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Mission Valley Groundwater Aquifer

OVERVIEW

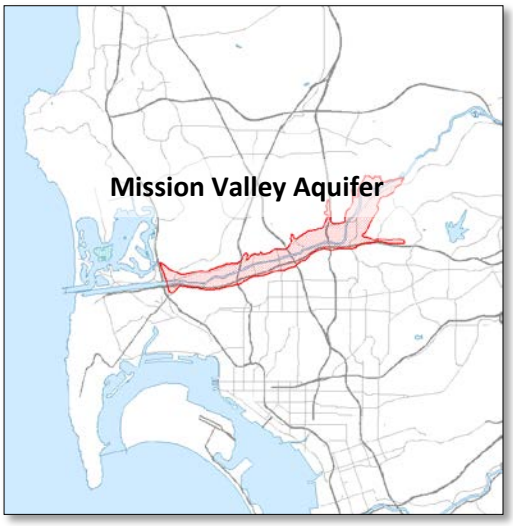
The Mission Valley Aquifer (MVA) follows the course of the San Diego River from Mission Gorge on the east to the Pacific Ocean on the west and is bound by its valley walls and covers about 6.2 square miles. The MVA is typical of riverine aquifers of southern California consisting of deposits of primarily gravel and sand conducive for high-yielding groundwater wells.

Mission Valley, its aquifer and river system, provided water to help establish and sustain the San Diego Mission dating back to 1769. A well field in the MVA, that spanned a distance from where Qualcomm Stadium is located to the Interstate 805 & Interstate 8 interchange, served as one of the City of San Diego's (City's) primary sources of drinking water from about 1914 until 1936.

The City owns a special water right called a Pueblo right, which is a prior and paramount right to all of the water of the San Diego River (surface and underground).

Eventually it was understood that local water supplies would not meet the ultimate demand for water, thus the City began importing water in the late 1940s. Although imported water was inexpensive, abundant and of good quality at that time, the demand and cost associated with imported water have both increased drastically. The City currently imports 85% of its water. In order to increase reliability

cost effectiveness and local resiliency, the City began to diversify its water supply sources and intends to re-establish the MVA as a local water resource.



In 2002, the City implemented a *Long-Range Water Resources Plan* (LRWRP), which recommended developing more local water supplies. Consistent with the LRWRP, the City has been investigating various groundwater aquifers within the San Diego region, including the MVA. The most conducive portion of the aquifer lies within the extent of its historic well field where the City has retained ownership of property, much of which is overlain by Qualcomm Stadium and its parking lot. Until recently (late 2016), City had not yet proceeded with re-developing the MVA for local water supply because of a large unauthorized discharge that contaminated the aquifer with petroleum products.

A fuel tank farm was built in Mission Valley at the mouth of Murphy Canyon in 1963 and is known as Mission Valley Terminal (MVT). Underground fuel contamination was suspected to begin in 1987. From 1987 to 1991 approximately 300,000 gallons of gasoline leaked underground from MVT located to the northeast of Qualcomm Stadium. This leak flowed toward Qualcomm Stadium and became the source of a major Light Non-Aqueous Phase Liquid (LNAPL) plume discharged into the aquifer system underneath the Qualcomm Stadium property. Generally, the LNAPL spill consisted of gasoline compounds, including Benzene, Toluene, Ethylene, and Xylene (BTEX) compounds, but also included a gasoline additive Methyl Tertiary-Butyl Ether (MTBE). Benzene and MTBE are known carcinogens.

The contaminant plume eventually migrated under Qualcomm Stadium property and extended westward to the Interstate 8 and Interstate 805 interchange. Cleanup and Abatement Order (CAO) No. 92-01 issued by the San Diego Regional Water Quality Control Board (RWQCB, Regional Board, Water Board) sought to remediate the contamination. Although the order was issued in 1992, it took the City and Kinder Morgan (KM, owner of the MVT and responsible party for the fuel contamination) until June 17, 2016 to announce they had entered into a settlement resolving all claims related to the historical contamination at the City's Qualcomm Stadium property.

The settlement provided for a $20 million payment to the City by KM, and also included an agreement by KM to cover increased additional costs related to contamination that may be incurred by the City in the redevelopment of the Qualcomm Stadium property or development of the groundwater beneath the property. This settlement ended nine years of litigation between the parties.

Additionally, the San Diego Water Board issued Addendum No. 8 to CAO No. 92-01 that established a January 31, 2024 clean-up deadline for the MVT on-Terminal Area and amended the Monitoring and Reporting Program to track the progress of the MVT on-Terminal clean-up.

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- *HISTORY*

San Diego was established as a presidio (a military settlement) and mission in 1769 as part of the Spanish Colonial Empire and depended on water obtained from shallow wells in the sands of the San Diego River up until about 1817. Water was then delivered to the mission through an aqueduct from a small dam built on the river, known as the Old Mission Dam, in Mission Gorge. California was admitted to the union and San Diego was incorporated as a City in 1850. Because it had been a pueblo, the City inherited legal rights and the lands assigned under Spanish and Mexican law, including Pueblo water rights to the San Diego River.

San Diego depended on wells for its water supply including the wells of the San Diego Water Company (SDWC) in Mission Valley. Following a vote of the people, the City of San Diego entered the municipal water supply business in 1901 when the City bought the water system from SDWC. The Mission Valley pumping area was developed in 1914 and contained 12 wells varying in depth from 40 to 90 feet. The water from these wells was pumped to a concrete sump then boosted 300 feet to the University Heights Reservoir. The property of the Mission Valley pumping area was owned by the City and extends roughly from Qualcomm Stadium to Interstate 805. The City completed construction of El Capitan reservoir in 1936 coincident with the Mission Valley Wells being taken out of service as discussed in the previous section.

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- *GEOLOGY*

Mission Valley is a narrow, east-west trending valley carved out by the San Diego River as it drained westward from Mission Gorge to the Pacific Ocean. The valley floor was backfilled over time with silt, sand and gravel deposits commonly referred to as alluvium. As the river meandered along the valley floor, it carried and deposited unconsolidated alluvial sediments within the river bed and along its banks causing the valley floor to slowly rise and the alluvium to thicken.

The alluvial sediments are underlain by consolidated hard claystone and sandstone geology known as the Friars Formation. In other words, the Friars Formation is a hard pan structure that underlies the unconsolidated alluvial sediments. As much of the finer grained sediments, such as silt, were carried away, coarser-grained sediments, such as sand, gravel and cobble, settled out over the Friars Formation to comprise the majority of the alluvium. As these coarse-grained sediments settled out, spaces remained between the particles called voids or pore spaces. Pore spaces may either be filled with air, water or another fluid.

Groundwater originates as surface water either from precipitation or urban runoff then percolates down through the alluvial sediment pores. The Friars Formation provides for an underlying confining structure, like a bottom of a bowl, that prevents the groundwater from percolating deeper into the earth. The percolating groundwater fills the pore spaces of the alluvium from the confining structure upward, much like adding water to a bowl of gravel. This percolation process is called recharge. The uppermost level at which the groundwater occupies the alluvial pore spaces is called the water table. Groundwater below the water table also moves through the sediments as it interacts with pumping wells, recharge, gravity and the river. The water bearing alluvial sediments make up what is called the Mission Valley Aquifer (MVA), discussed previously in the section above.

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- *PUEBLO WATER RIGHTS*

The City successfully established Pueblo water rights on the San Diego River in a California Supreme Court case entitled The City of San Diego vs. Cuyamaca Water Company (March 21, 1930, 209 Cal. 105). Pueblo rights are derived from laws that were in effect when California was under jurisdiction of Spain and Mexico. A pueblo land grant occurred in 1833 in which San Diego was recognized by Mexico as Pueblo de San Diego. The right to use water from the San Diego River, both

surface water and groundwater, from its source to the ocean was established as part of the pueblo land grant. The City was granted all rights (including water rights), claims, and powers assigned by Mexico when California was admitted to the Union in 1850 and San Diego was chartered as a city.

Pueblo water rights are the highest priority rights, superior to both overlying (riparian) and appropriative rights, and according to the court, extend to those waters of the San Diego River and its tributary water supplies necessary to support the growth of the City. Pueblo rights extend to all native flows of the San Diego River, including groundwater supplies that contribute to the flow of the river and its tributaries, as well as excessive or flood-level flows. Furthermore, the City's Pueblo right is not subject to claims of prescriptive rights from other users and is not forfeited by lack of use.

The Pueblo right requires that the City have a reasonable and beneficial use within the boundaries of the present City and to demonstrate a need for the amount claimed. The right may be called upon to meet growing municipal, domestic, and industrial needs of the citizens of the City. If necessary, the Pueblo right also could extend to irrigation or recreational purposes. The Pueblo right authorizes the City to stage water development and management efforts so as to reserve the ability to call upon its local resources to offset shortages in imported supplies. However, until such time that the City demonstrates a need or produces the water for beneficial use the water is available for junior appropriators and those with overlying groundwater rights.

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- *GRAND JURY REPORT 2013*

The San Diego County Grand Jury filed a report with the City of San Diego Mayor and City Council on May 7, 2013 entitled, Mission Valley Fuel Leakage and Contamination Abatement. The goal of the report was to address the monitoring and remediation of the contamination of the Qualcomm Stadium site and surrounding areas from the MVT. The Grand Jury Report included six findings and three recommendations; all of these were directed to both the Mayor and City Council. City staff reviewed the report and considered its findings and recommendations. Staff developed responses which were presented to City Council. The findings and recommendations were addressed in a City Council adopted written response (Resolution R-308498) and the response was transmitted via a letter to the presiding judge of the Grand Jury on October 15, 2013.

The Grand Jury Report covered the City's historical use of the aquifer, its importance as a water resource and facts about MVT The report's

main focus was on the contamination, the current state of the aquifer, remedial activities and clean-up status. The Grand Jury Report succinctly compiles a prolonged and regrettable situation. However, the report states the City has not been proactive in monitoring the scope and character of the contamination.

The City's own experts regularly analyzed and critiqued in submittals to the RWQCB, the reports prepared by KM (the responsible party), and their experts on the remedial progress and associated issues. The report also states the City had not kept the public adequately informed of the ongoing clean-up status. Although the City itself has not implemented an independent public relations effort on the clean-up status, the RWQCB has a publicly accessible data management system on the web called GeoTracker. This website application is designed to give the public user-friendly access to and provide regulator staff a means for managing site specific contamination cases that impact groundwater. GeoTracker is updated regularly as clean-up progresses. Although the City regularly submits information to the RWQCB about the effort, it was not until 2016, the Regional Board agreed to post City reports publicly on the GeoTracker website.

The City has participated in public meetings, attended workshops, provided interviews to the media and suggested ways to expedite clean-up. The City has also been utilizing its experts to watch over the City's interest ensuring adequate clean-up and compliance. To ensure greater transparency of clean-up activities, the City agreed with the Grand Jury's recommendation to post information publicly on its website.

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CONTAMINATION AND CLEAN-UP STATUS

After the MVA was contaminated with petroleum products from an unauthorized sub-surface discharge via MVT (a tank farm and fuel distribution terminal), KM, the owner and operator of the MVT was determined to be the party responsible for the contamination clean-up and remediation. An estimated 300,000 gallons of fuel was released and contaminated the aquifer below the MVT and then migrated beneath City-owned property at Qualcomm. The contamination extends to the Interstate 8 and Interstate 805 interchange and impacts a large area previously utilized by the City as a groundwater supply source. The RWQCB, the regulating body, issued a Cleanup and Abatement Order (CAO) in 1992. The terminal owner, KM, worked with the RWQCB on remediating this unauthorized release.

There are two types of contaminant plumes associated with the fuel release. The first is Light Non-aqueous Phase Liquid (LNAPL), a group of fuel substances that are less dense than water. LNAPL (pronounced

'el napple') tends to float, spread and layer on top of the water table forming what is called an LNAPL body. Fuel release LNAPL bodies are mainly Benzene, Toluene, Ethylene and Xylene (BTEX). Where the LNAPL body comes into contact with the water table, the soluble components of LNAPL mix with the groundwater giving rise to the second type of contaminant plume which is the dissolved type. While LNAPL bodies tend to remain relatively fixed, the soluble components dissolve in the groundwater and move in the direction of groundwater flow dispersing and contaminating a significantly larger area.

Two highly soluble contaminants that readily dissolve in groundwater are Methyl Tertiary-Butyl Ether (MTBE) and Tertiary-Butyl Alcohol (TBA). These components are gasoline additives that travel faster and farther than other gasoline components impacting a larger area. MTBE, banned in California in 2003, also breaks down in the environment. When it breaks down, it converts into TBA. During the process of breaking down, oxygen in the groundwater is consumed producing anoxic conditions. The anoxic conditions create an acidic environment which in turn dissolves minerals causing high total dissolved solids (TDS) and mineral concentrations in the groundwater which can lead to calcification or buildup in pipes and higher treatment costs if the groundwater were to be used for water supply. Lastly, Benzene and MTBE are known carcinogens.

There are a variety of methods available for aquifer remediation. KM uses a method called Soil Vapor Extraction (SVE) to remove the LNAPL. SVE works by applying suction to sections of perforated pipe installed at various locations vertically in the ground in and around the contaminated areas. The suction creates an airstream which entrains the hydrocarbon soil vapors. The airstream and hydrocarbons are piped to MVT, which is on KM's property, where the air stream treated to remove the hydrocarbons is then released to the environment.

To remove contaminants dissolved in groundwater, the contaminated groundwater is pumped out of wells located in the Qualcomm parking area to a treatment system at the MVT. The groundwater is treated using a variety of chemical and physical processes including granular activated carbon filtration to remove the contaminants that are dissolved in the groundwater. The treated groundwater is discharged to Murphy Canyon Creek adjacent to the MVT.

Since the RWQCB issued the CAO in 1992, there has been eight amendments and many extended deadlines. Amendment 5 required the LNAPL that migrated off KM's property to be removed to the extent technically practicable by December 31, 2010. The RWQCB ruled that KM was, for the most part, in compliance with the LNAPL

removal requirement, except for one location near the stadium entrance which wasn't discovered until 2009. Amendment 5 also required the concentration of dissolved contaminants that had migrated off KM's property to be reduced to background levels or whatever is technologically achievable or economically feasible by December 31, 2013. Another requirement of Amendment 5 was the clean-up and abatement reports to be submitted electronically. One reason for electronic submission was so the reports could be posted publicly on the RWQCB's GeoTracker Website.

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- *HISTORY*

As discussed previously, the MVA was once the City's primary water supply source from about 1914 until 1936. The City owned and operated a municipal water supply well field that spanned the distance between Qualcomm Stadium and I-805 along the course of the San Diego River. The City's use of the wells was discontinued in 1936. In 1963, the fuel storage and dispatch facility known as the MVT was constructed in the mouth of Murphy Canyon, which is just upgradient of where the City's well field was located. MVT eventually grew to have a storage capacity of 26 million gallons of fuel.

The City Council approved the City's *Long-Range Water Resources Plan* in 2002 that included development of groundwater for the City which included a desalination project in Mission Valley by 2010.

- CONTAMINATION CHRONOLOGY

1914 City's Water Supply Well Field Put Into Service
1936 Well Field Operation Discontinued
1963 MVT Tank Farm Built
1987 MVT Unauthorized Fuel Release Begins
1991 Release Reported to RWQCB
1992 CAO 92-01 clean-up by January 1996
1994 Addendum 1 Extends Deadline to January 1999
1998 Kinder Morgan (KM) buys MVT
1999 KM clean-up plan (Addendum 2)-widespread MTBE
2002 (Addendums 3 &4) deadline missed-City notifies of development potential
2003 Arbitrator (Court) - KM cause of contamination
2003 City Working Group-urges faster clean-up
2004 City-initial 2,200 AFY project by 2010 if clean by 2007
2005 (Addendum 5) deadlines 12.31.10 & 12.31.13 (estimated 50,000 gal. gasoline)

2007 KM reports 77,000 gallons gasoline spill

2007 City files lawsuit in the United States District Court against KM Energy Partners for the contamination of the soil and groundwater at and around the Qualcomm property with petroleum products from KM's MVT. A First Amended Complaint was filed April 1, 2008

2010 (Addendum 6) monitoring/reporting

2011 RWQCB (Oct.) determines clean-up MTBE complete (12.31.10)

2012 (Addendum 7) monitoring/reporting

2013 District Court grants summary judgment against City

2015 Ninth Circuit reverses summary judgment ruling

2016 Settlement Agreement and General Release

Addendum – new or revised requirement of a CAO
AFY – acre-feet per year
CAO – RWQCB Cleanup & Abatement Order
KM – Kinder Morgan Partners – owner of MVT
MTBE – primary pollutant in gasoline leaked to MVA (methyl-tertiary butyl ether)
MVT – Mission Valley Terminal
RWQCB – San Diego Regional Water Quality Control Board
DEH – San Diego County Department of Environmental Health
SFPP – Santa Fe Pacific Pipeline Partners – original owner of MVT
City lawsuit - Federal District Court – Case No. 07-CV-1883 (AJB)

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- *CLEAN-UP STATUS*

KM working with the RWQCB developed a clean-up plan in 1999. KM installed many wells in the Qualcomm Stadium parking lot and vicinity, eventually reaching 172 extraction wells.

Soil vapor extraction (SVE) http://en.wikipedia.org/wiki/Soil_vapor_extraction and other methods have been used to remove the gasoline. Groundwater is extracted, treated and returned to Murphy Canyon Creek and the San Diego River. Drawing down of the groundwater level beneath the surface has allowed the extensive clean-up process. Because of the value of the aquifer as a water source, the City has continually urged the RWQCB to accelerate and improve the efficiency of the clean-up. The City has waited before

moving forward with its groundwater development project because of the contamination and the pending conclusion of remediation efforts. The City has installed 4 monitoring wells to independently assess the status of the clean-up.

- Spill Prevention, Control, and Countermeasure Plan (SPCC) and Barrier Containment

The County of San Diego Department of Environmental Health (DEH) Hazardous Materials Division (HMD) (http://www.co.san-diego.ca.us/deh/hazmat/hmd_apsa.html) oversees the safety of the MVT fuel handling facilities. The HMD is a Certified Unified Program Agency (CUPA) in the County of San Diego. It regulates businesses storing petroleum in above ground containers and tanks. Spill Prevention, Control, and Countermeasure (SPCC) Plans are required for Tank Facilities. Large Tank Facilities, such as the MVT (storing more than 10,000 gallons) must use a Professional Engineer to certify the SPCC Plan.

MVT has a leak detection system monitoring pipelines and tanks. An independent party inspects the systems and reports monthly to the DEH inspector. Between 2008 and 2013, KM installed improved facilities including new pipelines. The delivery pipelines serving MVT are regulated by the California State Fire Marshal. The City of San Diego Fire Department is the first responder for public safety issues at MVT.

The RWQCB has required a rigorous leak-detection program since 2009. KM proposed, and currently uses, the following methods to detect releases from pipes, pumps, and storage facilities:

- Visual Inspections
- Cathodic Protection
- Inventory Monitoring and Reconciliation
- Tanks Inspections, Maintenance and Repairs
- Leak Detection Design Elements
- Pressure Piping Leak Detection Testing
- Groundwater Monitoring Well Network

On-Terminal MVT releases to soil or groundwater are required to be reported by KM to the Regional Board within 24 hours, with a written report required within 5 days as stated in the Regional Board's 1992 CAO.

A series of monitoring wells and a series of containment wells have been installed in the vicinity of Friars Road to intercept any gasoline leakage from the site. The RWQCB's letter dated April 27, 2009 discussed above, reviews KM quarterly reports including evaluation of the performance of the hydraulic barrier. Based on KM data from groundwater samples collected from all monitoring wells located on-Terminal and in the off-Terminal area, the RWQCB indicates that the hydraulic containment system is performing effectively.

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- *REGIONAL WATER QUALITY CONTROL BOARD OVERSIGHT*

The San Diego RWQCB is a creation of California's Porter-Cologne Act, which set up an overarching State Water Resources Control Board and nine regional boards to oversee and regulate issues related to the quantity and quality of the water used in the state. California's Constitution makes water a resource owned by the state, for the beneficial use of its residents and its environment. The nine RWQCBs are responsible for maintaining the quality of the state's ground and surface water.

When the RWQCB issue a clean-up order it is called a Cleanup and Abatement Order, or CAO, and it requires a party deemed responsible (a "discharger" in the words of the Porter Cologne Act) to take necessary steps to mitigate and remediate any nuisance it may have contributed to. When a CAO is issued, the discharger is required both to take action and report on that action to the RWQCB for review and approval.

In some cases, the RWQCB requires the discharger to pay for consultants to advise the RWQCB and assist the RWQCB's staff evaluate problems and progress. In this case, the RWQCB required KM, the discharger named in the CAO for the MVT release, to pay for two consultants (Dr. Paul Johnson of Arizona State University and Margaret Eggers, a California geologist) to advise RWQCB on the MVT CAO. As is typical with CAOs, the discharger is responsible for payment to the RWQCB for its use of special consultants and for staff time spent in reviewing and evaluating the data supplied by discharger's consultants to the RWQCB.

The data submitted to RWQCB by the discharger's consultant is recorded and the majority is uploaded to the RWQCB's Geotracker website, as explained previously. Other documents are included on that website as well.

- DOCUMENTS

Once the 2002 *Long-Range Water Resources Plan* was adopted by the City Council in December 2002, including groundwater desalination from the Mission Valley Basin, the City aggressively advocated with the RWQCB to assure removal of the gasoline in a timely manner. The City formed a working group comprised of legal and technical consultants. On April 29, 2004, a letter from the City to the RWQCB in advance of a workshop scheduled for May 3, 2004, outlined the City's concerns and suggested the clean-up be accelerated. Several meetings were held with KM in an attempt to assist the accelerated clean-up. Some of the documents that give some idea of the timing and level of City effort include:

21 Letters from the City to the RWQCB (2004 - 2014)
16 Letters from the RWQCB to the City (2004 - 2014)
33 Consultant Reports (2004 - 2014)

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WATER SUPPLY DEVELOPMENT

- *OVERVIEW*

The City has plans to develop the MVA as a water supply for municipal use. In fact, it was a historical water resource and the City depended on it up until about 1936, close to the time El Capitan Reservoir was put into service. The City began importing water from the Colorado River in 1947. Since the imported water was initially an inexpensive, high quality and reliable resource for San Diego, there appeared to be no longer a need to maintain a local ground water supply for municipal use. However, the City's imported water supplies have become less reliable over recent years due to drought, population growth, environmental and political issues. Imported water has also become increasingly more expensive.

The reliability issues and increased costs associated with imported water motivated the City to explore diversification of its water supply. Groundwater resource development is a component of a diversified portfolio. The historical Mission Valley well field is a proven groundwater source, but for the contamination and remediation operations of KM. The City has conceptual plans to re-develop the MVA and has furthered these plans through field investigations within the alignment of the historical well field. The City has not gone beyond limited field investigations to avoid interfering with KM's remediation operations. However, now that the settlement has been completed

between the City and KM, the City is moving forward in re-developing the MVA.

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- *CONCEPTUAL PROJECT*

A concept study of a Mission Valley Groundwater Desalting Project was initiated by the City in 2004. Because of the contamination, only a concept study was conducted to identify the MVA's potential. The study summarizes groundwater development strategies within Mission Valley, identifies facilities needed to implement a desalination project, presents an estimate of costs, identifies regulatory approvals needed, and identifies tasks to advance the conceptual project.

The conceptual project includes a year-round groundwater extraction of two million gallons per day, reverse osmosis membrane desalination of the groundwater to reduce a total dissolved solids concentration to 500 milligrams per liter, disinfection of the treated groundwater and conveyance to the City's water distribution system. The conceptual project preliminarily identifies a desalination facility on the practice field of Qualcomm Stadium. Groundwater wells sited within the parking lot, and within the extent of the City's historical well field, would extract groundwater from the MVA and feed it to the desalination facility where it would be treated and disinfected to drinking water standards. The treated water would then be conveyed to the City's potable distribution facility.

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- *FIELD INVESTIGATIONS*

In an effort to pursue the City's interest in developing groundwater for municipal supply from the MVA, the City tasked URS, its hydrogeological consultant, with installing a test well cluster at 3025 Camino Del Rio North in Mission Valley in March and April of 2011. The results of the field investigation demonstrate the aquifer is very conducive for groundwater well pumping but also confirmed the need for membrane treatment to reduce total dissolved solids content. The details of the field investigation results are documented in URS's Well Construction Report.

The City-owned property at 3025 Camino Del Rio North is a vacant lot that falls within the western most extent of the historical well field that the City operated between 1914 and 1936. The City selected this location because it was on the opposite side of the San Diego River and far enough away from KM's remediation operations on the Qualcomm property, that the City could pursue its groundwater interests without interfering with KM's remediation operations. Also,

the location would be free from contaminants which had emanated from the MVT. The field investigation, which involved pump testing to produce information about aquifer and water quality characteristics, also confirmed contaminants from MVT had migrated to this location and are persistent. The City continues to monitor water quality data at this location.

Another test well was drilled, constructed, developed and tested by Layne Christensen Company (Layne) with oversight by CH2M, on behalf of the City in the Mission Valley Groundwater Basin in September 2016. The well is located across the street from 3111 Camino del Rio North. The test well was installed following completion of a test boring to evaluate the productivity of the aquifer at that location. Soil boring log and well construction details are documented in CH2M's Well Completion Report.

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- *MODEL DEVELOPMENT*

A conceptual numerical groundwater model for the vicinity of Qualcomm Stadium was constructed by the United States Bureau of Reclamation. The computer program for the model is MODFLOW developed by the United States Geological Survey (USGS) that simulates groundwater flow through aquifers. MODFLOW can be adapted to fit almost any aquifer and is one of the most commonly used numerical models in the field of hydrogeology. The extent of the model is called the boundary, and the domain within the boundary is defined by its geologic framework. The numeric model is divided into layers coinciding with the layers of the aquifer such as layers consisting of sand, gravel or rock. Numeric values are assigned to each layer which mathematically describes how water flows through each layer called conductivity. The extent of the model is overlain with a grid.

Groundwater flow is then simulated from one cell to the next within the grid using mathematical equations that define groundwater flow and numerical constants that are characteristic of each model layer consisting of sand, gravel or rock or a combination thereof. The conceptual model will be further developed to determine if any stranded contamination will have an effect on municipal supply or to determine how groundwater pumping may affect the riparian zone of the river system thus allowing an adaptive management approach to groundwater development.

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