Opportunities for Developing Data Management Systems and Best Practices for SGMA Compliance. Matt addressed issues and considerations in developing an approach to data management under SGMA. As data management systems (DMSs) are developed to support GSP development and implementation, one must consider the GSA’s business needs, both near-term and long-term, in addition to the needs of other users. Business needs may include preparation of a water budget, reporting to the state, use of existing data and databases, supporting CEQA analyses, and funding-related documentation. Matt shared his vision for a groundwater information management system that includes reducing costs, developing and using standards that ensure web-enabling, use of open-source public-domain software, and a dedicated analysis toolbox that focuses on improved sharing, access and data quality.

Cleanup Approaches and Strategies
Moderated by Alyx Karpowicz, SF Bay RWQCB

Ron Goloubow of the SF Bay RWQCB presented Regional Water Quality Control Board’s Approach to Combined Remedies. The ultimate goal of the Water Board is to see sites remediated and closed. The best way to achieve closure is to present a comprehensive conceptual site model and remedial action plan that considers post-remediation testing. Although the Water Board does not specify the means by which a site can be cleaned up, the use of combined remedies to achieve closure is welcomed.

Ross Steensom of the SF Bay RWQCB presented Metabolites and Mixtures: Addressing Petroleum Contamination in Groundwater. In 2016, Water Board staff completed a literature review and developed a more comprehensive assessment framework for evaluating petroleum-derived polar compounds. Environmental concerns arise from parent hydrocarbons and the intermediate breakdown products (metabolites or degradates). They found that chemical mixtures containing petroleum metabolites clearly pose risks to humans and ecological receptors. Concentrations of polar compounds in groundwater at sites with historical petroleum plumes can be substantial; therefore, metabolites can be considered contaminants of emerging concern.

Melissa Harderode of CDM Smith presented the Value of Water Resources – The Next Step in Groundwater Remediation. The remediation community has made tremendous strides in minimizing waste generation, limiting natural-resource consumption, and reducing emissions of harmful chemicals. This is partly due to technology innovation, moving from ex-situ to in-situ focused treatments, advancements in promoting degradation processes, and increased understanding of source flux and discharge. Impacts to water resources from remedial activities currently are evaluated based on water consumption and potential reuse opportunities of treated groundwater. Water valuation techniques will provide scientifically-sound and transparent data to determine if resources should be spent on cleaning up aquifers to promulgated standards, or alternative risk management criteria. This valuation assessment can help prioritize where resources are best allocated to clean up an aquifer with significant reuse potential.

Evelyn Cortez-Davis of LADWP presented Groundwater Basin Remediation in the City of Los Angeles. Over 70% of the production wells in the San Fernando Basin (SFB) are impacted
by contamination caused by various commercial and industrial activities dating to the 1940s. The SFB aquifer provides drinking water to over 800,000 Los Angeles residents. Without comprehensive containment and groundwater basin remediation, the City will lose the ability to use this valuable local resource within the next decade. LADWP has begun the necessary planning for state-of-the-art groundwater basin remediation facilities, to effectively clean up and remove contamination from the SFB. The facilities will be designed to utilize multiple best-available technologies to clean up the majority of contaminants impacting LADWP’s most productive wellfields.

**SGMA & Technical Challenges for Groundwater Sustainability Plans**

*Moderated by Michael Burns, Environmental Science Associates*

Steven Springhorn of DWR presented *Data Availability and Assistance to GSAs*. Steven summarized the currently available and future technical expertise; data, tools and analysis; and reports provided by the DWR to help enable the development of GSPs. Challenges include the 3 V’s of data management—variety (over 80 GSP data compilation requirements and over 20 websites containing SGMA data), volume (data collection and reporting for each basin), and velocity (at least semi-annual data collection and annual data reporting). The next steps include complying with AB 1755 to integrate existing water and ecological data from multiple autonomous databases managed by federal, state, and local agencies and academia using consistent and standardized formats.

Trevor Joseph of DWR presented a *SGM Program Update – Best Management Practices for Groundwater Sustainability Plan Development and Implementation*. Trevor described the role, scope, and types of BMPs to be provided to aid in developing GSPs, including guidance, standards, case studies, and references. He then summarized the response of stakeholders to the DWR survey to identify needs and priorities. The results were heavily weighted on items associated with SGMA criteria (i.e., establishing measurable objectives, assessing undesirable results). Other items considered of importance included methods to assess sustainability and monitor basin conditions, evaluate and present current and historical conditions, and develop water budgets.

**Erfan Goharian** of the University of California, Davis, presented *Role of Managing Headwaters, Forestry Practices, and Reservoirs for Groundwater Management*. Erfan described the UC Water team’s activities in developing a watershed management approach to maximize total water storage. Their activities include developing innovative, quantitative water accounting and analysis methods, weaving in legal and policy research, and improving understanding of how water is extracted, conveyed and stored in constructed and natural infrastructure. Using the American-Cosumnes River system as a case study, the focus was how to get water underground, and how to collect and convey suitable water, using both natural and managed recharge. They explored the use of floodplains, agricultural groundwater banking, improved system observations, and the use of a dynamic-surrogate model to increase and better manage recharge.

**Juliet Christian-Smith** of the Union of Concerned Scientists presented *Integrating Climate Impacts into Integrated Groundwater-Surface Water Models: A Pilot Study Using Existing Data and Open Source Models*. The pilot study focused on precipitation, looking at the driest and wettest scenarios to capture the range of possible futures and using DWR’s C2VSIM model of the Central Valley. The study explored the sensitivity of groundwater storage, land subsidence, and recharge from streams to precipitation, and which climate scenario is more likely. The results quantified the sensitivity to precipitation, which was significant, and showed that climate scenarios are not probabilities—they are all equally likely to occur. Juliet also noted that evaluations incorporating future scenarios of hydrologic uncertainty are needed in order to understand how vulnerable plans or actions are to a variety of possible futures.

**Better Site Assessments**

*Moderated by Lisa Campbell, CDM Smith*

**Rick Cramer** of Burns & McDonnell presented *Environmental Sequence Stratigraphy: A Focus on Geology for Improved Remediation Decision Making*. There is increased awareness that geology defines the subsurface heterogeneity responsible for the permeable pathways that control groundwater flow and contaminant migration at contaminated groundwater sites. However, due to inherent geologic complexities, restoration is likely not achievable at many complex sites. Therefore, the environmental industry must emphasize modern geologic methods to better understand subsurface heterogeneity. Environmental Sequence Stratigraphy (ESS) applies current best practices for predicting and delineating reservoir geometry and continuity. Rick described a geology-based conceptual site model (CSM) in which ESS was used to tap “hidden” stratigraphic data in existing borehole logs, which were then used to map buried floodplain sand channels to predict contaminant migration.
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The CSM was critical to obtaining regulatory and stakeholder approval for a targeted remediation system that provided significant savings.

John Jansen of Leggette, Brashears & Graham presented Setting Boundaries: Using Geophysics to Build Better Site Models. Groundwater studies are always limited by the availability of subsurface data points and the uncertainty of interpolations between the points. Frequently there are elements of the flow system with sharp boundaries that are difficult to locate accurately, and getting these boundaries wrong can lead to inaccurate CSMs and incomplete site investigations. Drilling numerous boreholes to obtain sufficient subsurface data for an accurate CSM is largely cost prohibitive, whereas geophysical methods can quickly characterize large areas of the subsurface, and identify hydraulic boundaries, with minimal disturbance. Case studies illustrated the use of geophysics to map faults in basin fill using electrical resistivity and gravity methods, find narrow channel-sand deposits with seismic reflection and resistivity, screen potential recharge-basin sites for faults and perching layers using resistivity, and map saltwater intrusion using electrical resistivity and TEM.

Lisa Campbell of CDM Smith presented Combining High Resolution Site Characterization and 3D Visualization to Enhance a Conceptual Site Model. For a manufacturing facility located in a highly industrial area with multiple groundwater contaminant sources, cone penetration test (CPT) and membrane interface probe (MIP) data were input into 3D data-visualization software to enhance a conceptual site model. The 3D model included lithologic and VOC data from over 280 CPT/MIPs and groundwater sample points from onsite, upgradient, and downgradient areas. They were able to model the spatial extent of upgradient VOC plumes and co-mingled plumes associated with the manufacturing facility. This model is being used to optimize the design for a downgradient groundwater extraction system to effectively address the portions of the VOC plume associated with the manufacturing facility.

Murray Einarson of Haley & Aldrich presented DYE-LIFTM – A New LIF Tool for Rapidly Delineating Chlorinated Solvent DNAPL in the Subsurface. Cleanup of sites with residual chlorinated solvent DNAPL has been hampered by the significant challenge of locating DNAPL in the subsurface using conventional sampling tools and sensors. Colorimetric dyes can be used to locate chlorinated solvent DNAPL, but are expensive, time-consuming, and biased by sample collection methods. Laser-Induced Fluorescence (LIF) technologies advanced on direct-push platforms are extremely effective in quickly delineating the distribution of NAPL in the subsurface, although the lack of polynuclear aromatic hydrocarbons (PAHs) have made chlorinated DNAPL invisible to LIF technologies. A new version of LIF called “DYE-LIFTM,” developed by Haley & Aldrich, Dakota Technologies and the University of Guelph, has enabled quick delineation of chlorinated DNAPL in three dimensions by injecting a small stream of a hydrophobic fluorescent dye ahead of the LIF detector. Mr. Einarson, co-developer of the new DYE-LIF system, presented results of a DOD-funded research project that validated its performance.

Upland-Lowlands and Surface-Water/Groundwater Interactions

Moderated by Thomas Harter, University of California, Davis

Kirk Klausmeyer and Melissa Rohde of The Nature Conservancy (TNC) made a practical distinction between groundwater-dependent ecosystems (GDEs) that rely directly on groundwater and ecosystem-related services provided through groundwater discharge into streams and lakes. TNC is engaged with DWR and the California Department of Fish and Wildlife (CDFW) on mapping over 6 million acres of potential GDEs in CA. All medium- and high-priority basins contain identifiable potential GDEs. TNC is also doing a rapid assessment of surface-water/groundwater interactions, using groundwater-level and stream-elevation data to broadly map potentially gaining and losing stream reaches. Initial mapping efforts for GDEs and surface-groundwater connectivity will be completed by early 2017. These maps will be complemented by guidance on using these tools to address the regulatory requirements of GSPs to assess, monitor, and protect GDEs and beneficial uses in interconnected streams.

Kristal Davis Fadtke, groundwater program coordinator of CDFW, noted that key drivers of CDFW engagement in groundwater are threefold: they manage over 600,000 acres overlying groundwater basins; are a groundwater user for wildlife areas, ecological reserves, and fish hatcheries; and carry responsibilities as a public trust agency. Importantly, through its Instream Flow Program, CDFW is already engaged in a wider-ranging effort to better understand instream flow requirements, specifically to protect ecological health. Requirements are developed based on an understanding of hydrology, biology, stream geomorphology, water quality, and ecosystem connectivity in space and time. Once completed they will be recommended to the State Water Board for consideration in water-rights permitting and identification of beneficial uses.
Kristal also reviewed several online database systems that are relevant to GSP efforts: the California Natural Diversity Database and BIOS, which includes VEGCAMP.

Professor Jean Moran of California State University East Bay discussed the use of geochemical tools to delineate recharge areas in headwaters. These areas are often sparsely populated, with limited existing monitoring resources. Snowfall, evapotranspiration from vegetation, and groundwater resources are often poorly understood, yet important, particularly where volcanic rocks are present. Professor Moran’s team focused on using geochemical tools in conjunction with a field-sampling campaign around Mt Shasta to identify recharge areas. Numerous springs and some wells were sampled and analyzed for stable isotopes of water, salinity, temperature, and noble gases. Stable isotopes of water become lighter as the elevation of precipitation/recharge on Mt. Shasta’s very porous surface increases. Noble-gas concentrations in groundwater depend strongly on the temperature and pressure at the time of recharge. Combined, these data indicate that the zone at and just above the tree line is the main recharge zone of water captured in springs and wells at the base of Mt. Shasta. Temperature data indicate that groundwater flow paths have been as deep as 1,500 feet below ground surface.

Tim Bayley of E.L. Montgomery and Associates presented a case study that may be increasingly common in basins subject to SGMA: has a specific pumper caused the streamflow reduction observed in a perennial stream in the southwest US (anonymous location), 12 miles from the well. Historic streamflow data through the early 1970s establish long-term predevelopment conditions; however, no streamflow records are available from then until 2005, when streamflow was found to be significantly less than earlier. The well began pumping at low rates in the 1960s, and production ramped up to current levels in the 1980s. A groundwater model was developed to determine whether pumping could have impacted streamflow, whether impacts may worsen in the future, the impacts associated with this well versus neighboring wells, and to quantify uncertainty in model predictions. Using advanced stochastic model sensitivity tools and focusing on groundwater-level changes at the stream rather than groundwater discharge to the stream, Tim was able to determine that the pumper caused about two-thirds of the streamflow depletion and that future pumping reductions would quickly lead to streamflow recovery. This was further confirmed by a large-scale field test involving significant seasonal reductions in pumping.

Remediation Technologies

Moderated by Murray Einarson, Haley & Aldrich

Day two of the Contaminants Session focused on remediation technologies. In particular, speakers in this session were asked to present data that validated the key findings of their studies. Dan Nunez and Steve Nigro of REGENESIS focused on combinations of technologies that enhance both the speed and certainty of groundwater remediation. Mr. Nunez first described how combinations of technologies are typically necessary at different locations and times during the life of a remediation project. For example, aggressive in situ treatment or excavation may be appropriate in source areas with high concentrations of residual contamination. Less aggressive treatment, such as enhanced natural attenuation, may be more appropriate to treat late-stage contaminants diffusing out of low-permeability zones. Steve Nigro then described a new REGENESIS injectable liquid-activated-carbon product, called PlumeStop, which strongly retards the migration of many dissolved organic contaminants. When delivered with a biodegradation amendment, PlumeStop and the amendment can dramatically reduce the flux of contaminants beyond the zone of treatment, according to Mr. Nigro.

Dr. Robert Hinchee of IST discussed thermally-enhanced soil-vapor extraction (XSVE) for enhanced removal of 1,4-Dioxane in the vadose zone. Dr. Hinchee described an ESTCP-funded applied research project where injection of heated air into the treatment zone dramatically enhanced the partitioning and removal of 1,4-Dioxane from the vadose zone. At the site, the former McClellan Air Force Base in CA, the injected air was heated to between 100 and 120°. This resulted in enhanced removal of 1,4-Dioxane, as predicted by the temperature-dependent Henry’s Constant for that compound. Dr. Hinchee presented data from a rigorous confirmation sampling program that showed ~95% 1,4-Dioxane mass removal at the site. Dr. Hinchee also noted that higher flow rates are required for XSVE compared to regular (non-heated) SVE, and the heating added approximately $25 per yard of soil to the treatment cost.

Dr. Gorm Heron of Terra-Therm/Cascade discussed the effectiveness of in situ thermal treatment (ISTT) in reducing downgradient groundwater concentrations and contaminant mass in volatile organic contaminant (VOC) source zones. ISTT can dramatically reduce the contaminant mass in VOC source zones (to near or < 1 mg/kg), but at many sites has difficulty achieving very low concentrations of dissolved VOCs due to back diffusion. Dr. Heron discussed a dry-cleaner site in Denmark where a clay till aquifer was heated to over 100°C to remove VOCs from the source zone.
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The ISTT program also resulted in dramatic decreases in VOC concentrations in groundwater near the treatment area. Dissolved concentrations farther downgradient, however, were still elevated, but are decreasing. A rigorous ISTT of a VOC source zone at a dry-cleaner source zone in New York consisted of 224 Thermal Conductivity Heater (TCH) wells, 19 TCH wells w/ vacuum, and 15 multi-phase extraction wells. VOC concentrations in source-zone soils were reduced by orders of magnitude; strong declines in dissolved concentrations were measured downgradient. At that site, there was a calculated 99.99% reduction in PCE contaminant mass in the treatment zone and a reduction in PCE mass discharge from 57 to <0.1 kg/year.

Robbie Ettinger of Geo-syntec Consultants concluded the session with Risk Management Strategies to Address Vapor Intrusion Assessment and Mitigation Uncertainties. Mr. Ettinger noted that EPA issued a TCE toxicity reassessment in September 2011 that established low Short-Term TCE Response Action Levels (RALs). These new RALs have generated controversy amongst risk assessors and toxicologists, but have also resulted in a shift in investigation methods towards a “top-down” approach where particular attention is paid to indoor air measurements versus estimated values. He showed examples where VOCs in indoor air varied significantly over time due to ambient VOCs in cleaning products and other room contents, and the operation of building ventilation systems, and suggested that longer-duration sampling using passive devices may be valuable in indoor-air assessments. Alternatively, real-time continuous monitoring using portable detection instruments (GC-ECD or HAPSITE GC/MS) can be useful to document the temporal range and variability of VOCs in indoor air. Mr. Ettinger concluded with a list of expedited response actions for mitigating vapor intrusion.

Groundwater Replenishment/Recharge

Moderated by Adam Hutchinson, Orange County Water District

Lyndsey Bloxom of the Water Replenishment District of Southern California (WRD) presented Water Independence Now – The Road to Locally Sustainable Water Resources in a Growing Urban Region. By increasing basin recharge with supplemental sources, WRD has successfully reduced overdraft in the Central and West Coast Groundwater Basins in Los Angeles County by 250,000 AF since its formation in 1959. In the early years, supplemental water was 100% imported; WRD has steadily increased the usage of recycled water since 1962. Their Water Independence Now (WIN) program began 13 years ago with the goal of eliminating remaining reliance on imported supplies. The Groundwater Reliability Improvement Project (GRIP), the most recent and significant component of WIN, will provide 10,000 AFY of fully advanced-treated recycled water and an additional 11,000 AFY of tertiary-treated water. The WIN projects will be completed by 2018, providing a 100% local and sustainable water replenishment source for the region.

Ate Visser of Lawrence Livermore National Laboratory presented Importance of River Water Recharge to Selected CA Groundwater Basins. Identifying the sources of recharge in a groundwater basin is important for interpreting water-quality data and managing water supply. The sources and mechanisms of recharge, whether through natural processes, irrigation return flow or MAR, result in distinct stable-isotopic and noble-gas signatures in the recharged water. These signatures are valuable constraints for numerical flow models. A statistical analysis reveals that river recharge represents approximately 63, 86 and 46% of modern groundwater in the Mojave Desert, Owens Valley, and San Joaquin Valley, respectively. In pre-modern groundwater, river recharge represents a lower fraction: 36, 46, and 24% respectively. The importance of river-water recharge in the San Joaquin Valley has nearly doubled, likely resulting from a total increase of recharge of 40%, caused by river-water irrigation return flows. This emphasizes the importance of recharge of river water via irrigation for renewal of groundwater resources.

Mark Wildermuth of Wildermuth Environmental, Inc. presented 2013 Chino Basin Recharge Master Plan Implementation. The Chino Groundwater Basin in southern CA is an adjudicated basin. Over the past several decades, the area has rapidly urbanized, with agriculture displaced to other parts of the country. Most storm channels in the basin were concrete-lined for flood control purposes, which eliminated their use for stormwater recharge. These activities have resulted in reduced natural recharge to the groundwater basin; in response, the Chino Basin Watermaster and the Inland Empire Utility Agency (IEUA) developed a recharge master plan

Continued on the following page...
in 2000 and implemented it completely in 2005. The master plan was updated in 2013; new recharge improvements, planned for completion by 2020, will increase stormwater recharge by 14,600 AFY and offset the loss of the recharge due to the concrete lining of the channels.

Dick Thompson of Tucson Water presented Fifteen Years of Recharging Colorado River Water. Since the 1990s, Tucson Water has recharged over 1.6 million AF of Central Arizona Project (CAP) water from the Colorado River in its Clearwater Project, which consists of three major surface-water recharge facilities. Through this recharge program, Tucson has been able to add over 500,000 AF of storage credits to the groundwater system. In addition, the recharge facilities have been used to bank water for many other local agencies. An important and often overlooked effect of Tucson Water using its Colorado River water is the recovery of its central wellfield. The static water levels have recovered by dozens of feet and subsidence has been virtually halted throughout central Tucson.

Modeling and Visualization
Moderated by Steven Phillips, US Geological Survey

Colin Kikuchi of E.L. Montgomery and Associates presented Global Sensitivity Analysis of Land Surface Model Predictions to Model Parameters: An Applied Case Study in California’s Central Valley. A global sensitivity analysis, which yields how much each parameter contributes to model predictive uncertainty, was used to evaluate estimates of deep percolation of irrigation water and groundwater pumping for irrigation supply. The area studied was in northern Sacramento Valley; DWR’s C2VSim model and Irrigation Demand Calculator (IDC) were used to simulate these processes. A Monte Carlo approach was used to conduct the global sensitivity analysis, allowing for a broad range of deep percolation estimates, which was the focus of the presentation. Simulated deep percolation was found to be most sensitive to the hydraulic properties of soils, indicating that more information on these values would best improve confidence in model results.

Todd Kincaid of GeoHydros, LLC presented Leveraging Advanced Modeling & Visualization Methods to Support Sustainable Groundwater Management in California. Two case studies were used to demonstrate the effectiveness of visualization methods in understanding groundwater issues. The first involved industrial contaminants in an unconfined aquifer, and whether they could leak into the underlying confined aquifer. Extensive available data were incorporated into a site conceptual model using commercial visualization and analysis software. Resulting animations showed that local subway dewatering was a key factor in contaminant migration, and helped explain greatly varying contaminant concentrations in closely-spaced wells. For the second case study, a groundwater flow model, based on a geologic framework model, was animated to show capture zones for wells as part of a wellhead-protection analysis. This involved a relatively simple, but effective, dual (pumping on/off) steady-state simulation approach.

Ali Taghavi of RMC Water and Environment presented Hydrologic Modeling Needs to Support SGMA? Basin-Scale or Local-Scale Models? Ali began with a general comparison of the basin-scale models of the Central Valley – C2VSim (DWR), and CVHM (USGS). He described the current coarse-grid version of C2VSim as being appropriate for basin- and regional-scale problems, but not for local. DWR is developing a fine-grid version that will allow for local-scale applications. He described the current version of CVHM as being appropriate at all scales. A comparison of the water budgets from these models show that they do not agree overall; both models are going through substantial updates, and Ali anticipates that over time the water budgets will converge. Local models were discussed, using an IWFM model of the Merced region as an example. The USGS sediment-texture model developed for the CVHM was incorporated into the Merced model, as was METRIC data for estimation of evapotranspiration. Summary tables were presented, showing information on existing models.

Joe Hughes of the USGS presented The New MODFLOW. The proliferation of new, more complex MODFLOW versions and packages; related incompatibilities; and restrictions associated with the existing MODFLOW framework have led to the development of MODFLOW 6. This new code has a modern structure, consolidates popular features from previous MODFLOW versions, and has improved solution techniques that support linkage to multiple models of varying type. Each of these models can exchange information with the others, and can have its own resolution; all exchanges between models are tracked in a global budget. The input structure was revised to be human readable, reduce input error, improve error-checking, and allow for easy time-series input of stresses, observations, etc. Both structured and unstructured grids are now fully supported, as is seamless local grid refinement (at much-improved run times). Version 1.0 (groundwater flow) is planned for release by the end of 2016. Near-future versions will focus on transport processes, landscape hydrology, surface-water flow and conduits.

Lunch Program Day 2 – GRA’s 25th Annual Meeting

Chris Petersen, GRA President, opened the Annual Meeting by recognizing GRA’s Directors and Officers present; they introduced themselves and described their roles on the Board. Chris summarized GRA’s accomplishments in the first 25 years. Continued on the following page…
2016 – Groundwater Supply, Quality and Sustainability: the Challenges Ahead, GRA’s 25th Annual Conference & Meeting – Continued

Chris Peterson

years, thanked the founding Directors, and invited two of them (Paul Dorey and Brian Lewis) to the podium to share their thoughts on the original objectives in forming GRA, and our progress to date. Chris then described the current state of the organization, including our 6 Branches, 12 committees, healthy financial condition, and membership location and composition. He closed his presentation with a glimpse into where GRA is heading in the future, including continued Branch growth and expansion, potentially fewer but larger GRA events, increased influence at the Capitol and focus on leadership development and succession planning.

Chris then presented the 2016 President’s Award to the following:

Adam Hutchinson, Director and Officer in Charge of Special Projects
In recognition of your leadership and dedication to the formation of the Ad-Hoc Branches Committee, formation of a new North Sacramento Valley Branch, your continued good work with the Communications Committee and launching of our new GRA Website in 2016.

Jim Strandberg, Director
In recognition of your leadership and tireless energy in Chairing the Events Committee, dedication towards GRA’s 25th Annual Groundwater Conference, and for your continued good work as Chair of the Nominations Committee.

Director Abigail Madrone and Treasurer R.T. Van Valer kept things lively during the President’s reception.

Eddy Teasdale, President of Northern Sacramento Valley Branch
In recognition of your taking the initiative to form and lead our new Northern Sacramento Valley Branch, and your efforts to recruit new GRA members in this region of the state.

Abigail Madrone, Director
In recognition of the energy and innovation you bring to each of your committees, for bringing a positive attitude and encouraging word to every meeting and phone call you participate in, and for promoting GRA’s interests with sponsors, exhibitors and new members.

Director Lisa O’Boyle introduced our 2017 David Keith Todd Distinguished Lecturers for northern and southern CA.

The 2017 northern CA lecturer is Dr. Rosemary Knight, who will present The Use of Geophysical Methods for Groundwater Evaluation and Management. Dr. Knight is the George L. Harrington Professor of Earth Sciences at Stanford University, leads a research group using geophysical methods to image groundwater systems, and is Director of the Center for Groundwater Evaluation and Management.

The 2017 southern CA lecturer is Dr. Claudia Faunt, who will present Water Availability and Sustainability in California’s Central Valley: Past, Present, and Future. Dr. Faunt is a hydrologist at USGS where she has been working since 1988. Her research focuses on water availability and regional groundwater modeling; she is currently the Program Chief of the USGS California Water Science Center’s Groundwater and Applied Modeling section.

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(l-r) Eddy Teasdale, Jim Strandberg, Abigail Madrone and Adam Hutchinson receive President’s Awards from Chris Petersen, and have fun doing it.
2016 David Keith Todd Distinguished Lectures

Moderated by Lisa O’Boyle, Geosyntec Consultants

The 2016 David Keith Todd Distinguished Lecturers delivered their presentations to a general session, concluding the year with a lectureship that was developed to foster interest and excellence in applied groundwater science and technology at CA universities and colleges, and at GRA events. This educational program also promotes the understanding and implementation of groundwater assessment, protection, and management, which are key GRA objectives. This year’s series was made possible through sponsorship by Geosyntec Consultants, Luhdorff & Scalmanini, and Todd Groundwater.

Dr. Behrooz Mortazavi, Principal at Water Resources Engineers Inc., gave an insightful talk addressing the Role of Groundwater in Integrated Water Resources Management. This talk built on his twenty-plus years of experience with establishing water resources management plans at Eastern Municipal Water District (EMWD), 60 miles southeast of Los Angeles. He discussed CA water supply challenges, including implicit uncertainty in climate-change projections, contemporary rainfall and runoff occurring in different months with different intensities than historically seen, and our statewide dependence on the Delta with its own sustainability concerns, including fishery issues, subsidence of low-lying Delta lands protected by aging and minimally-engineered levees, and the potential risks posed by likely seismic events.

Dr. Mortazavi then explored how active water-management planning could better navigate these and other challenges, through a case study of efforts undertaken at EMWD. The district has developed an integrated water resources program that reduces Delta reliance, employing strategies including water recycling, desalination, and conjunctive use. He discussed the process of developing this plan, and the fundamental value of data, modeling, and related technical tools in supporting all policy makers as they develop such plans. Dr. Mortazavi discussed how water rights were secured by EMWD, highlighting the role of a congressional Indian water rights settlement in his basin, and navigating basin adjudication through a stipulated judgment.

He closed with a discussion of efficiency and conservation as a part of sustainable water management, including EMWD’s allocation-based rate structure with its pros and cons. In a figure comparing three years under the tiered-rate plan to the year preceding its rollout, it was evident that this approach was effective in significantly reducing consumption, with a continued downward demand trend in subsequent years for almost every calendar month.

Dr. Miranda Fram, Geochemist and Program Chief of the Groundwater Ambient Monitoring and Assessment (GAMA) Program Priority Basin Project (GAMA-PBP) with the USGS’s California Water Science Center, presented the Quality of Groundwater Used for Drinking Water Supplies in California. Dr. Fram set the stage by discussing the regulated public-supply wells and unregulated private/domestic wells that form the program’s focus, and the role of science in determining where effort is most effective toward end goals, including protecting human health. She offered a glimpse into alternate analysis approaches that could include what percentage of wells versus what percentage of the population as consumers was affected by the top-ten constituents studied by concentration, which included both anthropogenic and naturally-occurring compounds.

As contrasted with public-supply and irrigation wells, domestic and small-system wells tend to have screens that are both shallower and span a shorter depth range. Between the heavy reliance for drinking-water supply and the more pronounced drought effects, the GAMA-PBP prioritized shallow aquifers for focused assessment. A compelling graphic depicted for each basin the proportion of each aquifer falling into three concentration categories (above a benchmark, between benchmark and half-benchmark, and below half-benchmark) for an array of five constituents. In most cases, the impacts were more severe in the shallow/domestic aquifer than the public-supply aquifer.

Dr. Fram concluded with a case study of uranium to explore factors controlling groundwater quality, including anthropogenic activity, the geochemical setting, and assorted effects of time, such as wells accessing groundwater of different geological ages, and combined effects of surface activity and recharge acting to drive groundwater impacts deeper into aquifers.

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A highlight of the conference, the final panel represented some of the state’s leadership in its diverse groundwater engagement. The session focused on the immediate future of groundwater management in CA.

David Gutierrez, Executive Program Manager of DWR’s Sustainable Groundwater Management Program, envisions that DWR will work very closely with the multitude of GSAs as they are preparing and implementing their GSPs over the next years. While DWR has little control in the formation of GSAs, it is offering facilitation services and participating in many of the local meetings. For David it is important that locals are informed about their groundwater basin to enable them to make effective decisions. Transparency and good communication around the technical knowledge of groundwater basins is critical as GSAs work toward solutions. For DWR, having sufficient data and solid data-collection programs, complementary between local and state efforts, in smart and transparent ways, will be an important ongoing activity beyond the initial GSPs. Adaptive management and balanced basins are long-term goals.

David Guy, President of the Northern California Water Association, conveyed three critical points as he considered next steps in groundwater management: first, SGMA will change the culture of groundwater management in the state. More people will be engaged and much more collaboration will occur; he anticipates a change in mindset from SGMA being considered a state-imposed burden to local engagement and buy-in into the process. Second, he cited Governor Brown’s favored policy principle: subsidiarity, i.e., the idea that a “central authority should have a subsidiary function, performing only those tasks which cannot be performed effectively at a more immediate or local level.” (Quoted from Brown’s 2014 State of the State address). Third, there will be new and unanticipated opportunities in the realms of MAR and conjunctive use, the evolution of land-use authorities, changes in contradictory State Water Board policies, the surface-water/groundwater spectrum, and the supply/water-quality/ecosystem-services spectrum.

Erik Ekdahl, Director of the Office of Research, Planning, and Performance at the State Water Board, pointed out that much of the early SGMA work has been with DWR, but that the State Water Board has taken an active role in gearing up for intervention if and when necessary next summer, after the GSA-formation deadline has passed. They are in the middle of rolling out a proposed fee schedule and preparing for contracting services to enable the Board financially and technically for its stewardship role, where it may have to take over groundwater control, at least temporarily. The Board is also actively engaging in a renewed focus on groundwater recharge, and in providing information needed to manage surface-water/groundwater interactions under SGMA.

Kristin Dobbin with the Community Water Center spoke to the challenges and opportunities ahead in the engagement of disadvantaged communities (DCs). Among many, SGMA is considered to be automatically benefitting DCs, especially with CA’s new human right to safe and affordable drinking water. However, affordability remains a critical issue; the definition of minimum thresholds by GSAs may have significant repercussions for DCs, depending on how they are chosen; and the distribution of benefits resulting from SGMA remains largely uncertain. Kristin recounted the day-to-day successes and challenges in implementing SGMA in the Tulare Lake Basin, where she works: existing relationships between DCs and water districts have been a constructive basis for engagement with SGMA; GSA and GSP discussions can create meaningful relationships for discussing groundwater management and protection. Many of these relationships develop organically among local stakeholders and there is a strong desire by local water managers to include DCs in GSA/GSP discussions. Challenges facing DCs include the large number of GSAs, and associated committees, that stretch the capacities of DCs and their representatives. Targeting appropriate technical assistance for DCs remains a challenge.

Jack Rice, counsel for the California Farm Bureau and a Humboldt County grower, had a takeaway message that SGMA will be a very big thing for agriculture. The many regulatory changes of the past 5 years have been somewhat head-spinning for farmers, with some regulatory pieces having been very dynamic, lacking established trust. Groundwater has always had its technical and legal complications for farming interests; with SGMA, it also becomes a bureaucratically complex process. Farmers are currently reinventing the processes by which they engage in SGMA and related processes. Jack foresees that policy-level changes are needed to address storage (above and below ground), more accurate species mapping, and recharge as a beneficial use.

The ensuing panel discussion was lively. The question of whether SGMA addresses current drought issues was raised. David Gutierrez pointed out that SGMA and drought go together, as folks are expected to soon begin the work of bringing groundwater into balance. Addressing groundwater pumping requires considering complex issues, including

Continued on the following page…
social justice, environmental justice, and agricultural economics. Erik Ekdahl expressed the need to better integrate groundwater management and land-use planning, which will remain a challenge under SGMA. Kristin Dobbin pointed out that addressing the well drilling and increase in groundwater pumping is critical to linking groundwater management with land-use planning. Jack Rice added that addressing the lack of surface water and conveyance through the Delta will ultimately be the more important issue.

*Photos taken by Brian Lewis and others.*
California Oil, Gas and Groundwater: 2016
The Latest in Research, Monitoring, Legislation and Regulation Related to Groundwater Protection near Oil and Gas Exploration Sites

November 2-3, 2016, Bakersfield, California

Contributed by Ted Johnson, Jean Kulla, Lynn Edlund, Rob Gailey, Bill Pipes and Chris Petersen

GRA organized a 2016 follow-up to our highly successful 2012 and 2015 symposia on the wise protection and monitoring of CA groundwater near oil and gas production sites. We went to the heartland of petroleum and groundwater extractions in the state—the San Joaquin Basin in central CA—for the perfect setting to discuss the latest information on research performed since the passing of Senate Bill SB-4 (2013, Pavley) that required, among other things, for the State Water Resources Control Board to develop model criteria for groundwater monitoring. Since the 2015 event, there has been increased focus on petroleum waste disposal, underground injection control (UIC), recycling and reuse of produced water, and aquifer exemptions.

As CA increases the scrutiny on, and regulation of, the state’s groundwater resources, technical experts in the oil and gas industry, academia, and governmental agencies are responding to better understand the interactions between the state’s valued oil and gas reservoirs and the aquifers that provide beneficial uses to so many state residents. Whether it is SB-4, the UIC program, or the new General Orders regulating oilfield discharges to land, a commonality is the need to accurately assess potential impacts to groundwater supplies from oilfield activities and to monitor for these going forward.

The California Oil, Gas, and Groundwater 2016 Symposium was designed to provide information on the successful applications, and/or problems encountered with the current requirements, for groundwater monitoring and protection related to oil and gas activities in the state. It proved useful for petroleum and groundwater geologists, engineers, policymakers, regulators, legislators, academia, and other interested parties to learn about current practices, operations, requirements, successes and challenges that create the current context for the relationship between petroleum production and groundwater protection and management in CA.

Over 120 attendees listened to and interacted with experienced speakers from state and federal agencies and academic research institutions, and other professionals working in the groundwater, petroleum, and legal industries. A poster session was held, and an optional field trip featured the Belridge Producing Complex, a major oil and gas exploration and production region operated by Aera Energy LLC. Copies of the available presentations are being sent to the attendees to memorialize the information they heard; a brief summary of symposium content is below.

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California Oil, Gas and Groundwater: 2016 – Continued

Welcome & Keynote Address

Moderated by Ted Johnson, Water Replenishment District of Southern California

The symposium opened with two distinguished keynote speakers from state regulatory agencies to provide a big-picture overview of the current status of the oil/gas/groundwater nexus. After a warm welcome by GRA’s President Chris Petersen, the stage was taken by John Borkovich of the State Water Resources Control Board (SWRCB). John, the Section Chief of the State Water Board, gave a well-organized presentation on the major activities the state is overseeing, including a background leading to where we are today, petroleum-well stimulations and groundwater monitoring (model criteria), produced-water ponds, and underground injection control.

Protected water must be monitored around well-stimulation projects, unless an exemption is granted; protected groundwater is that with less than 10,000 mg/L total dissolved solids outside of an exempted aquifer. The model criteria for groundwater monitoring was adopted on July 7, 2015 in consultation with Lawrence Livermore National Laboratory (LLNL), Division of Oil, Gas, and Geothermal Resources (DOGGR), technical experts, and public stakeholders; data were collected and analyzed by the U.S. Geological Survey (USGS) to help develop the model criteria. The model criteria require Area Specific Monitoring around well-stimulation projects, neighbor-requested sampling, and Regional Groundwater Monitoring programs. Reports on the findings of the regional monitoring program will be prepared every two years, starting January 2018.

John then covered the details of the UIC program, produced-water disposal, and aquifer exemptions. The SWRCB and DOGGR jointly address UIC under a 1988 agreement between the two agencies that is currently under review for an update. They review aquifer-exemption requests and new UIC project proposals, and evaluate existing UIC injection wells to assess the potential impact to protected water. To date, over 30,000 Class-II UIC wells have been reviewed; 23 wells were required to be shut-in, and information orders have been submitted for 257 wells. Regarding disposal of produced water in ponds, the SWRCB is working to ensure that the practice has not negatively affected waters of beneficial use. A total of 1,061 ponds were identified in the Central Valley; 437 of them were unpermitted. Enforcement orders are being drafted for those not covered by permits to ensure protection of groundwater. Exempted aquifers have lesser requirements, and the process for exempting aquifers is under review. Requests for aquifer exemptions by the petroleum industry are increasing. The SWRCB expects 40 proposals by February 2017; they are arriving at a rate of 3 per week. The primary goal of the state before approving an aquifer exemption proposal is to ensure the protection of current and future beneficial uses of water.

Our second Keynote Speaker, Bill Bartling, Inland District Deputy for DOGGR in Bakersfield, presented San Joaquin Valley Aquifer Exemptions, UIC Reviews and Produced Water Use. Bill drilled down into the history and activities of the petroleum industry for this part of the Central Valley, providing context and meaning for the location of the symposium. He explained how the natural groundwater salinity in the valley generally increases from the east (fresher groundwater) to the west (brackish groundwater), and from shallow to deep, due to fresh recharge from the granitic Sierra Nevada on the east side, versus sparse rainfall on the west side. The minimal recharge on the west side is insufficient to dilute the naturally saline formation waters from sedimentary source rocks.

Bill also described the aquifer exemption and UIC proposal and approval processes in the valley, and the extensive reviews, analysis and interaction with other agencies that now take place to ensure the safety of protected waters. He described DOGGR’s statewide roles and responsibilities, and the modernization of several techniques, reviews, permitting, and oversight activities that DOGGR is employing. DOGGR regulates all activities associated with drilling, producing, and abandoning wells associated with oil and gas production, and enforces the laws and regulations to optimize the value of the underground resource, while ensuring maximum protection of safety, health, life and the environment, including underground and surface waters suitable for irrigation or domestic use.

Some of the activities on the front burner for DOGGR are (1) water-quality issues, including aquifer exemptions and UIC; (2) implementing new hydraulic fracturing requirements under SB-4, which is a rigorous process that saw the first two permits taking over a year to issue; (3) induced-earthquake monitoring— unlike Oklahoma, there is no evidence of earthquakes caused by injection of produced water.

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waters in CA, although studies continue; and (4) fugitive emissions, such as what occurred in the Aliso Canyon natural gas leak from late October 2015 to mid-February 2016. To meet these new challenges, DOGGR is modernizing data management; converting from paper to digital formats; reviewing and revising past practices, including regulatory overhaul, new regulations, and ensuring a high-quality work force; developing a risk-based data management system; and using new technologies to expand the scope and breadth of hydrocarbon resources understanding, including earth observatory, remote sensing, multi-variate statistical analysis, and predictive analytics. DOGGR is on a path to revise its past paradigm from a reactive and punitive mode to a predictive and preventative mode to avoid trouble in advance and to recognize and intervene in impacting events and practices.

Groundwater Supply and Protection

Moderated by Lynn Edlund, Trihydro Corporation

Matt Landon, Project Chief for the USGS California Oil, Gas, and Groundwater project in support of the SWRCB’s regional monitoring program in oil and gas areas, presented Overview of Regional Monitoring of the Potential Effects of Oil and Gas Development on Groundwater Resources in California. Several factors make it difficult to separate the effects of well stimulation from other activities, such as the long history of oil and gas in CA (100-plus years), and the UIC program (which has operated for 60 years). He discussed salinity mapping, oil-field water sampling and groundwater sampling, and the importance of understanding the geologic framework.

Rich Juricich is a Principal Water Resources Engineer with the California Department of Water Resources (DWR), and manages the Sustainable Groundwater Management Branch. His presentation was titled Water Available for Water Replenishment. He provided an overview of the Sustainable Groundwater Management Act (SGMA) of 2014, with the goal of empowering local agencies to manage their resources. Key milestones were included in the Act: phase 1 requires that a governing agency be created for each groundwater basin covered in the Act by October 2017; phase 2 requires the development of a Groundwater Sustainability Plan by 2020 or 2022; phase 3 requires management through water budgets and/or modeling, other tools, development of water projects and other management actions as defined by the Plan; and phase 4 is achieving sustainable groundwater management by 2040 and beyond.

Steve Bohlen of the LLNL is the E-Program Manager in the Global Security Directorate, and also is the former head of DOGGR. His presentation was titled Science Advisory Board’s Review of USEPA’s Draft Assessment of Potential Impacts of Hydraulic Fracturing on Drinking Water Resources. The major findings of the report stated that there is no evidence of widespread, systematic impacts on drinking-water resources from hydraulic fracturing. However, there were some challenges with the study. The study was a national-level review, not at the scale of regional and local impacts; and it provided an overview of conditions in a fast-changing environment. He concluded the presentation by stating that “good science takes time,” which seemed to be a common theme in other talks during the symposium.

Clay Rodgers is an Assistant Executive Officer at the Central Valley Regional Water Quality Control Board. His presentation, titled General Orders for Discharges to Land, discussed the three types of General Orders issued by the CVRWQCB: (1) discharges of produced wastewater, either to ponds or for use as dust control [no produced wastewater can be used for the irrigation of crops for human consumption]; (2) discharge of solids as road mix; and (3) existing facilities only.

Continued on the following page...
California Oil, Gas and Groundwater: 2016 – Continued

Lunch & Keynote Speaker

Moderated by Murray Einarson, Haley & Aldrich

After informative morning talks followed by a fine meal, we heard from our lunchtime keynote speaker, Richard Jackson of GeoFirma Engineering in Ontario, Canada. Dr. Jackson has worked both in the U.S. and Canada as a hydrogeologist since the early 1970s, has expertise in the characterization, migration and fate of radioactive wastes and non-aqueous phase liquids in the subsurface, and has led teams on petrophysics and geochemistry.

Richard’s talk was on Fracking, Wellbore Integrity and Groundwater Quality: A Canadian Perspective. He presented detailed information from his first-hand experiences and research on topics including (1) incidents involving hydraulic fracturing stimulation, (2) the leaky-well issue, (3) formation of fugitive gas, (4) penetration of aquifers, (5) reactions with groundwater, and informed the audience that the perceptions Canadians have of hydraulic fracturing come from the U.S. By that he meant the protest signs and demonstrations that have been pervasive in the media over the past few years. Well-documented technical reports, such as the 2014 Expert Panel findings in “Environmental Impacts of Shale Gas Extraction in Canada,” helped to provide facts over myth.

Unconventional oil and gas development is widespread in Canada, and much research has been done. Western Canada alone has at least 13 unconventional/tight oil resource plays and 7 gas resource plays. They have learned that operator error can make fracturing hazardous, and that shallow depths are problematic for multi-stage fracturing because the induced fractures are horizontal. Numerous other potential pathways for fracturing fluids to interact with the environment were presented, along with actual Canadian case studies of incidents that occurred during hydraulic fracturing, including well interference, blowouts, and interwellbore communication.

On the leaky-well issue, he noted that well integrity is the key to minimizing many of the risks associated with hydraulic fracturing, and cited many examples indicating this is not a new finding. The literature has reported for decades the potential problem of contaminating aquifers by over-pressurizing the annulus of oil and gas wells. Even oil and gas wells that have been plugged and abandoned can leak along the casing due to cement shrinking, channeling, poor mud-cake removal, and high cement permeability. Fugitive gas that forms downhole and rises in slugs and pulses, or continuously, can find these pathways and migrate into aquifers or out into the atmosphere. He provided an example of gas invasion into the Berea sandstone aquifer in Ohio. The implications of wellbore leaks are that seepage of methane remains endemic in both legacy wells and new wells.

This all led to the importance of monitoring both groundwater and oil/gas wells for potential methane leakage. He concluded by pointing out the consequences of water-well contamination by natural gas, which included an increase in pH, decrease in Eh, increase in alkalinity, sulfate reduction to hydrogen sulfate, nitrate reduction to ammonium, reduction of iron and manganese to allow release of the dissolved phases into groundwater, and readjustment of common cations to new equilibrium conditions. The audience laughed with his final comment on this point, that “oxidation of an organic compound produces an inorganic waste → ‘geochemical hangover’.”

Assessment and Monitoring – Part 1

Moderated by Brent Miyazaki, AECOM

Shawn Paquette of GSI Environmental led off the session and presented a Tiered Approach to Evaluation and Management of Produced Water Impacts on Groundwater Resources. The two key questions to start the process are (1) is there an impact from produced water, and if so, (2) how do we manage the impact in a sustainable manner? He went on to explain the principal elements to explore, which are injury (groundwater impact), loss of service (i.e. beneficial use of groundwater), and the damage (monetary value of the lost service). A tiered evaluation approach is used to provide the most effective and efficient evaluation, and includes techniques to distinguish salinity sources and develop multiple lines of evidence. Several examples of natural resource assessments were shown to emphasize his points.

Murray Einarson of Haley & Aldrich presented an Overview of Groundwater Monitoring Technologies to Support Groundwater Monitoring in California Oil and Gas Fields. Murray covered several important considerations for proper groundwater monitoring in deep environments, including differences in solute concentrations, vertical head distributions, and the pros and cons of various monitoring-well construction strategies. Direct-push geochemical profiling has shown that solute mobility can be highly complex and non-uniform.

Continued on the following page...
owing to discrete heterogeneities of the subsurface. Detecting contamination that is following narrow discrete paths may be extremely difficult with single, long-screened wells, or may even be missed with improperly placed nested or clustered wells. Vertical gradients between aquifers are very common and poorly understood, and can drive groundwater (and any contaminants) upward or downward. Engineered multi-level monitoring systems (MLS) can have significantly more water-level measuring and sampling points than traditional monitoring wells to provide the high-resolution data needed to more thoroughly monitor and understand groundwater conditions and potential risk from oil and gas operations. Over 2,000 MLS systems have been installed in CA in the last 30 years, and generally have proven successful, although there are a few disadvantages to MLS that Murray highlighted.

John Sankey of True Blue Technologies continued the theme of MLS technologies with his presentation on Groundwater Characterization for Unconventional Oil, Gas, and Mine Developments. He focused on one particular MLS technology, the Westbay System, which has been used extensively in CA as a multilevel groundwater monitoring platform to measure formation pressures, obtain water-chemistry samples, perform hydraulic-conductivity testing, develop vertical profiles of hydraulic gradients and water quality, and automated monitoring of pressures and temperatures over time. With the ability to have 26 or more separate monitoring zones in a single borehole, the system can be used in deep oil and gas environments to monitor potential leakage and impacts to shallower groundwater systems.

Lyndsay Ball of the USGS Crustal Geophysics and Geochemistry Science Center presented Use of Airborne and Surface Geophysics for Mapping Changes in Groundwater Salinity and Geology. She provided an overview of resistivity of earth materials (lithology and groundwater), and applications for interpreting the subsurface geology and water quality (salinity), focusing on defining the base of protected water (TDS < 10,000 mg/L). She reviewed the typical methods for collection of resistivity data, from borehole and surface geophysics (including transient electromagnetic soundings, or TEM) to the relatively new use of airborne electromagnetics (AEM) for faster and more widespread data collection. AEM surveys, which are done from helicopters or airplanes, are able to collect about 100 km of lines per hour, compared to about 1 km per day for traditional ground-based methods. As with other electromagnetic surveys, too much interference from metallic features and urban areas impact the quality of AEM data. Lyndsay provided preliminary results from a Kern County AEM survey that showed good contrasts between relatively high and low resistivity markers. Understanding that resistivity is affected by both lithology and water salinity, processing and interpretation approaches were outlined for defining the likelihood of freshwater aquifers based on the resistivity data. To do this, resistivity-salinity relations were developed, as well as probability-based maps showing relations between clay content, groundwater salinity, and resistivity.

Water Supply, Handling and Recycling
Moderated by Jean Kulla, K2 Enviro Inc.

Earl Hagström, attorney and partner with Sedgwick, LLP, and former petroleum geologist, presented Produced Water: Valuable Resource or Waste by-Product? He discussed the increasing demand for water as a limited resource, and the competing demands for domestic, agricultural, industrial, and other uses. He emphasized that produced water is no longer a waste, but a potential resource; however, not all users of recycled produced water need the same finished quality of water. Therefore, he concluded that a better way to manage the treatment needs of the produced water is to match the treatment technology and final quality to the desired end use. Currently, there are overlapping jurisdictions, laws, and conflicting standards inhibiting the best uses of produced water as a resource.

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Eric Averett of the Kern Groundwater Authority presented *How is SGMA Being Implemented in Kern County?* He discussed the inevitable need for regulation now encompassed in the SGMA that requires a basin to be managed in a manner to avoid or eliminate “undesirable results,” including: chronic lowering of groundwater levels, reduction in groundwater storage, seawater intrusion, degraded water quality, land subsidence, and depletions of interconnected surface water. SGMA requires the formation of a Groundwater Sustainability Agency (GSA) and formulation of a Plan (or Plans), which takes significant coordination. The Kern Groundwater Authority is trying to coordinate among competing interests to keep planning ‘local’ and provide a venue to present and discuss issues, such as water budgets, sustainable agency formation, and other matters. As conveyed by Mr. Averett, California water is a story of doing more with less:

- Regulatory burdens/environmental restrictions challenge agricultural & oil interests, but can be overcome
- Water is critical to a successful economic engine
- Strategic investments in infrastructure are needed
- Legal/Policy adjustments are needed to balance social, economic and environmental needs for water.

Willie Morris of Aera Energy provided an introduction and preview for the optional field trip at the end of the symposium. Aera Energy, which is jointly owned by affiliates of Shell and ExxonMobil, is headquartered in Bakersfield with a daily production (2015 values) of 126,300 barrels of oil/day; 32 million cubic feet of natural gas/day; and 431,000 barrels of steam/day. Eighty percent of its production comes from oilfields in Kern County. Aera is the second-largest oil producer in California, representing over 25 percent of the state total, with 2015 revenues of more than $2 billion, and over 1,000 employees and thousands of contractors. A surprising fact for the audience was that Aera drilled about 1,000 wells per year, every year, between 2000 and 2015—that’s 2 to 3 wells per day, every day! With the new SB4 regulations and other compliance criteria and associated reviews and delays, that has been reduced to about 500 wells in 2016. Currently, Aera has 11,049 production wells and 3,635 injection wells. He stated that Aera’s goal is to be self-sufficient in water use; over 99% of Aera’s enhanced oil recovery (EOR) water is recycled produced water. They use about 150 acre-feet per year of “fresh” groundwater (TDS from 4,000-10,000 mg/L) for EOR and about 3,000 acre feet per year for remaining operations. At the Belridge Complex, they have reduced reliance on aquifer source water by incorporating a closed system and have eliminated freshwater use for EOR. Their “Water Treating Plant” has a new filtering plant that enables reinjection of 360 thousand barrels of water per day, and the “Soft Water Plant” enables reinjection of 200 thousand barrels of water per day as steam. The water treatment facility is a $700 million facility.

**Poster Session**

After a full day of interesting and diverse technical talks on oil, gas and groundwater, it was time to relax at the reception room, where hors devours and drinks were served while participants mingled, networked, and visited the 7 posters and their authors. The posters were prepared by authors from the USGS, CSU Sacramento, CSU Long Beach, Intera Petroleum Consultants, and BESST, Inc. Their titles were:

- Preliminary Prioritization of California Oil and Gas Fields for Regional Groundwater Monitoring Based on Intensity of Petroleum Resource Development and Proximity to Groundwater Resources
- Converting Scanned Oil Well Data into Usable Digital Data
- Calculation of Groundwater Salinity Using the Resistivity-Porosity (RP) Method on Digitized Geophysical Logs from California Oil and Gas Fields
- Scaling Up Well Log Interpretation for Groundwater Salinity Mapping in the Age of Big Data
- Mechanical Properties of Siliceous Mudstones Relative to Composition, Porosity, and Diagenesis. Upper Monterey Formation, Belridge Oil Field, San Joaquin Basin, California
- Optimization to Reduce Water Use while Increasing Asset Value
- The Tracer Pulse Flowmeter and Depth Dependent Sampler: High Resolution Groundwater Data from Long-Screened Test Wells and Boreholes.

They were all very interesting posters that contributed to the knowledge provided at the event. And Day 2 was still to come...
Groundwater Assessment and Monitoring – Part 2

**Moderated by Bill Pipes, Amec Foster Wheeler**

**Peter McMahon** of the USGS presented results of his current work regarding produced-water injection at oilfields for EOR and/or disposal, and a conceptual model for the design of a groundwater monitoring program. Peter’s model consists of two basic parts: (1) identifying the zones of useable groundwater in the vicinity of the oilfield, and (2) the depth and density of injection wells in the oilfield. He then discussed the design for the initial round of monitoring and how to use these data to design a longer-term program.

**Deborah Olson** of PayZone, Inc., presented techniques for developing water-salinity profiles from resistivity logs. Given the size of oilfields and the multiple oil and gas reservoirs in most fields, monitoring groundwater quality near oilfields can be quite challenging. Most investigators find that existing temporal and spatial data can be sparse, and even for a well-designed sampling program, data gaps can be substantial. One of the tools scientists are using to close these data gaps is estimating groundwater quality from the interpretation of downhole geophysical logs (e-logs). E-logs are numerous in oilfields, and since the 1930s, petroleum geologists have developed techniques to measure water salinities in water-saturated reservoir sands. Developing salinity profiles from resistivity logs is called the resistivity-porosity method, and the derivation of the resistivity of water in a formation using the Archie equation can be used to calculate the total dissolved solids (TDS) of the water. However, it’s not quite that easy, as Deborah explained, because the resistivity-porosity method using the Archie equation can prove very useful in providing the needed data. Taking it one step further, Deborah and her team are using statistical methods to speed up the log interpretations (“Statistical Learning Method”). First, they are digitizing the logs; from these digital data, they calculate water and rock parameters. They then optimize the results by an iterative process where they estimate what combination of water and rock parameters best explain the observed log data using standard petrophysical equations. Although still preliminary, this work may prove useful in supplying critical temporal and spatial water-quality data in the future.

**David Shimabukuro** of California State University Sacramento presented the initial results of work being conducted by him and his students, in collaboration with the USGS, in mapping groundwater salinity near oilfields. After documenting the limitations of existing datasets, David discussed the use of geophysical logs to fill the data gaps and, as Deborah explained, the resistivity-porosity method using the Archie equation can prove very useful in providing the needed data. Taking it one step further, David and his team are using statistical methods to speed up the log interpretations (“Statistical Learning Method”). First, they are digitizing the logs; from these digital data, they calculate water and rock parameters. They then optimize the results by an iterative process where they estimate what combination of water and rock parameters best explain the observed log data using standard petrophysical equations. Although still preliminary, this work may prove useful in supplying critical temporal and spatial water-quality data in the future.

**Justin Kulangoski** of the USGS presented the results of work by him and his colleagues regarding the design of monitoring systems under California’s SB4 program. Their work focuses on the possible use of indicator chemicals and/or chemical ratios that may point to potential impacts to groundwater by oil and gas production. Using data from oilfields in the LA Basin and the San Joaquin Valley, they have studied indicators of salinity and methane from produced water and the use of petroleum and manufactured hydrocarbons and radium as tracers. They have concluded that indicator chemicals and/or chemical ratios in groundwater are a useful way to identify produced water mixed with groundwater, but that multi-tracer approaches are needed to distinguish sources and pathways of groundwater-oil/gas interactions. Additional data will be needed regarding the chemical and isotopic compositions of produced water within and between oilfields.

*Continued on the following page...*
California Oil, Gas and Groundwater: 2016 – Continued

Legislative and Water Quality Updates and Issues

Moderated by Rob Gailey, R M Gailey Consulting Hydrogeologist

The final session of the conference included four speakers. Thomas Minter of AECOM summarized recent legislative and regulatory developments at the state and federal levels. Luis Navarro of ERM provided a detailed overview of a risk-based development of water-quality guidelines for using produced water to irrigate crops and demonstrated a favorable comparison between the water-quality guidelines and quality of produced water from certain oilfields in Kern County. Bill Gorham of AECOM provided an overview of the status of, and challenges with, permitting well stimulation treatment at the state and county levels under the California Environmental Quality Act. Jon Parker of the Kern Water Bank Authority summarized water-bank function, emphasizing the importance of good water quality to successful operations. He then provided examples of challenges to water quality posed by some oil and gas operations, and pointed out some weaknesses in the groundwater-quality monitoring guidelines for well-stimulation treatment projects within the context of water-quality protection.

Field Trip to Aera’s Belridge Producing Complex

Moderated by Chris Petersen, GEI Consultants

A group of 25 attendees participated in the optional field trip to the Belridge Producing Complex on the afternoon of the second day of the symposium. The Belridge Producing Complex of Aera Energy LLC (Aera) includes exploration and production operations in the North and South Belridge, Lost Hills, Cymric and McKittrick oil fields located about 50 miles northwest of Bakersfield.

Upon arrival, the group was provided a security and safety briefing at the Learning Center. Aimee Blaine, VP Engineering, then provided a brief presentation of Aera’s Total Water Stewardship program, including regulatory compliance and water conservation. The Group then re-boarded the charter bus with Operations Managers John O’Conner and Cory Wolf and were treated to a driving tour of the oil fields while John and Cory described the oil and water production and processing infrastructure. During the tour, we learned several fun facts about the Belridge Production Complex, including:

- It produces over 77,641 barrels of oil per day
- Aera employs more than 1,600 people at this location
- Comprised of 6,613 oil production wells (Photo 1)
- 1,354 steam injection wells
- 1,298 water injection wells (Photo 2)
- 250 miles of pipeline
- 400 miles of road
- 5 oil plants
- 5 water plants (Photo 3)
- Oil production began at this location in 1916
- South Belridge is the 6th most productive field in the US.

*Photo 1 – Oil Production Wells*
California Oil, Gas and Groundwater: 2016 – Continued

One of the highlights of the trip was a stop at the recently completed (2015) water treatment plant. We took a group photo at this location (Photo 4). Here we learned that this plant is capable of treating 300,000 barrels per day, or in water units, 17 million gallons per day (MGD). Our last stop of the tour was the Oasis Office Complex, or the “brain center” of the operation. (Photo 5). We were impressed with how open and transparent Aera is about sharing information and data on their production operations with all of their employees.

This was a very interesting and informative field trip and we were encouraged to see first-hand the investments Aera is making to protect the safety of their employees, protect the environment, and to achieve their commitment to treat and reuse 100% of their oil-produced water.

Closing

GRA would like to thank the Committee members who spent the last year volunteering their time to organize and put on this symposium, including Ted Johnson, Jean Kulla, Brent Miyazaki, Rob Gailey, Lynn Edlund, Murray Einarson, and Dan Segal. GRA also thanks the team at Smith Moore Associates, led by Sarah Kline, who managed all of the logistics of the event. Thanks also go to the sponsors and exhibitors whose contributions helped to keep costs down and provided a showcase of useful information on their services, and of course to all the speakers and attendees.

Photo 2 – Water Injection Wells (to maintain fluid pressure in the oil reservoir and prevent land surface subsidence)

Photo 3 – Belridge Water Softening Plan

Photo 4 – Team Photo at Water Treatment Plant

Photo 5 – Oasis Operation Center and Office Complex
Sustainable Groundwater Management Conference: Groundwater Sustainability Plan Tools

MAY 3-4, 2017 – MODESTO, CA

Symposium Details:

A critical step for compliance with the Sustainable Groundwater Management Act (SGMA) is the development of a successful Groundwater Sustainability Plan (GSP). This conference focuses on tools and techniques that can support key elements and programmatic considerations for GSP development.

- Best Management Practices (BMPs) for Sustainable Groundwater Management
- Quantifying GSP Measurable Objectives
- Water Available for Replenishment
- Streamflow Depletion and Groundwater Dependent Ecosystems (GDEs)

The conference program provides policy-makers, stakeholders, regulators and other government entities, NGOs, consulting professionals and practitioners, growers, and landowners the opportunity to present their work, and to interact and learn about the emerging BMPs; quantifying measurable objectives for GSPs under the six criteria defined by the SGMA for groundwater sustainability; and new research on water availability, streamflow depletion, and GDEs.

Conference Outline for Abstract Topics

This two-day conference features keynote speakers on water resource management practices and presentations from DWR policy makers and state regulators, NGOs, water resource stakeholders, and academic and consulting industry leaders. Featured topics for abstracts for podium and poster presentations include:

- BMPs for Sustainable Groundwater Management
  - Groundwater Monitoring Networks
  - Water Budgets
  - Hydrogeologic Conceptual Models
  - Modeling
- Quantifying GSP Measurable Objectives
  - Groundwater Data Collection and Uses
  - Subbasin Baseline Assessment - Methods for Hydrogeologic Analysis
  - Practices, Techniques, and Tools in Hydrologic Modeling
  - California’s Open and Transparent Water Data Act
- Water Available for Replenishment
  - Beneficial Use of Water in Replenishment
  - Type and Timing of Water Available for Replenishment
  - Effects of Climate Change Scenarios on Water Availability
- Stream Depletion and Groundwater Dependent Ecosystems
  - Understanding and Quantifying Surface/Groundwater Interactions
  - GDE Impacts/Mitigation
  - Field Methods and Simulation Approaches
  - Legal, Policy and Regulatory Compliance

Call for Abstracts:

Abstracts are being solicited for the topics listed above. Abstracts will be accepted through December 31, 2016. Click here to submit an abstract for a paper or poster presentation.

Need additional information for submission of abstracts? Contact:

Technical – Brett Wyckoff, DWR: Brett.Wyckoff@water.ca.gov or (916) 651-9283

Administrative – Sarah Kline: skline@grac.org or (916) 446-3626

Sponsor and Exhibitor Opportunities:

If you are interested in being a sponsor or exhibiting your organization’s services or products, please contact us at conference@grac.org or by telephone - Sarah Kline (916) 446-3626. Please visit the conference website for more event information.
Wells and Words
By David W. Abbott P.G., C.Hg., Consulting Hydrogeologist

Straight-Line Versus Curve-Matching Methods for Evaluating Pumping Tests

Groundwater elevation changes caused by a discharging well during a pumping test are measured in observation (obs) wells at varying distances and directions from the pumping well. Storativity (S) and transmissivity (T) of the aquifer can be derived using obs data from multiple wells; in contrast, only T can be estimated with a single-well pumping test. When groundwater is discharged from a well, a cone of depression forms in the shape of an inverted cone. This shape is due to radial groundwater flow converging at the well through progressively smaller cross sections; hence, the hydraulic gradient must increase as flow approaches the well, according to Darcy’s Law. T affects both the depth and radius of the cone of depression, S affects the rate of lateral expansion of the cone, and discharge (Q) affects the depth but not the radial expansion of the cone. The shape of the cone of depression around a well is defined by the familiar non-equilibrium formulae: either the more formal Theis Equation (curve-matching method using double-logarithmic [log] plots) and/or the equivalent, more simplified, Cooper-Jacob (C-J) Equation (straight-line method using semi-log plots).

Q is in gallons per minute (gpm)
T is in gallons per day per foot (gpd/ft)
\( t \) = elapsed time of pumping in days
\( r \) = the distance from the pumping well to an obs well in feet (ft)
S is unitless
\( W(u) \) is the well function, which is an exponential integral

Tables of values of \( W(u) \) for estimates of u can be found in most textbooks. These two equations form the basis for evaluating pumping tests and provide about the same answers if u is less than (<) 0.05. Groundwater hydrology textbooks provide these equations in other formats and in metric units; care must be taken to use consistent units.

Figure 1 shows a family of semi-log plots of 5 obs wells that responded to a pumping test. The x-axis (log) is elapsed time since pumping began in minutes (min) and the y-axis (arithmetic) is the measured drawdown (dd) from the static (non-pumping) water level. The distances from the pumping well to the 5 obs wells are shown on Figure 1 and range from 1,222 to 3,732 ft. The pumping well, not shown on the figure, was pumped at an average of 1,621 gpm for 72 hours with a “stabilized” (no significant change during the test) dd of about 26 ft. Shown on Figure 1 (gray line and right-hand scale) is the measured discharge during the test. The dashed gray lines show the ±5% suggested tolerance-level of discharge variation during a pumping test. The discharge varied significantly during the first 24 hours, which can affect the early time-dd data and subsequent interpretations.

It is easy to notice that the time-dd plots for these 5 wells form straight lines on semi-log plots; some are nearly parallel. The slope s or “delta s” of the straight line in ft per log cycle is used to estimate T; for the red well, s = 0.72 ft; for orange, s = 0.81 ft; for purple, s = 0.46 ft; and for green, s = 0.40 ft. The blue well did not stabilize (constant slope indicates stability), and should not be used to estimate T; the dds observed in the blue well, in late time, represent a part of the curve that is commonly referred to as the “roll-over” portion. The following simple equations, derived from the C-J Equation, can be used to estimate T and S.

The term \( t_0 \) is the elapsed time when the dd = 0 (i.e., the straight-line back-projection to the 0-dd axis). For the red, orange, purple, and green wells, \( t_0 = 28, 28, 40, \) and 170 min, respectively. T and S for each well are tabulated on Figure 1. T ranges from about 528,000 to 1,061,000 gpd/ft, and S ranges from 0.0016 to 0.0068. These variations in T and S can be caused by changes in aquifer architecture in different directions (anisotropy, aquifer thickness, heterogeneity, etc.), differences between obs-well construction profiles and screen...
locations, or not meeting the $u < 0.05$ criterion for the C-J Equation. Calculations show that the elapsed time that meets the $u < 0.05$ criterion ranges from greater than (>) 311 min for the red well; >313 min for orange; >443 min for purple; >1,919 min for green; and >2,900 min for blue. The red, orange, and purple wells meet this criterion.

The estimate of $T$ depends on the value of $s$ provided for each obs well from the time-dd curve at times that yield $u < 0.05$; $s$ ranges from 0.40 to 0.81 ft (a difference of 0.41 ft, or 5 inches) and are based on 2 complete log-time cycles for red, orange and purple, but only 1 cycle for green, and $\frac{1}{2}$ cycle for blue. A greater level of confidence for parameter estimations occurs if an obs well exceeds a dd of at least 1 ft; the red well is $>1$ ft of dd; the orange and purple wells approach 1 ft of dd; and the green and blue wells are significantly $<1$ ft of dd. This implies that the pumping test was either not long enough or the discharge was too slow to achieve significant dds in the more distance obs wells; alternatively, the green and blue wells are too far from the pumping wells to provide meaningful data under these operating parameters.

Figure 2 shows the same data given on Figure 1, but on a double-log scale used for the Curve-matching method of Theis. A Theis type curve (shown in black on Figure 2) is constructed on a template and is used to select paired match points using the best-fit or best curve matches. The paired points correspond to $s$ and $t$ on the obs well chart and $1/u$ and $W(u)$ on the type-curve chart. These match-point values are then inserted into the Theis Equation to estimate $T$ and $S$. $T$ and $S$ for each of these wells are tabulated on Figure 2 using this method. $T$ ranges from about 539,000 to 985,000 gpd/ft, and $S$ ranges from 0.0027 to 0.0074. These values are comparable to other values estimated from the straight-line method, especially considering that hydraulic conductivity can vary over 13 orders of magnitude. The estimates for $T$ and $S$ for the blue well using this method deserve further attention, since $S$ is an order of magnitude higher than the other estimates.

Because the straight-line method is easier to apply, it is recommended that pumping-test data be evaluated in the field using the C-J Equation prior to turning the pump off for the recovery phase of the test. The data collected during a pumping test, especially for the pumping well, should be evaluated “point by point” to allow proper field adjustments to be made during the test to avoid significant discharge variations. However, the Theis analysis should be conducted to verify the C-J analysis; this can be done in the office. Field evaluation of the data also allows adjustments to be made to the length of the pumping test; for example, a 3-day pumping test would be unwarranted if the water levels flatten after 10 hours of pumping.

While conducting pumping tests, be flexible but methodical. Ideally, the initial data evaluation should be completed before the end of the test, and before the technician packs up to leave the site, to allow for modifications in the field. Back in the office, follow-up the straight-line method used in the field with the curve-matching method. Recall that the analysis is based on $s$, or ft per log cycle; more frequent measurements between 0 and 10 min will sometimes yield one or two additional log cycles. Measure the discharge frequently and review the dd responses during the pumping test; this technique can yield more reliable and consistent data. Look for drawdown patterns, such as flattening or steepening of the drawdown slopes of cyclic patterns, that may suggest earth- or ocean-based tidal or atmospheric responses. Always calculate the critical casing storage time to evaluate early time-dd data, and always estimate if $u < 0.05$ for the time-dd data. Larger dds in obs wells are better, more significant, and reliable than smaller dds in estimating $T$ and $S$. Assign greater importance to obs wells that have dds that exceed 1 ft to avoid circumstances, like the blue well above that suggest $s$ had not stabilized. Don’t forget to also evaluate the pumping test with distance-dd plots, which will be discussed in a future edition of Wells and Words.

3 Theis, C.V., December 1957 reprint from the USGS, *The source of water derived from wells essential factors controlling the response of an aquifer to development* [originally published in May 1940 in the American Society of Civil Engineers’ magazine (p. 227-280)]; USGS Ground Water Notes, Hydraulics, No. 34
EPA Launches the Climate Resilience Evaluation and Awareness Tool

EPA’s Climate Ready Water Utilities (CRWU) initiative has launched the latest update to its Climate Resilience Evaluation and Awareness Tool (CREAT). CREAT 3.0 assists drinking-water, wastewater and stormwater utility owners and operators in understanding potential climate-change threats and in assessing the related risks at their individual utilities. CREAT 3.0 is now web-based and features a series of intuitive modules designed to help utilities complete a climate-change risk assessment, redesigned from the ground up to provide a more user-friendly experience. For more on CRWU and CREAT, check out: https://www.epa.gov/crwu.

Scientists Assess 100 years of Los Angeles Groundwater Replenishment

A new study offers the most sophisticated analyses to date on how Los Angeles-area groundwater supplies are replenished. The analyses provide water managers with a clearer understanding of the sources and amount of available groundwater in the region—information that is important for planning and management of the vital resource. The study was conducted by the U.S. Geological Survey in cooperation with the Water Replenishment District of Southern California. Scientists used a new computer model to simulate rainfall and runoff in the greater Los Angeles area and surrounding watersheds. They found that the average groundwater replenishment rate in the greater Los Angeles area from 1915–2014 was about 69,000 acre-feet per year, but varied with precipitation from less than 20,000 acre-feet in drier years to more than 200,000 acre-feet in wetter years. The study, *Estimating spatially and temporally varying runoff and recharge from rainfall and urban irrigation in the Los Angeles basin, California*, is available online.

Importance of Young Dissolved Organic Carbon to the Release of Arsenic in Aquifers

Carbon from relatively new sources of organic material on the surface, or young carbon, can stimulate microbial communities deep in aquifers, leading to the release of arsenic into water, according to a recent field study by Columbia University Superfund Research Program (SRP) Center researchers. The researchers found that near-surface sources of organic carbon are central in microbial metabolism, even in aquifers that are far below, and separated from, the land where carbon is derived. For more information, click here.

EPA Launches Tool to Improve Reporting of Drinking-Water Data

EPA’s new Compliance Monitoring Data Portal (CMDP) allows water laboratories and public drinking-water systems to electronically share drinking-water data with their states and tribal agencies. The portal will replace the paper-based system, leading to more timely and higher-quality monitoring data. CMDP’s launch marks the completion of the first phase of EPA’s multi-year Safe Drinking Water Information System (SDWIS) modernization project. EPA is also making improvements in the development of a system called SDWIS Prime. Prime will improve state decision-making by using the sample data received from CMDP to develop new reports and provide automated notifications. Prime is currently scheduled for release in 2018. For more on the release of CMDP, please visit this site.

Jamie Marincola is an Environmental Engineer at the U.S. Environmental Protection Agency Region 9 Water Division. For more information on any of the above topics, please contact Jamie at 415-972-3520 or marincola.jamespaul@epa.gov.
Submarine Groundwater Discharge (SGD)

By Bart Simmons

SGD is reviewed in a recent article in the journal Science (Audrey H. Sawyer, Cédric H. David, James S. Famiglietti, Continental patterns of submarine groundwater reveal coastal vulnerabilities, vol. 353, pp 705-707, Aug. 2016). The authors used a simple water-budget analysis plus state-of-the-art continental-scale hydrography and climate datasets to estimate fluxes of SGD. Estimates of fresh SGD were made for catchments draining to the coast, outside the catchments of rivers draining to the coast. Their estimates may be low because of contributions from upland catchments; however, the estimates of flux are significantly lower than previous estimates at the same locations.

The authors found local variability in SGD to be almost as large as large-scale variability along the coast. Local structures that affect groundwater flow may add local variability. Along the western coast of the U.S., SGD is correlated with net precipitation, increasing from south to north.

The estimate of average annual fresh SGD was 25 cubic km, which is less than 2% of the total land runoff. However, saline SGD may be three to four times the global runoff.

Contaminants and SGD

Earlier, Willard Moore at the University of South Carolina measured 226Ra and concluded that the excess 226Ra in coastal areas is due to SGD, and that the SGD 226Ra flux was about 40% of that from rivers. Seasonal variation was observed, with the highest flux during summer. Nutrient-rich SGD exacerbated coastal algal blooms. SGD also may affect ocean temperature and alkalinity, potentially affecting global warming estimates.

In 2009, researchers from U.C. Santa Cruz and Stanford estimated the SGD of mercury to the coastal waters of central California. Total mercury and monomethylmercury (MMHg) were measured in groundwater; these data were combined with short-term isotopes to produce estimates of mercury flux. They concluded that total mercury concentrations in SGD exceeded those in adjacent surface waters, although the total concentrations were less than 29 pM. They concluded that SGD estimates for MMHg flux were greater than those for surficial sediments, which had been thought to be the major source of MMHg to estuaries and coastal waters.

It has also been shown that SGD continuously delivers nitrate and SiO4 to Monterey Bay, resulting in phytoplankton blooms. A group at Woods Hole Oceanographic Institute found that SGD delivered mercury at a flux ten times that from atmospheric deposition at Waquoit Bay in Massachusetts. A study of Jeju Island, south of Korea, concluded that SGD is a main source of mercury in Hwasun and Bangdu Bays. A similar study of Lynch Cove, WA found that nutrients (NH4+, Si, PO4, NO3 + NO2, TDN) were in SGD, and that the dissolved inorganic flux far exceeded the contributions from atmospheric deposition and surface-water runoff.

Many studies have concluded that fluxes of nutrients and selected contaminants, such as total mercury and MMHg, are significant in SGD. The recent paper by Sawyer et al. shows that previous quantitative estimates may need revision downward, but SGD is well established as an important input to estuaries and coastal waters.

Bart can be reached at bartonps@aol.com.
GRA proudly announces the speakers for the seventh year of the David Keith Todd Distinguished Lecture Series. Dr. Rosemary Knight (northern California) and Dr. Claudia Faunt (southern California) have enthusiastically accepted the 2017 David Keith Todd Lectureship. The objective of this program is to foster interest and excellence in applied groundwater science and technology through GRA-sponsored lectures at California universities, local GRA meetings, and statewide GRA events. These lectures further a key GRA objective: to develop scientific educational programs that promote the understanding and effective implementation of groundwater assessment, protection, and management.

GRA held Dr. David Keith Todd in the highest esteem for his enormous contributions to groundwater science and technology, and in 1999 awarded him GRA’s Lifetime Achievement Award. We named the series in his honor to pay tribute to his legacy as a groundwater science and education leader. The nomination and evaluation process for lecturers ensures that highly-qualified individuals are selected to represent GRA and David Keith Todd’s legacy.

Dr. Knight will generally give presentations in northern California, and Dr. Faunt will generally give presentations in southern California. Each will provide a minimum of five lectures, including lectures at two GRA Branch Meetings, two academic institutions, and the 2017 Biennial Groundwater Conference. Lecture Series funding comes from sponsors; voluntary support from the lecturer’s institution, organization, or firm; and universities hosting the lecturer. Universities and GRA Branches interested in hosting a lecture should contact the GRA Education Committee (dkt2017@grac.org) no later than January 31, 2017. Look for the Lecture Series schedule to be posted on GRA’s website.

**Rosemary Knight, Ph.D.** (Northern California)

**Bio**: Rosemary Knight has worked for over 30 years on the challenge of using geophysical methods to image groundwater systems. Her research ranges from carefully controlled laboratory experiments to large-scale field experiments, all designed to explore new ways of remotely imaging hydrologic properties and processes. In 2008, Dr. Knight founded the Center for Groundwater Evaluation and Management, with the vision of advancing and promoting the use of geophysical methods through the development of partnerships—with real people, in the real world, with real problems. Dr. Knight has been active within the Society of Exploration Geophysicists, serving as Second Vice-President and Distinguished Lecturer, and within the American Geophysical Union, serving as the founding Chair of the Near-Surface Geophysics Focus Group, and as Associate Editor for Water Resources Research and the Journal of Geophysical Research. Current and past students and post-doctoral scientists within her research group all share her commitment to, and enthusiasm for, finding new ways to use geophysical methods to support the sustainable management of our groundwater resources.

**Claudia Faunt, Ph.D., P.E.** (Southern California)

**Supervisory Hydrologist**

**Program Chief, Groundwater Framework and Applied Modeling**

**California Water Science Center, United States Geological Survey**

**Lecture: Water Availability and Sustainability in California’s Central Valley: Past, Present, and Future**

**Bio**: Claudia Faunt has been a hydrologist for the U.S. Geological Survey since 1988 and a part of the California Water Science Center since 1998. As a USGS hydrologist, she has led studies that focused on regional groundwater flow systems, including the Central Valley of California and Death Valley, California and Nevada. Her research has specialized in water availability, regional groundwater flow modeling, hydrogeologic framework modeling, and incorporation of hydrologic and geologic spatial information into groundwater models. Claudia’s recent technical experience includes several projects related to water availability in California’s Central Valley. Claudia received her Doctorate in Geological Engineering in 1994 from the Colorado School of Mines. In 2013, Claudia became Program Chief of the California Water Science Center’s Groundwater Framework and Applied Modeling section.
Presentation of GRA’s 2016 Lifetime Achievement Award to Dr. Miguel Mariño of UC Davis

The awards ceremony occurred during the luncheon on the second day of the 25th GRA Annual Groundwater Conference and Meeting in Concord, CA on September 29, 2016. On behalf of GRA’s Awards Committee and the Board of Directors (BOD), Mr. Ali Taghavi from RMC Water and Environment graciously accepted and was honored to present the Award to his former professor and mentor. The GRA BOD selected Professor Miguel A. Mariño as the 19th recipient of the Lifetime Achievement Award for his lifetime career in the hydrologic sciences; promotion of research, education, and application of scientific techniques, methods, and approaches; dedication to public awareness and outreach to policy makers in the area of groundwater hydrology, planning, and management; and for other important career accomplishments in hydrogeology.

Lifetime Achievement Award Presentation

Dr. Miguel Mariño obtained an A.A. in Liberal Arts from Andrew College in Cuthbert, Georgia in 1959; a B.S. in Petroleum Engineering and M.S. in Groundwater Hydrology from the New Mexico Institute of Mining and Technology in 1962 and 1965, respectively, and a PhD in Civil Engineering Systems from UC Los Angeles in 1972. Upon completion of his PhD, he took a faculty position at UC Davis. Miguel remained there throughout his academic career, becoming a full professor in 1980 and a distinguished professor in 2003. He retired in 2009.

Professor Mariño is a recognized world leader in the fields of groundwater hydrology and water resources management. Miguel pioneered the development of simulation models that determine the transient transport of water and solutes in saturated and unsaturated aquifer systems. He was among the first to include stochastic systems modeling into subsurface parameter estimation. He developed a unified theory of parameter identification, estimation and statistical properties. Miguel has made major and lasting contributions to the planning, design, operation and management of surface-water systems through the development of methodologies for risk analysis and stochastic management of reservoir systems. He has made seminal contributions to irrigated agriculture; for example, he was the first to link simulation with stochastic optimization techniques to develop irrigation management models for better management of salinity in the root zone of plants, and to develop statistical models to provide reliable forecasts of evapotranspiration (ET) and canal transmission losses in many agricultural areas of CA. Miguel has published over 250 journal papers.

The models and methodologies developed by Miguel for the planning and management of water resources have been implemented by agencies in the U.S., Japan, Chile, Mexico, Brazil, Italy, China, Spain, and Korea. In the CA Central Valley Project, an application of the methodology yielded a potential increase in total annual energy production, flows to the Sacramento Delta, and agricultural water deliveries. Miguel’s work on irrigated agriculture has helped to determine the impact of crop uptake and volatilization on the vulnerability of soils and groundwater to contamination by pesticides under different soil environments and agricultural practices in CA. His work has been used to help regulate the use of agricultural chemicals relative to their potential to pollute the subsurface environment, and for designing protective buffer strips against potential contamination of wells and surface-water bodies. His work on the use of stochastic models for subsurface parameter estimation and for guiding groundwater management decisions has laid the foundation for investigations at the interface between hydrology and systems analysis.

Continued on the following page...
Miguel has had an outstanding career as an educator. He has mentored 29 Ph.D. students and over forty M.S. students. Many of his former students are now successful teachers and researchers in the U.S. and abroad. In addition, he has created educational programs and taught at several universities in the U.S. and abroad.

Miguel has served the scientific community with dedication and distinction. He has been chair and/or member of numerous committees of AGU, ASCE, AWRA, and other societies. He is a regular reviewer of journals in the U.S. and abroad, is serving or has served as associate editor of four U.S. journals, and is an award-winning editor of the Journal of Water Resources Planning and Management. In addition, he has organized many national and international scientific symposia and conferences and has given many keynote addresses. Finally, he has received four awards for outstanding journal papers and several national awards in recognition of his many contributions to research and teaching.

The GRA Awards Committee received many letters of support from his students and colleagues for this nomination, including: Professors William Yeh of UC Los Angles; Ahmad Abrishamchi of Sharif U.; Mohamed M. Hantush of U.S. EPA; John C. Tracy of Texas A&M; Slobodan P. Simonovic of Western U., Canada; and Thomas Harter of UC Davis.

Professor Mariño could not personally attend the ceremony because of health conditions. At his request, Dr. Tariq Kadir, Chief of the Integrated Hydrologic Modeling Unit in the Bay Delta Office of the CA Department of Water Resources, received the award on his behalf.

Written Acceptance from Professor Mariño

“I want to thank you from the bottom of my heart for having selected me for this prestigious award. My sincere apologies for not being here in person to receive this award in person or even deliver this speech remotely, mainly due to my health. I want to thank those that were instrumental in selecting me for the award, including the GRA, the awards committee, and those who supported this nomination. I know it was not an easy decision to make when other groundwater hydrologists were more worthy than me and highly qualified to receive the award. I thank you for your kindness and generosity.

I would like to acknowledge several individuals who have played an important role in my education and mentoring. First, the late Mahdi Hantush who was my major professor at New Mexico Tech, in Socorro, New Mexico, one of the most respected groundwater theoretician in the 1960s. Also, I have to acknowledge hydrologists at the Illinois State Water Survey from whom I learned and refined fieldwork skills. It was there that I met my wife Irma who was studying at University of Illinois at Urbana-Champaign. I also have to acknowledge John Dracup, who was instrumental in my going to UCLA, and Bill Yeh, my major professor there, who mentored and guided me in many ways. I owe a great deal to both Yeh and Dracup. The late Warren Hall, who was a Davis faculty member before moving to UCLA and afterwards to UC Riverside recommended that I go to UC Davis after completing the Ph.D. degree at UCLA.

Some of you know I had three appointments at UC Davis: LAWR Hydrologic Sciences, Civil and Environmental Engineering, and Biological and Agricultural Engineering. I started out by teaching Jim Luthin’s class on groundwater hydrology and also Verne Scott’s graduate class on groundwater hydrology. I also created with Jerry Orlob’s help my first optimization and simulation class. In my nearly 37 years at UC Davis, I was blessed by having many supporting colleagues like Jay Lund, Carlos Puente, and Jerry Orlob.

Continued on the following page...
My success in academia is largely due to the students I have had and from whom I learned a lot, and who also inspired me to go into areas of research I had not contemplated at the time. First, George Matanga, now retired from the Bureau of Reclamation, with his interest on the application of deterministic and stochastic systems analysis techniques in irrigation planning. Also, Richard Cuenca, now a retired professor at Oregon State University, with his interest in evapotranspiration and irrigation management. And, Gilles Patry who prompted me to the area of rainfall-runoff modeling, and who later became President and Vice-Chancellor of the University of Ottawa, and then President and CEO of the Canada Foundation for Innovation.

At UCLA I had been exposed to the applications of Linear Programming and Dynamic Programming in surface-water reservoir management. At UC Davis, I first worked in that area with Slobodan Simonovic from Yugoslavia, and who is now a professor and administrator at the University of Western Ontario in Canada and Director of Engineering Studies at the Institute of Catastrophic Loss Reduction. Other reservoir management projects followed with students like Behzad Mohammad and Hugo Loaiciga. Hugo later made substantial contributions in groundwater and surface-water modeling, and is now a successful teacher and researcher at UC Santa Barbara.

I also want to acknowledge the contributions of Eduardo Holzapfel and Jesús Chávez in irrigation planning and management with applications in the United States, Chile and Mexico; John Tracy in water and solute transport in soils; Mohamed Hantush in groundwater parameter estimation; Xuefeng Chu in pesticide transport modeling; Ali Taghavi using finite elements and non-linear optimization management techniques for the Chino Basin in Southern California; Tariq Kadir for linking simulation, optimization, and heuristic models for application in the Central Valley. Over the years, I have also had many excellent students from Iran, including Abbas Afshar and Ahmad Abrishamchi, who are professors in Tehran. My thanks also to the many other Masters and Ph.D. students from the United States and abroad I have not mentioned here today.

On a closing note I would like to share with you some thoughts.

While we like to develop complex hydrological and water-resource models, to advance knowledge, publish in journals, and gain the respect of colleagues and peers, it is important that we strive for simple models and “satisficing” solutions, not necessarily optimal solutions. Prior to the construction of any model, simulation or optimization, we must know the hydrology of the system we are trying to model. Too many computer models I’ve seen operate the aquifers simplistically as a “sponge,” neglecting a better understanding of the hydrology of aquifers. Models help us to understand and address important issues in our line of work. However, we must never abandon the fact that models only help us to make decisions. But it is our horse-sense and experience that should guide us in making those decisions.

Finally, I would like to thank my wife of 48 years, Irma, and my daughter Raquel for their patience, understanding, and love.”
GRA Welcomes the Following New Members

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Raghavendra Suribhatla - INTERA Incorporated
Meredith Goebel - Stanford University
Clayton Sorensen - GSI Water Solutions, Inc.
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Jennie Bahramian - Cal State East Bay
Fernando Idiarte - Brown and Caldwell
Ben King - Hydrometrics Water Resources Inc.
Elise Sharbori - City of Palo Alto
Teresa O’Carroll - State Water Resources Control Board
George Gallis - Los Angeles County Sanitation Districts
Elin Garner - Brown and Caldwell
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David Shimabukuro - Dartmouth College
Cleet Carlton - Dartmouth College
Larry Kunkel - Larry Walker Associates
Michael Priestaf - Balance Hydrologics, Inc.
Nima Jabbari - Aquatic Informatics
Amir Mani - GHD Services Inc. - Emeryville
Nathan Veale - Clean Water Action
Colleen Harade - Sustainable Technologies
Jason Myers - Trinity Source Group, Inc
Denise England - Trinity Source Group, Inc
Andrew Grinberg - Santa Barbara County Water Agency
Mike Bauer - Larry Walker Associates
Spencer Davis - University of California, Santa Cruz
Jon Gamble - Northgate Environmental Management, Inc.
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For information on how to sponsor or exhibit at an upcoming event, please contact Sarah Kline at skline@grac.org.
The GRA Sacramento Branch is alive and well, but due to the vacating and replacement of a previous Secretary position, we fell behind in the provision of our quarterly updates. Since the last Branch update was published in the Fall 2015 edition of HydroVisions, the Branch has continued to hold monthly meetings at Aviator’s Restaurant at the Sacramento Executive Airport, changing that up each March when the Branch meets at the CSUS Alumni Center on the Sacramento campus. The Branch has continued to enjoy and learn from a large variety of topics, a partial list of which is available on GRA’s website. With this writing, David promises to complete the list of Branch topics available on GRA’s website.

The presentations have covered scientific topics ranging from contaminant fate and transport, “clean water” hydrology and water resources, drilling and dewatering, regulatory updates, field geology, professional licensure and even “California Climate, Groundwater and their Interrelated Future.” In spite of consistently informative presentations, the Branch Officers have contemplated a slightly diminished number of attendees. The Officers are cognizant of such trends and work diligently to analyze and correct where we can. The drop-off in monthly attendance seems to be the result of both the end of the Great Recession where we see many employers “doing more with less” (which can lead to employees being too exhausted and/or out-of-town on meeting nights), and/or bumps-in-the-road with the deployment of State GRA’s new website and meeting announcement emailing system.

The Branch will continue its long-standing tradition of an annual holiday-timeframe joint meeting with the Sacramento Section of the Association of Environmental & Engineering Geologists, which is the host this year. Aviator’s Restaurant will once again be the venue, and the topic will be posted on both the GRA and AEG websites soon! In the meantime, the GRA Sacramento Branch is geared-up to hold its annual Officer election. The candidates, some of whom are continuing from prior years, are lined up and the vote will occur electronically as in years past. The Branch remains fiscally sound under the financial- and meeting-analytics expertise of the current (and continuing) Treasurer, Rodney Fricke. The Branch has made consistent annual contributions of at least several thousand dollars under the Scholastic Sponsorship Program to the Sacramento State Geology Department. Those donations are made each year during the Branch’s on-campus CSUS meeting.

Since SGMA passage, agencies around the state have been grappling with how to comply with the new law. The presentations focused on several related issues, including identifying groundwater basin boundaries, particularly those that contrast with basin definitions provided in DWR’s Bulletin 118; formation of Groundwater Sustainability Agencies (GSAs); compilation of required well data; preparation of Groundwater Sustainability Plans (GSPs) and Alternatives to GSPs (AGSPs); and unclear SGMA requirements for adjudicated basins.

In addition to the speakers’ presentations summarized below pertaining to SGMA, the potential for developing a local GRA Branch was presented to the attendees. It was mentioned that our meeting’s joint host, the IGS, was formed when worsening traffic conditions made it difficult for Inland Empire geologists to attend South Coast Geological Society meetings held in Orange County. Interest in forming an Inland Empire Branch of GRA was thus solicited; it was noted that in addition to addressing the traffic issue, meetings of an Inland Empire Branch of GRA would be able to focus on more localized groundwater interests.

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Southern California – Continued

Adam Hutchinson is a Senior Hydrogeologist and Recharge Planning Manager for the Orange County Water District (OCWD). After introducing GRA to the attendees, Mr. Hutchinson discussed some unique challenges faced by the OCWD in responding to SGMA requirements. He noted that, despite demonstrated sustainability, the groundwater basin managed by the OCWD is ranked as a “medium priority” basin due to a 70-percent reliance on groundwater for water supply. Minor discrepancies in the OCWD’s basin boundaries versus boundaries shown on previous basin maps were found, so the OCWD submitted clarifications as “scientific changes” to the DWR, which reviewed and accepted the revisions. The OCWD also had to consider issues and concerns of local water agencies, such as the La Habra Heights County Water District and El Toro Water District, whose service areas are surrounded by OCWD’s service area. He also noted OCWD’s plans to submit an AGSP that will include four management areas, consisting of the OCWD’s main service area and the La Habra, Santa Ana Canyon, and Southeast Hills areas; these will be separately addressed by technical memoranda.

Bob Page is a Principal Management Analyst in the Administrative Office of the County of San Bernardino. Mr. Page indicated he performs special projects at the direction of San Bernardino County’s Chief Executive Officer and Board of Supervisors, and his current responsibilities include managing the Countywide Vision Project that seeks to improve the quality of life in the county, and managing water-related issues for the Administrative Office, including developing policy recommendations, tracking legislation and regulations, and following how local agencies are implementing SGMA. He discussed the county’s particular challenges associated with SGMA, describing the impressive size of the county and its 91 basins and sub-basins; these include 18 basins and sub-basins of high to medium priority, of which 11 are covered by adjudication and one is designated by DWR as critically overdrafted. He described two major issues raised by SGMA: (1) fringe areas, which are portions of basins within boundaries specified by Bulletin 118, but outside and adjacent to adjudicated areas that technically would require specific GSAs and GSPs; and (2) “white areas” within basins not under the jurisdiction of a local water supply or resource agency, but including some under federal control, that may fall to the county or state to manage.

Mr. Page also mentioned San Bernardino County’s challenges in documenting the location and construction detail of every groundwater well, and a potential California Environmental Quality Act challenge involving the permitting process for new groundwater wells.

Kirby Brill has been General Manager of the Mojave Water Agency since October 2000, following 25 years working in the public and private sectors, and has experience in water resources management. He emphasized the paradigm change of SGMA, and the expected large effort needed in the next decade to clarify its hydrogeological, legal, and practical implications. He presented example graphs of groundwater levels over time and apparent changes in storage, and addressed two main issues faced by the Mojave Water Agency: fringe areas, and requirements concerning adjudicated basins. He noted that fringe areas around a basin may be addressed by submittal of an AGSP. Local areas, such as Wrightwood, California, that have complicated surface-water and groundwater rights and usage, will require special evaluation. He indicated that adjudicated basins still require reporting under SGMA concerning extraction and changes in storage, and therefore do not appear to be strictly exempt.

Brad Herrema is a shareholder in the Brownstein Hyatt Farber Schreck law firm and a member of the firm’s Water & Public Lands and Public Agency Groups. He has experience with a broad range of water issues, and serves as counsel to the Chino Basin Watermaster. The Chino Basin was adjudicated in 1978, is governed by a nine-member Board, and its groundwater is managed by a “physical solution” whereby a pumper can pump as much groundwater as it needs if it covers the cost of replenishing the volume extracted beyond its rights. He noted that when SGMA was adopted, it was thought that the Chino Basin would be largely unaffected, but it created two unexpected issues: (1) although adjudicated, the basin will nonetheless be subject to annual reporting; and (2) the fringe areas where the adjudicated basin’s boundaries do not exactly correspond with Bulletin 118 basin descriptions are not subject to an exemption from compliance with SGMA. He mentioned that under the present regulations, the fringe areas could not be eliminated through boundary modification.

During the ensuing discussion, the audience remarked that discrepancies between basin boundaries shown on agency maps versus Bulletin 118 maps appear to be artificial data-quality-related issues involving a lack of mapping detail, rather than representing actual distinct fringe areas. For the many students in attendance, each of the four speakers noted that a large amount of technical work is expected to be required in the next few years to solve the challenges posed by SGMA.

The Branch would again like to thank the speakers for their engaging talks, and we also thank all GRA Members and non-members who participated in this meeting.
The Soberanes Wildfire in Big Sur State Park

This photograph shows burned slopes west of Mount Manuel in Pfeiffer-Big Sur State Park. On July 22, 2016, the Soberanes wildfire was started by an illegal campfire in Garrapata State Park, located 16 miles from Mount Manuel. The wildfire burned for 82 days over an area of 132,127 acres (206 square miles) in the Los Padres National Forest, Ventana Wilderness, several state parks, and adjacent private land in Monterey County. In early October, 2016, officials announced that the Soberanes wildfire had become the costliest fire to fight in US history. At the fire’s peak, over 5,000 personnel were assigned to the blaze, and an estimated $236 million was spent on the effort.

In this area, the wildfire primarily burned steep slopes covered with chaparral and grasses. Interestingly, this scene highlights the unpredictable nature of the wildfire, with surviving trees and shrubs in the deep ravines and one narrow, linear band of oaks.

Areas denuded by wildfires are especially susceptible to debris avalanches and debris flows (both popularly called “mudslides”) during and immediately after major rainstorms, because of steep topography and loose soil. Debris avalanches and debris flows are shallow landslides, saturated with water, that travel rapidly downslope as muddy slurries. The flowing mud carries rocks, vegetation, and other debris, generally following stream courses. Studies have shown that, in the first year following a wildfire, sediment yields and peak discharges on impacted streams can increase up to 35-fold.

The wildfire also exposed new outcrops of the Sur Series along the thrust-fault-bounded western margin of the Salinian block. The Sur Series consists of Precambrian quartzofeldspathic schist and gneiss as well as marble granofels. The Sur Series and Salinian granitic rocks (Cretaceous) share petrochemical and geochronologic characteristics with similar rocks of the western Mojave Desert and the Tehachapi Mountains from which they were displaced by movement along the San Andreas Fault.

Photographed by John Karachewski, Ph.D., October 21, 2016, along Highway 1 south of the Big Sur Ranger Station. GPS coordinates of photograph: 36.241386 -121.778064 (www.geoscapesphotography.com)

Please check the Los Padres National Forest and California State Park websites for current conditions, closure information, and warning alerts.