Drilling and Testing of Montara Water and Sanitary District's Well 2004-4, APN 036-180-030, San Mateo County, California

Well Completion Report

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Balance Project Assignment: 202075

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1. INTRODUCTION

Water supply in the unincorporated communities of Montara and Moss Beach, California is provided by a public water system managed by Montara Water and Sanitary District (Figure 1). Montara Sanitary District (MSD) purchased the system from California-American Water Company (formerly Citizens Utilities Company of California) on August 1, 2003 and became Montara Water and Sanitary District (MWSD). The water system relies on the collection of local ground-water supplies at a current capacity of 300 gpm. It provides an annual total of 448 acre-feet of treated water to 1,594 connections.

MWSD is contending with a number of challenges unique to coastal water systems, especially those with aging infrastructure. Two, in particular, shape the substance and importance of this report:

- MWSD extracts 60 percent of its water use from the "San Vicente, Denniston, Half Moon Bay Airport Groundwater Sub-Basin" as designated by California's Department of Water Resources. The District draws most of this water from three wells located southwest of Highway 1 (Figure 2). The northernmost well has levels of nitrate that periodically exceed the MCL of 45 mg/L, measured as nitrate. MWSD blends water extracted from the well with water pumped from the other two wells at the airport, and is in the process of installing a nitrate treatment system. Numerous nitrate sources exist in this basin. Northeast of the production wells (and Highway 1), the recharge area for this sub-basin is farmed for brussel sprouts, requiring fertilizer and pesticides; west of the wells is the airport restaurant septic leach field. The remaining 40 percent of MWSD's water use is supplied from four wells and a surface-water diversion in the Montara Creek watershed, about a mile to the northeast. The two wells with the greatest capacity are potentially affected by MTBE originating in a former underground tank on an agricultural parcel some distance upstream. Water pumped from these wells is treated with carbon filtration.

- Former owners of MWSD's recently-acquired water system have not been capable of expanding production levels or protect its water quality. This situation triggered serious concern over the sustainable yield of the sub-basin during a drought or even several consecutive drier-than-normal years, as well as the related potential for sea water intrusion. In late 1999, the California Department of Water Resources (DWR) issued a report titled 'Montara Water Supply Study' that identified the Martini Creek terrace and alluvial aquifers as a potential source of ground water to meet supplemental drought-year demand. MWSD was awarded a Local Groundwater Assistance Program Grant (fiscal year 2002-2003) that provided partial funding for a Martini Creek sub-basin ground-water program. The funding provided assistance for the establishment of four new test wells, among other tasks.

MWSD completed and tested five wells during 2004, with one of the test wells (well 2004-4) proving to be high yielding. A successful five-day well test (described below) was conducted at 300 gallons per minute (gpm), yielding high-quality ground water. MWSD proposes to operate the well at 150 gallons per minute (gpm), which is equivalent to 242 acre-feet per year if continuously pumped. This well completion report documents the borehole drilling and well completion activities, geologic and geophysical logging, and yield and water quality testing of test well 2004-4. It also evaluates potential effects of extracting water at the proposed pumping rate of 150 gpm.

2. WELL DRILLING AND TESTING

2.1 Site Selection and Preparation

The drilling site for Borehole 9b, which was completed as well 2004-4, is located on APN 036-180-030 about 900 feet northeast from the MWSD treatment and storage tanks on Alta Vista Road. The site is on a ridge that extends down from Peak Mountain (and North Peak), on a divide separating the watersheds of the north fork of Montara Creek and Daffodil Canyon. Maggiora Brothers Drilling (Maggiora) was the drilling contractor. Balance Hydrologics (Balance) selected the site, specified well construction and testing, observed the drilling and development, and is overseeing the well completion activities.

The site was prepared for drilling by local contractors, Collin Tierra and Daughters. Two pits (about 12 cubic yards each) were excavated in series to retain water and sediment brought to the surface while drilling the well. Silt fence and straw wattle were installed at the bottom of the parcel at a flat to gently-sloping area. Water filtering beyond this outflow point trickled to the northwest down the ridge, heavily vegetated with coastal scrub.

2.2 Borehole Drilling and Well Completion

Drilling began on May 19, 2004 and the well was completed on July 7, 2004. The drilling rig used was an Ingersoll Rand 1150/350. Balance geologists Jason Parke and Gustavo Porras with assistance from local geologist Vic Abadie were on site to observe and sample drilling chips and cuttings, and log lithologic interpretations and hydrogeologic conditions. From May 19 to 27, a 9-inch borehole (approx.) was drilled to 743 feet below ground surface (bgs) using air. An 8 ¾ rotary bit was used from the surface to a depth of 272 feet bgs, where an 8 ¾ hammer was used to 743 feet bgs. Heavily-weathered granitics were found from 0 to 15 feet bgs, characterized as orangish brown cohesive sandy clay, which we interpret as developed-in-place soil. Weathered granitic rock was found from 15 to 235 feet. Fractured, typically unweathered Montara Mountain granitic rock was encountered from 235 feet to the final depth of 743 feet. The geologists' log of the well is presented in Appendix A.

First sustained water was found at a depth of 233 feet, just above the transition from weathered granitics to granitic rock. Below this depth, we encountered a considerable amount of uniform, almost unfractured granitic rock. Drilling rates averaged 30 feet per hour and varied from below 15 to 45 feet per hour. While drilling, 63 feet of 10-inch steel (conductor) casing was incrementally extended down the borehole to prevent sloughing of the weathered granitics. Water flow, airlifted from the borehole, was about 25 to 30 gallons per minute (gpm) from below first water to about 660 feet bgs, where flows increased to 60 gpm, and then to about 90 gpm at 720 feet bgs. As we extended the borehole beyond 720 feet bgs, the flow of water lifted by the compressed air from the borehole increased to several hundred gpm, a rate that accelerated borehole erosion within the weathered granitics interval near the top of the well. At this point, we stopped drilling and ran geophysical logs for this borehole. Norcal Geophysical Consultants conducted the logging. Results are presented in Appendices A and B.

The geophysical logs confirmed competent bedrock from about 350 feet bgs to about 714 feet bgs, where open joints and fractures were logged and yield was abundant while drilling. In consultation with Maggiora and MWSD, we decided to complete the well with solid 12-inch steel casing from the surface to competent bedrock and seal off the weathered granitics. This stabilized the upper erodible portion of the borehole. It also meant that the well will be fed also solely from deep joints and fractures, minimizing effects on nearby domestic wells completed in the weathered granitic aquifer. Sealing the well above a depth of 350 feet bgs allowed the well to be tested at high rates as a production well. It also allowed drilling to continue as necessary without further erosion of the borehole wall. The larger diameter uncased borehole would also allow installation of a larger pump than if completed with a 6-inch diameter PVC casing (as was done at the adjoining well 2004-3, previously designated as BH-9[1]).

From June 4 to 16, the drillers reamed the borehole with an 18-inch rotary bit, using drilling mud, to the depth of 370 feet bgs, and on June 17, installed the 12-inch steel casing with centralizers at the top and bottom sections of the casing. At completion, the casing descended on its own weight, landing solidly where intended at the bottom of the reamed borehole. The casing was then pressurized with water to test the casing welds and contact with competent bedrock. Water did not rise to the surface on the outside of the casing, indicating a successful installation. Final placement and testing of the casing was witnessed by San Mateo County Environmental Health.

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[1] Boreholes sites are number in the order that they were permitted by San Mateo County, and bear designations of BH-1 through BH-12. Not all borehole sites have been drilled. Once a borehole has been completed as a well, it becomes known by its well number, given sequentially within the year it was completed.

From June 21 to June 30, further cleaning of the well took place and a tremie pipe was extended to pour the concrete seal in the annulus between the borehole and casing. Installing the tremie pipe was laborious. On June 30, the concrete and bentonite mixture was poured from 180 feet bgs. San Mateo County inspector Panaka Chea was on site to observe and approve the pouring of the seal.

On July 1, the spoils from reaming the upper portion of the borehole were cleaned out using air-hammer drilling, and then drilling resumed extending the depth of the borehole beyond the high-yielding joints. Large quantities of water periodically blew out of the borehole with such force that it continued to blow off the bushings that kept the drill centered over the well. The drillers welded reinforcements to the bushings. Drilling resumed on July 6 with an excess of 300 gpm emanating from the well from. Drilling was then immediately terminated because the amounts of water overwhelmed the drillers' ability to contain and control the flow. At this point, we concluded that safety considerations required either termination of drilling or bringing in a bigger rig and additional water containment.

Well 2004-4 was completed to a depth of 780 feet bgs. It was cased with a solid 12-inch steel casing to a depth of 370 feet bgs, and sealed to the surface with a neet (sand-free) cement and bentonite mixture from a minimum depth of 180 feet bgs. Below 370 feet bgs, the well is bored through uncased granitic rock, with a nominal diameter of about 9 inches.

2.3 Geologic Interpretation of Borehole Samples

As cuttings were brought to the surface during drilling, borehole chip samples were collected at a 5-foot depth interval using a 1 mm (approx.) kitchen screen. The samples show that the weathering front in Borehole 9b is abrupt, with a sharp decrease in oxides and clay content at 235 feet, immediately above a 5-foot zone of very concentrated green hornblendes. The upper limit of the active weathering zone appeared to be between 180 and 185 feet bgs, where clean chips of relatively unweathered and completely non-rounded feldspars first became apparent.

Cuttings from Borehole 9B below the weathering front are fairly uniform rock of predominantly quartz-diorite composition.[2] A 15-foot zone of markedly darker and more mafic composition, with slight signs of alteration, is evident at a depth of about 565 feet. Below 660 feet the cuttings gradually become more felsic, markedly so between 695 and 710 feet, where slight oxidation and feldspar weathering are apparent. A small percent of a very fine-grained lustrous green and orange mineral (augite?) is disseminated in the cuttings. At 715 feet, we encountered relatively fresh and undeformed quartz diorite containing slightly more than 40 to 50 percent hornblende. Samples from 720 to 735 feet are heavily altered. Fully-developed saussuritization is evident in the middle portion of this zone, with small crystals of zoisite(?) observed. Cuttings and chips are subrounded, and show 'ghosts' which may have been veinlets of quartz and feldspar. The lowermost 10 feet of the borehole is composed of progressively fresher felsic granitic rock, including a dispersed very fine-grained or cryptocrystalline mineral with apparent cubic or dodecahedral habit. It is possible that this mineral could be sphene, sphalerite (or related sulfide), and/or possibly (but doubtfully) garnet.

Cuttings from borehole 9 (located about 400 feet to the northeast from BH-9b) also show a progressive lightening from 700 to 770 feet, with material similar to that encountered in the 695-710 foot zone in 9B. Between 780 and 790 feet (?), cuttings are highly-altered and -weathered and include classic epidote crystals with clearly-evident drag structures on the shear planes. Alteration and weathering extend 5 to 10 feet above and below this interval, with the rock seemingly become fresher above and below this zone.

2.4 Geophysical Logging

Down-hole geophysical surveys were conducted by Norcal Geophysical Consultants (Norcal) on Tuesday, June 1, 2004.[3] Norcal ran several surveys: an acoustic televiewer survey, caliper log, and elog suite (comprising natural gamma, resistivity and spontaneous potential). The graphical logs by depth are integrated with the geologists' lithologic and hydrologic observations and well construction details, and presented in Appendix A.

[2] Montara Mountain is mapped as granodiorite (most recently, Brabb and Pampeyan, 1989), but this boring is almost entirely quartz diorite (synonym: tonalite), based on paucity of potassium feldspars, high hornblende percentage of total rock, and minimal percentage of biotite.

[3] Drilling ceased on May 28, just prior to the Memorial Day weekend, such that mud had not been circulated for nearly four days. Static water level was 218 feet bgs on June 1, after removing the drilling stem.

The logs showed heavily fractured granitics above 350 feet bgs with principal fractures at 245 to 255 feet bgs, 310 to 315 feet bgs, and 330 to 340 feet bgs. Below 350 feet, there is about 360 feet of uniform, almost unfractured granitic rock to 714 feet bgs where dense fractures continued to the bottom of the surveys at 736 feet. Two large open joints were found at 724 and 727 feet bgs, which were interpreted as a primary source of the high water yields observed while drilling. The largest joint (at 724 feet bgs) strikes 3 degrees west of north, and dips east 58 degrees east (or dipping 58° N87°E). The other joint strikes north 21 degrees east and dips 40 degrees east (40° N111°E).

The borehole acoustic televiewer survey images the rock formation and is helpful to assess anomalies indicated by the other geophysical logs, particularly in fractured bedrock. Analysis of the images measures the orientation of fractures intersected by the borehole, which are illustrated on a stereo net plot[4]. Using the stereo net plot of borehole 9b we were able to identify four fracture/joint populations:

- Striking about north 33 degrees east and dipping 50 degrees to the southeast. Similar orientations were also logged in BH-3 and BH-9, and is a dominant orientation of valleys and channel courses (Figure 4);
- Striking roughly north 63 degrees east and dipping 65 degrees to the south;
- Striking about north 83 degrees east and dipping 65 degrees to the south; and,
- Striking approximately south 60 degrees east and dipping 36 degrees to the southwest.

Broadly similar joint and fracture orientations were noted along the crest of Montara Mountain by USGS geologic-mapping staff (Brabb and Pampeyan, 1983 and Pampeyan, 1984). Fracture orientations are shown in Figure 4, as well as the orientation of the high-yielding open joint (see Appendix B for details).

[4] The conventional method to plot a 2-D feature like a fracture or a joint is to project the plain of the fracture as one-dimensional poles-to-planes on a stereo net projection. Clusters of data points in specific regions of the stereo net projection define a population. When contoured, the highest density can be interpreted as an average orientation of the fracture population.

2.5 Yield Testing

Yield tests were conducted at well 2004-4 during two periods: on September 21 to 23, 2004, when short-duration tests were carried out while discharge pumped water to surface soils with sprinklers; and November 2 to 12, 2004, when tests including a 5-day constant-rate pumping test and recovery were carried out, while discharging water to Montara Creek.

Balance Hydrologics planned and directed the yield tests, with Maggiora Brothers Drilling (Maggiora) as the pumping contractor. On September 17, Maggiora installed a Berkeley submersible turbine pump model 7T-350 with a 60 HP pump at a depth of 609 feet below ground surface (bgs). A 4-inch diameter steel pipe extended from the pump, to the surface and to a 4-inch diameter PVC sprinkler line that was setup along Alta Vista Road extending about 400 feet northeast from the well. During the tests in September, water pumped from the well was sprayed to the west towards Daffodil Canyon from large sprinklers onto MWSD parcel. The sprinkler system was removed after the yield tests and a 4-inch flexible line was setup in late October to take the pumped water directly to Montara Creek. Rainfall during October storms totaled 2.7 inches at the McNee State Park ranger's residence near Old San Pedro Trail Bridge. Rainfall was not sufficient to generate runoff in Martini Creek prior to the 5-day yield test in early November, and Montara Creek was dry[5] southeast of well 2004-4 upstream of the point where the pumped water was discharged.

Several yield tests were conducted at well 2004-4:

- On Tuesday September 21, a 'step test' was conducted that consisted of pumping at 100 gpm for three hours, then increasing to 200 gpm for three hours. We attempted to increase the rate to 300 gpm but a PVC pipe fitting leading to the sprinkler system failed.
- On Wednesday September 22, an 8-hour test was conducted at 300 gpm. At the end of pumping a water sample was collected and analyzed by a state-certified laboratory for general mineral and Title 22 inorganic (Table 2; Appendix C).
- On Thursday September 23, a 72-hour test at 200 gpm was begun but discontinued on the morning of Friday September 24 when we observed that discharge from the well had exceeding the infiltration rate of receiving soils.

[5] The channel bed was wetted, having barely a trickle of flow at times when MWSD were not actively diverting water.

- From November 2 through 12, we conducted a 5-day constant-rate yield test at 300 gpm, and then a recovery for 5 days. At the end of pumping, a water sample was collected and analyzed by the state-certified analytical laboratory for general mineral and Title 22 inorganic constituents (Table 2; Appendix C). Prior to this test, from September 24 to November 2 there was a pause in the testing program in order to obtain a permit from the Regional Water Quality Control Board that would allow pumped water to be discharged into Montara Creek.

In addition to monitoring drawdown in the well 2004-4 while conducting the yield tests, we concurrently monitored water levels in the other test wells and in the domestic well located at 770 Alta Vista Road, and measured flow at the MWSD raw water diversion on Montara Creek and in Daffodil Canyon above Old San Pedro Trail[6]. Streamflow and rainfall were also being continuously gaged in the Martini Creek watershed, as provided in the DWR grant to Montara Water and Sanitary District. Figures 8 through 14 illustrate the monitoring data collected during the 5-day constant-rate pumping test at 300 gpm. Results of the short-term tests in September are not shown, but the findings were similar.

A plot of the water-level elevations in all 5 test wells and in the domestic well at 770 Alta Vista Road (Figure 9) illustrates that under static conditions (when not pumping well 2004-4) that wells 2004-3 and 2004-5 are upgradient, and the others are downgradient. Under pumped conditions, water levels in well 2004-4 fell below the static water level in the domestic well at 770 Alta Vista Road, but resulting drawdown was not observed in the domestic well. Other domestic wells along Alta Vista Road are similar in depth and construction to the domestic well at 770 Alta Vista Road (Table 3). It is likely that this well is representative of others in the neighborhood, as neighbors were advised of the pumping schedule, and no problems were reported or complaints made to the MWSD office or to Balance.

The absence of drawdown in the wells at the adjoining homes is significant. Ground water flows from a high elevation (head) to a low elevation, unless impeded by low permeability or in bedrock having few interconnecting fractures. We believe that, locally, bedrock beneath the weathered zone is sufficiently impervious and lacking in fractures such that the shallow and deep aquifers act largely independently. Hence, domestic wells on Alta Vista Road

[6] In Daffodil Canyon and at the diversion on Montara Creek, flow was measured periodically throughout the summer, and then each day prior to, during and shortly after the yield tests.

seem largely unaffected by pumping of well 2004-4. If the perched weathered-bedrock aquifer from which the domestic wells on Alta Vista Road draw water were directly connected to the deep joints from which well 2004-4 draws water, then the water level in the domestic well would have been lowered during the extended pumping of well 2004-4.

Other wells that did not show drawdown were:

- Well 2004-2, located at the mouth of Daffodil Canyon just west of the mapped fault on Ocean View Farms, which penetrates alluvium and associated marine terrace deposits, plus the underlying fractured bedrock; and
- Well 2004-1, a shallow well in the marine terrace on Ocean View Farms at Highway 1.

Wells 2004-3 and 2004-5 did show drawdown while pumping 2004-4 (Figure 10). Well 2004-3 is a bedrock well nearly as deep as well 2004-4, but with only intersecting fractures in the granitic rock and not deep open joints as in well 2004-4. It is located about 400 feet to the northeast and upgradient of well 2004-4. Well 2004-5 is a shallow well located about 860 feet south of well 2004-4. Well 2004-5 is screened in the weathered, fractured granitics at the base of the alluvium and coluvium at the west edge of the north fork of upper Montara Creek. After 5 days of continually pumping well 2004-4 at 300 gpm and lowering the water level in the well 215 feet, well 2004-3 showed 14 feet of drawdown, and well 2004-5 drew down 3 feet.

The conventional technical approach to analyzing drawdown data in pumped wells and observation (non-pumped) wells is to plot drawdown on a semi-log chart as a function of the duration of pumping (Figure 8). In a homogeneous and anisotropic ground-water flow media (or under approximate conditions) this analysis can quantify permeability and storage, and predict ground-water capture areas. The limited effects of the pumping on wells 2004-3 and 2004-5, as well as the observation of no effect on water levels at 770 Alta Vista indicate that the aquifer near well 2004-4 is neither homogeneous nor isotropic, and the weathered granitic rocks are by their very nature highly anisotropic. Hence, the aquifer flow characteristics of the fractured bedrock are too diverse and vary over short distances, and conventional well-test analysis is of limited use. Put in other terms, conventional analysis of time-drawdown or distance-drawdown plots is not a supportable approach, given how sharply local conditions depart from the assumptions on which they rest. We have attempted to avoid analyses requiring a foundation of isotropy, homogeneity, and knowledge of aquifer thickness in our subsequent discussions in this report, because the observed conditions deviate strongly from such assumptions.

Qualitatively, though, changes to the rate of drawdown do tell us about recharge sources and limits to the aquifer, if interpreted together with field evidence. The form of the curves in Figure 8 – the rate of drawdown slowing after about a half a day of pumping well 2004-4 – suggests that the wells were influenced by upgradient recharge to the pumped well during the 5-day yield test. This is commonly called vertical leakage, but in this case may also predominantly include recharge to the well from other high-yielding joints upgradient. Further away, drawdown in well 2004-5 began after well 2004-4 received upgradient leakage, and the rate of drawdown was similar to well 2004-3. Towards the end of the test, well 2004-4 was trending toward 'equilibrium' when there would be no further drawdown. No signs of major barrier boundaries to the recharge source were recorded during the well test, implying that the aquifer is horizontally continuous at least to the limits pumped during the five-day test. Among other implications, it appears that the major fractures and/or the zones from which they draw without significant energy losses are laterally continuous within these limits.

2.6 Water Quality

Water samples were collected from well 2004-4 on September 22 after 8 hours of pumping at 300 gpm, and then again on November 7 after 5 days of pumping at 300 gpm. The samples were analyzed for general mineral composition and Title 22 inorganic constituents by Soil Control Laboratories in Watsonville (Appendix D), a facility certified by the State to conduct such analyses. Results are shown in Table 2, and compared in the table and in Figure 14 with analyses of other sources in the immediate area, including samples collected at:

- The other test wells (2004-1, 2004-2, 2004-3, and 2004-5);
- The domestic well at 770 Alta Vista Road;
- The well at the McNee State Park ranger's residence at Old San Pedro Trail Bridge;
- The well at the stables on Ocean View Farms
- Montara Creek at the gage above Old San Pedro Trail Bridge;
- Daffodil Canyon at Old San Pedro Trail; and
- MWSD raw water diversion on Montara Creek.

The quality of water from well 2004-4 is excellent. With a concentration of 160 mg/L total dissolved solids, and with iron and manganese not detected, this ground water is some of the freshest and seemingly most healthful reported from San Mateo County. Both samples collected satisfy Title 22 drinking water standards for the constituents tested, and meet source-water concentration requirements for connection to a municipal water supply.[7]

General-mineral analyses (Figure 14) show that ground water from well 2004-4, drawing water from the granitic bedrock, is similar to other regional surface waters, and differs to varying degrees from water drawn from (1) weathered granitics, (2) valley alluvium, and (3) marine terraces. The waters from this well and local streams is sufficiently similar to suggest that they have a common aquifer of origin. The small amount of nitrate found well 2004-4 also indicates some connection with the near-surface waters (deep percolation from nearby sources such as septic systems, irrigated agriculture, or perhaps even decomposition of natural vegetation). Conversely, the trace amount of arsenic may also suggest that a portion of the ground water emanates from considerable depth.

[7] Consistent with regional practice, the well has not been tested for bacteria until it is formally disinfected and flushed, a step usually taken just prior to bringing the well into service.

3. DISCUSSION

3.1 Conceptual Understanding of the Fractured-Bedrock Aquifer

Ground water within Montara Mountain generally moves through a reasonably complex coastal aquifer system composed of:

- Deeply weathered granitic bedrock extending uphill to the catchment divide, sustaining both runoff and bedrock-aquifer recharge;
- Underlying, heavily-fractured Cretaceous granitic rocks of the Montara Mountain batholith that form the basement bedrock, from which well 2004-4 draws water;
- Holocene coarse-grained alluvium and colluvium, and Quaternary marine terrace deposits of various ages, forming the principal aquifers of the region that have been the focus of municipal well development;
- West of faults nearer to the coast, weakly to moderately consolidated sandstone and siltstone of the Pliocene-aged Purisima Formation overlying the granitics in the Moss Beach area and to the south, but which is not found in the vicinity of well 2004-4.

Figure 3 shows mapped unconsolidated deposits (after Brabb and Pampeyan, 1983) and location of hydrogeologic cross sections (Figures 6 and 7). These figures illustrate the concept of a coastal 'pocket' aquifer, which we have introduced in other reports (such as Woyshner and others, 2002). A 'pocket' aquifer is a mountain-watershed hydrogeologic system comprising weathered bedrock (soil), colluvial (up-slope) wedges, alluvial (valley-bottom) deposits, and underlying fractured bedrock. Pocket aquifers are composed of coarse-grained decomposed granitic rocks overlying deeply-fractured Montara Mountain granitics, and have enhanced recharge attributes that manifest in less runoff with a markedly less 'flashy' hydrograph than in areas underlain by other rock types in coastal San Mateo County (Owens and others, 2001). 'Pocket' aquifers are separated by minimally-fractured competent bedrock, similar to the uniform, almost unfractured granitic rock found at well 2004-4 that separates the weathered granitics from the deep high-yielding joints.

Montara Mountain rises over 1,800 feet in less than 2 miles, setting a steep regional gradient for ground-water flow to the coast. The granitic bedrock of Montara Mountain is heavily fractured and is dissected by regional faults and open joints.[8] Figure 4 shows the orientations of fractures, joints and faults in the vicinity of well 2004-4 (see Appendix B for details of the fracture orientations). The high water-yielding joints found at depth in well 2004-4 (the largest shown in Figure 4 and 5) appear to intersect this fracture flow and is broadly connected to even more permeable 'pocket' aquifers on the mountain through the fracture network of the batholith. Several springs are found at considerable elevations, including the springs feeding the MWSD raw-water diversion (Figure 15), suggesting similar joint and fracture ground-water sources elsewhere on the mountain.

3.2 Effects on Local Wells

Multiple lines of evidence indicate that local wells will not show significant or adverse drawdown effects by long-term pumping of well 2004-4 at the proposed rate of 150 gallons per minute.

3.2.1 Geologic differentiation. Local domestic wells along Alta Vista Road and vicinity are drilled 200 to 300 feet into the weathered granitics that have permeability and capacity for ground-water storage, and locally may be characterized as being perched on the unweathered granitic bedrock, where permeability and storage is limited to fractures and in discrete joints. At well 2004-4, there is about 360 feet of uniform, almost unfractured granitic rock that separates the 'weathered aquifer' and the deep water-yielding joints from which well 2004-4 extracts water (Figure 6).

3.2.2 Pumping-test confirmation. Domestic wells along Alta Vista Road are similar in depth and construction (Table 3) and draw water from weathered granitic rock. We monitored the water level in the domestic well at 770 Alta Vista Road as and indicator of ground-water levels in this area (Figure 5). The 5-day 300-gpm yield test showed no drawdown in the monitored domestic well at 770 Alta Vista Road (Figure 7); rather, drawdown was observed in monitoring wells 2004-3 and 2004-5. The rate of drawdown in the two monitoring wells also resembled the reduced drawdown rate in the pumped well, which suggests leakage from an upgradient fracture flow and overlying and underlying ground water (see section 3.3.2 for further explanation).

[8] Considering its tectonic history and location near the convergence of at least two major faults, it probably should not be surprising that the Montara Mountain granitic rocks are much more fractured than their counterparts in the Sierran or Klamath batholiths.

3.2.3 Water chemistry. The chemical signatures of the two aquifers are moderately contrasting, showing differences in the composition of dissolved minerals in the ground waters in the weathered zone along the Alta Vista Road ridge and the deeper waters in the largely unweathered granitic rocks (Figure 14). The unweathered granitic rocks have similar chemical signatures to those of local streams, suggesting a common source in the larger Montara Mountain ground-water system.

3.2.4 Favorable location. Well 2004-4 is located upgradient (upstream) of the local domestic wells in the vicinity (Figure 5), which would capture disproportionately more ground water from areas upgradient of it. In addition, the principal high-yielding joint from which well 2004-4 extracts water, strikes approximately north-south, which is generally perpendicular to downgradient domestic wells.

3.3 Effects on Springs and Stream Baseflow

When pumped, well 2004-4 will draw the majority of ground water from areas upgradient of it (to the north and east, as illustrated Figure 5), and springs in this area or their source water may be affected to variable degrees. All wells have similar effects to greater or lesser degrees. Related effects on vegetation and habitat are possible unless changes can be kept below thresholds at which the biotic organisms experience some stress. We searched for a set of reliable criteria applicable to the Montara setting to guide pumping of this well such that riparian or wetland habitats are not stressed or placed at risk.

We were able to find an established set of drawdown criteria, developed and used by the Monterey Peninsula Water Management Water Management District in a similar geologic environment not far away. These criteria have been used by MPWMD staff to control ground-water pumping to minimize or eliminate plant-water stress of riparian vegetation, can be applied to obtain no effect to the related spring and spring baseflow riparian vegetation from pumping well 2004-4. These are further explained in section 3.3.3 following a discussion of ground-water support to such habitats near the well.

There are three springs located upgradient of well 2004-4 that flow year-round (see Figure 15):

1. A relatively large ground-water discharge area that defines the upper extent of the perennial portion of Montara Creek about 400 feet southeast of well 2004-4.

2. Further upstream on Montara Creek, about 1,400 feet northeast of well 2004-4, MWSD diverts about 70 gpm from other headwater springs[9]. These springs – which we believe to be fed by similar a north-south trending joint – are located about 1,000 feet higher in elevation and upgradient of the principal water-yielding joint at the bottom of well 2004-4 (at elevation -194 feet).
3. Springs to the north in Daffodil Canyon are about 500 feet from well 2004-4.[10]

Further north, about 2,600 feet from well 2004-4, are some of the headwaters of Martini Creek, which has a very low likelihood of being affected by pumping -- as do other springs on Montara Mountain -- because the distance from the pumping source attenuates drawdown effects to below detectable levels.

Two separate lines of evidence – water chemistry signatures and aquifer drawdown test results – help explain how the springs and related stream baseflows are related to ground water extracted from well 2004-4.

3.3.1 Water chemistry signatures as a source indicator. General mineral analyses conducted on regional ground water and surface-water baseflow samples (Figure 14) show several locations with mineral signatures similar to water 2004-4:

- Upgradient bedrock fractures collected from well 2004-3 (BH-9);
- Montara Creek collected at MWSD raw water diversion;
- Daffodil Canyon collected just upstream of Old San Pedro Trail;
- Martini Creek at the gaging station upstream of Old San Pedro Trail; and
- McNee Ranch State Park well at Old San Pedro Trail bridge, which is positioned at the top of the terrace about 50 feet from the creek.

These results suggest first and foremost that most of bedrock of Montara Mountains is remarkably uniform in its ground-water chemistry and the ions it contributes to percolating ground water. They also suggest that baseflow in the regional streams originate from bedrock fracture flow, and likely flow through concentrated by open joints in the bedrock

[9] The canyon is steep and rugged at and above the diversion and the exact location of the spring(s) is not known.
[10] Daffodil Canyon is covered with a dense mosaic of coastal scrub having riparian vegetation along the stream channel. The stream flows year-round but the precise location of the spring source(s) is not differentiated.

that surface downgradient. Baseflow in Martini Creek is about 100 to 200 gpm, Montara Creek, about 70 gpm at raw-water diversion, and 20 to 30 gpm in Daffodil Canyon. The proposed pumping rate – whether at a continuous 150 gpm or 12 hours on and 12 hours off – is similar to natural yields of the regional springs, suggesting an appropriate rate.

The sites that showed different signatures were:

- The marine terrace at well 2004-1 (BH-1);
- The mouth of Daffodil Canyon at well 2004-2 (BH-3), which is influenced by the marine terrace, alluvium, and fault related waters;
- Montara Creek alluvial aquifer at well 2004-5 at (BH-11); and
- The domestic well at 770 Alta Vista Road.

These areas likely are not drawn upon when pumping the well.

A minor amount of nitrate (1.3 to 1.4 mg/L as nitrate) was detected in the water samples collected when pumping well 2004-4 (see Table 2). Since nitrate is not a constituent of granitic rocks, and is seldom found where no surface sources occur, this suggests contributions from surface sources, such as fertilizers, leach fields, or natural decomposition of vegetation. Presence of nitrate is also an indication of dispersed ground-water contributions, since nitrate was not detected in samples from close-in surface waters of Montara Creek and Daffodil Canyon, as well as Martini Creek, further away. It should be emphasized that the detected levels are well below the State Title 22 drinking water standard maximum contaminant level (MCL) of 45 mg/L as nitrate; nitrate is important at this well primarily as an indication that at least some of the water is recharged from not too far away. The well also shows trace levels of arsenic (also well below MCL), which is often an indication of waters emanating from considerable depth. The geochemical evidence suggests that multiple and mixed sources of waters seem to be produced from well 2004-4.

3.3.2 Implications from drawdown in observation wells. Test well 2004-5 is located 800 feet south of well 2004-4, at the west edge of Montara Creek canyon, and about 300 feet from the creek and 400 feet downstream of the springs nearest to well 2004-4 (Figure 5 and 15). It is a shallow well, 85 feet deep and screened in the weathered granitics. It was initially drilled to test the potential for water production from granitic rocks in that portion of the canyon and was also used to qualitatively assess water levels in the canyon while testing well 2004-4. It has characteristics, though, that limits its use in assessing levels of near-surface or perched ground water near the springs upstream:

1. the well is 85 feet deep and screened in the bedrock rather than at the water table or perched water level (Figure 6); and
2. it is located over the high-yielding joint (as projected from well 2004-4; see Figure 5 and 15), which might tend to measure levels more directly related to the joint rather than the springs

Test well 2004-3 is located on Alta Vista ridge, about 400 feet northeast of well 2004-4. This well intersects many fractures but no open joints in the bedrock (Figure 7). Consequently, it only yields a maximum of 10 to 15 gpm. It was used to qualitatively assess water levels in the bedrock while testing well 2004-4.

The drawdown rates from pumping a well are typically highest at the onset of pumping and decrease logarithmically with time and distance as the well draws from more portions of the aquifer. For example, drawdown on Day 10 will generally be about double that at the end of the first day; after 100 days of constant pumping, the well may draw down only three times as far as after the first day. A common way of expressing this concept graphically is by plotting drawdown on a semi-log chart, which shows the decline in water levels as a straight line, as in Figure 8, rather than showing an abrupt drawdown when plotted on a linear chart, as shown in Figure 10. This straight line plot facilitates short-term drawdown projections beyond the end of the test. The capture area continues to enlarge and the curve continues to plot straight on the semi-log chart until one or more of the following conditions are met:

1. It intercepts enough of the flow in the aquifer to equal the pumping rate;
2. It intercepts a body of surface water from which enough additional water will enter the aquifer to equal the pumping rate when combined with all the ground-water flow toward the well;
3. Enough vertical recharge from precipitation occurs within the radius of influence to equal the pumping rate;
4. Sufficient leakage occurs through overlying or underlying formations or fractures to equal the pumping rate.

When the capture area has stopped expanding because of one or more of the above conditions, equilibrium exists and there is no further drawdown with continued pumping. During the aquifer test on well 2004-4, wells 2004-4 and 2004-3 both showed an upward inflection in the semi-log plot after about a half a day (Figure 8), indicating a trend towards equilibrium. In addition, well 2004-5 showed delayed drawdown that began after wells 2004-4 and 2004-3 showed this trend toward equilibrium. Given that the high-yielding joint supplying well 2004-4 is about 460 feet below the bottom of well 2004-5, it is reasonable to expect to see some drawdown in well 2004-5 when well 2004-4 shows effects for formation leakage (condition #4 above). Other sources also recharge the well, as discussed in section 2.3.1 (above).

After pumping well 2004-4 for 5 days at 300 gpm and drawing down the water level in the well 215 feet, the water level in nearby well 2004-3 lowered 14 feet, and 3 feet in well 2004-5, further away in the valley below. Extrapolating the pumping at 300 gpm to 70 days (to 100,000 minutes on Figure 8), drawdown in well 2004-5 is estimated to reach 7 feet. If pumped continuously at the proposed 150 gpm for 6 months (260,000 minutes), then drawdown in well 2004-5 is estimated to be 9 feet; and if regularly pumped 50 percent of the time (12 hours on and 12 hours off), drawdown is estimated to be 4.5 feet.

Inflow to the raw-water diversion box located further upstream on Montara Creek was measured during the 5-day pumping test, and no decrease in flow was observed. No effect on the source springs appeared evident, and none would be expected under proposed operations.

Wells 2004-3 and 2004-5 and the MWSD raw-water diversion are appropriate locations to monitor drawdown effects in the vicinity of the well 2004-4, but to monitor specific effects to the springs upgradient of well 2004-5 (nearest to well 2004-4), a shallow monitoring well, screened across the water table in the alluvium is preferred. We recommended a location next to the springs and the creek, as shown in Figure 15, subject to approval of the landowner, Coast Wholesale Florist. Drawdown criteria, recommended pumping rates and an adaptive management program are discussed in the next section (3.3.3).

3.3.3 Proposed thresholds of significance for monitoring drawdown. Recognizing that a potential exists to reduce ground-water availability to riparian vegetation, we searched for site-appropriate information bearing on (a) what might be the appropriate threshold of significance such that riparian vegetation is not stressed, and (b) how to plan monitoring so that such a threshold will not be exceeded and the vegetation will be protected. We found a useful prototype adaptable to the Montara setting in work conducted along the Carmel River by Monterey Peninsula Water Management District staff in a respected report on the "effects of production well pumping on plant water stress in riparian corridor of the lower Carmel Valley" (McNiesh, 1986). The report provides results and a ground-water drawdown model useful to estimate general impact of water-table drawdown on riparian plant-water stress[11] levels:

1) Water-table drawdown will have nominal impact when soil water is readily available. Normally, soil-water will be readily available during the period beginning with the first heavy autumn rainfall and generally ending in late May or early June, but varying from year to year.
2) After soil water becomes limited, the following general levels of water stress may be expected:
   a) Severe water stress when total drawdown of 8 feet or more below the elevation of the winter water levels, or incremental drawdown of 2 feet or more in any given 7-day period.
   b) Mild water stress when total drawdown of 4 to 8 feet below the elevation of the winter water levels, or 1 to 2 feet in any given 7-day period.
   c) No effect when total drawdown of less than 4 feet below the elevation of the winter water levels, or drawdown of less than 1 foot per week throughout the summer and autumn.
3) The timing of water-table drawdown during the period of limited soil-water availability may moderate the level of water stress. Drawdown effects will be less severe:
   a) the greater the delay in the onset of drawdown, and
   b) the shorter the length of the drawdown period.
4) Many environmental factors will contribute to the influence of water table drawdown on plant-water stress.

McNiesh measured stress in the riparian woody and herbaceous species with which he worked by measuring differences in osmotic potential of leaves in the near-dawn and mid-afternoon hours, an established, conservative measure of physiological stress. MPWMD had used this measure in earlier years, and continues its use where warranted. Because of the

[11] In addition to monitoring reference evapotranspiration, pan evaporation, ground-water level and soil moisture availably, McNiesh used three measurements to evaluate plant water stress: a depressed dawn plant-water potential level (indicating a plant water deficit), induced daytime stomatal closure (a plant mitigating response to water stress that constrains growth), and early canopy defoliation.

agency's interest in using the criteria to establish and maintain riparian vegetation, younger plants (more subject to stress) were often emphasized.

Regarding item #4, we view the MPWMD criteria for the Carmel River as fundamentally applicable to the Montara area, because the soils, geology, and hydrology are typical of riparian areas in granitic watersheds. This point is crucial, because the criteria are suited to a granitic substrate and because they were field-calibrated (e.g., empirical). The MPWMD criteria may, though, overestimate effects on riparian vegetation from pumping well 2004-4 for the following reasons:

- Montara area is in a climatic region having lower potential (or 'reference') evapotranspiration (Eto). The region is characterized as reference evapotranspiration zone 1, "coastal plains heavy fog belt" by California Irrigation Management Information System (CIMIS), which has the lowest evapotranspiration in California (Snider, 1999). For comparison the coastal mixed fog area (zone 2), found in the Monterey and San Francisco Bay areas, has on average 15% more evapotranspiration. In addition, the micro-climate of the coastal canyon bottom has lower evapotranspiration than typical for the region, and almost certainly lower than in central Carmel Valley.
- The soil supporting riparian vegetation near well 2004-4 has a higher clay content and fine-grained texture than prevails in the central Carmel Valley, for which the MPWMD criteria were developed. More moisture will be held in the soils and demonstrated in the report to provide water to riparian vegetation at low ground-water levels.
- The report demonstrated that off-channel riparian vegetation was adapted to tolerate lower ground-water levels than stream-side vegetation. Flow in Montara Creek is intermittent in the vicinity of well 2004-4, making most if not all of the riparian vegetation off-channel relative to the findings of the report.
- The nearest riparian vegetation to the well is about 400 feet, and the well draws water from joints over 500 from the canyon bottom. The report showed highest water-stress effect from alluvial wells near the river that quickly lowered ground-water levels when pumped.

Charlie McNiesh developed these guidelines while he was working at MPWMD in 1986, largely in response to severe die-offs of riparian vegetation near major wells in the Carmel

Valley area during and following the drought of 1976 and 1977. In particular, MPWMD was focused upon (a) preventing recurrence of the dieoffs by keeping the rate of pumping in selected water-supply wells under their jurisdiction within thresholds of water-level decline likely to not harm most or all riparian trees, and (b) avoiding damage to extensive replanting efforts which MPWMD undertook following the drought. Extensive erosion occurred along the Carmel River during the floods following this drought because the roots of the trees were the primary element holding the banks together; once they died, the Carmel River rapidly eroded laterally, a situation that MPWMD was able to successfully control with the extensive replantings.

The Monterey Peninsula Water Management District has successfully used these guidelines during the intervening years, avoiding the loss of riparian vegetation that had catalyzed the original McNiesh work. We contacted Nikki Nedeff (former wetland ecologist with MPWMD) and Thomas Christensen (current holder of the position) to find out more about their experience in subsequent years. Both of the Carmel-experienced riparian ecologists noted that the guidelines have successfully prevented loss of post-1983 replantings or of young vegetation re-establishing after the 1995 and 1998 floods. They both felt that the guidelines were quite conservative for protecting existing riparian areas; they cited a number of locations and instances where the one-week and full-season maximum drawdowns recommended in the McNiesh study had been substantially exceeded without noticeable response, let alone loss. Mr. Christensen noted that seasonal drawdowns of 18 to 20 feet had been recurring for years in several areas with fully-mature cottonwoods or sycamores without discernible effects. Both ecologists independently suggested that one way of responsibly approaching the effects of well drawdown in settings similar to Carmel Valley would be to initially apply the MPWMD guidelines, monitoring the response of the most sensitive species or reaches, and using the results to evaluate whether further drawdown might be tolerated.

We recommended in section 3.3.2 (above) to use a shallow monitoring well for assessing potential drawdown effects to a specific 'indicator' spring located closest to well 2004-4 (Figure 15). Wells sited near the spring and next to Montara Creek is recommended, subject to the owner's willingness to participate. It should be installed per State monitoring well standards (CDWR Bulletin 74-90 and 74-81) and equipped with a continuous-recording datalogger.

MWSD proposes to pump well 2004-4 at 150 gpm, which we have shown to be an appropriate level (section 3.3.1). The MPWMD drawdown guidelines provide specific thresholds of significance after soil water is limited – generally beginning late May or early June – and prior to this, nominal effects are anticipated when soil water is readily available. Given the highest drawdown rate occurs following the onset of pumping, the rate of pumping should be ramped up gradually when pumping commences after June 1 to avoid exceeding the 7-day threshold of significance. The rate of ramping can be established based on the monitoring results. We propose the following operational protocol for pumping the Alta Vista production well (2004-4):

1. *Initiating pumping during the dry season when soil moisture is limited*. If ground water pumping at Alta Vista Well #1 starts between June 1 and the first onset of heavy rains during the following autumn, then the pumping rate will begin at lower rate than the proposed 150 gpm. Otherwise, pumping may begin at the proposed rate of 150 gpm.
   .

2. *Short-term drawdown during the dry season when soil moisture is limited*. Between June 1 and the first onset of heavy rains during the following autumn, drawdown in the monitoring wells caused by pumping the Alta Vista production well shall not exceed 1 foot during any 7-day period. If pumping induced drawdown measured at the monitoring wells exceeds 1 foot over any 7-day monitoring period, then the rate of pumping will be reduced such that the 7-day drawdown is not greater than 1 foot, based on results of data collected during the prior week(s). Otherwise, ground water pumping may increase, so as the threshold of 1 foot drawdown per any 7-day period is not exceeded

3. *Maximum seasonal drawdown during the dry season when soil moisture is limited*. Between June 1 and the first onset of heavy rains during the following autumn, drawdown in the monitoring wells caused by pumping the Alta Vista production well shall not exceed 4 foot below the winter water level. If pumping induced drawdown measured at the monitoring wells at any time during the dry season exceeds 4 feet below the elevation of the winter baseflow water levels, ground water pumping will be reduced to a rate that at most maintain this 4-foot maximum drawdown level.

4. *Adjusting thresholds of significance*. It may prove beneficial if an approach for monitoring responses to the wetland and riparian vegetation is developed by a wetland ecologist with expertise in riparian-vegetation moisture-stress dynamics. The 4-foot and 1-foot criteria outlined above are applicable for the duration of the monitoring plan unless a biological assessment recommends that different drawdown levels are more appropriate for the local habitat.

3.3.4 Proposed management of ground-water drawdown.

We have concluded that most recharge to well 2004-4 come from the area north and east of the well and especially from areas nearest the well (Figure 5). This conclusion is based on:

a) *Geologic differentiation and well construction (Appendix B)*. Well 2004-4 draws ground water from high-yielding joints below a depth of 720 feet (an elevation of -190 feet), and there is about 360 feet of uniform, almost unfractured rock that separates the deep water-yielding joints from overlying ground waters. Well 2004-4 was completed with solid casing to seal off overlying fractures and weathered granitic rock.

b) *Water chemistry (Figure 14)*. The composition of dissolved minerals suggests the well draws on a large body and/or interconnecting sources of ground water within joints and fractures of unweathered granitics of Montara Mountain.

c) *The fracture orientations within the granitic bedrock and the regional gradient of flow to the coast (Figure 4)*. For a given a ground-water flow gradient, a well will capture disproportionately more ground water from areas upgradient of it, and therefore have greater effects to water levels in those areas.[12] At 2004-4 the capture area is towards the northeast.

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[12] In a porous media with negligible lateral flow (like a broad sediment basin), well pumping creates a "cone of depression" (like a funnel), but if there is lateral ground-water flow (a flow gradient; like in valley or canyon alluvium) then the water-level (or piezometric) depression from pumping the well will be skewed upgradient. In plan view, the capture boundary resembles an arch, opening upgradient (like a catenary curve). Modeled estimates of the of the ground-water capture boundary may not be applicable to the fracture-flow conditions at well 2004-4 as they would be in a porous media with known aquifer characteristics, but the capture direction is similar.

d) *The orientation of the principal high-yielding joint from which well 2004-4 extracts water (Appendix A)*. The joint approximately strikes north-south, crossing the gradient of flow and thereby minimizing downgradient contributions to well recharge.

e) *Aquifer testing confirmation*. The 5-day 300-gpm yield test showed drawdown effects only in upgradient observation wells. No effects were documented in the downgradient domestic well at 770 Alta Vista Road near the headwaters of Kanoff Creek, nor of flows from Daffodil Canyon (measured above Old San Pedro Trail) or at the mouth of Daffodil Canyon at test well 2004-2. There were also no effects further upstream, at the diversion on Montara Creek,

Well 2004-4 is located at the divide of three watersheds (Figure 15): Montara Creek watershed to the east, Daffodil Canyon to the northwest, and Kanoff Creek to the southwest.

- There is little likelihood of observing effects from long-term pumping of the well, on **Kanoff Creek**, principally because the watershed is not within the potential capture limits of the well. Domestic wells penetrating the shallow aquifer within the upper watershed will potentially serve to monitor ground-water conditions if needed (such as the domestic wells along Alta Vista Road), but domestic wells would also potentially effect ground water levels at a local level (as seen in Figure 9). In addition, the watershed is partially urbanized and partially irrigated; hence, it seems to be also supported by 'nuisance flows' (domestic and agricultural dry-season runoff).

- We suggest that low flows in **Daffodil Canyon** be observed for possible effects of the project. Potentially, these low flows may be affected because Daffodil Canyon's uppermost watershed overlies the well's theoretical limit of capture. On the other hand, both the flows from the canyon and the ground-water level at the mouth of the canyon were not affected by the pumping tests. Daffodil Canyon is vegetated with a dense mosaic of coastal scrub and supports a ribbon of riparian vegetation along the stream channel. It is locally known for its diverse plant communities. Access within the canyon is solely by hiking trails and deer trails. Because any attempt to drilling boreholes and install monitoring wells within the canyon would be unduly disruptive, we propose monitoring water levels and specific conductance in test well 2004-2 at the mouth of the canyon for diminished recharge (which will appear as lower static water levels) or increases in 'salinity' that would reflect diminish low flows from this source. This approach will prove more effective than gaging surface flows because a considerable proportion of the tributary's summer flows seems to percolate into the bed. In addition, the watershed is so small that it may be difficult to discern subtle diminution of flows; since major effects were not observed during the pumping tests, the focus of monitoring might reasonably be upon detecting relatively slight differences. By measuring static water levels and specific conductance during the low-flow months, two independent lines of evidence – ground-water and hydrochemical data – can be used to seek such effects.

- Closest to the well is a spring area that generally defines the upper extent of the perennial portion of **Montara Creek**, and one way of responsibly measuring the effects of pumping well 2004-4 on the springs, riparian vegetation and wetlands in the vicinity would be to limit drawdown at this indicator site to a level known to not be harmful to riparian species, per the proposed thresholds of significance outlined in Section 3.3.3 (above). We have proposed using two shallow monitoring wells located near the wetland and channel riparian for this purpose (Figure 15).

Following are proposed elements to an adaptive monitoring plan that uses the above outlined approach of emphasizing (or weighting) the level of monitoring to the level of effect by pumping. The program is based on the thresholds of significance outlined in Section 3.3.3 that were adapted from the Monterey Peninsula Water Management District (McNiesh) criteria.

1. Continuously monitor ground-water level supporting wetland and riparian vegetation nearest the Alta Vista production well in two shallow wells. These are the primary stations with which to regulate pumping from the Alta Vista production well using the thresholds of significance outlined in Section 3.3.3.

2. Monitor flows further upstream in Montara Creek. The canyon becomes steep and rugged upstream of the agricultural fields and monitored wetland proposed in Condition #1, and the MWSD "raw water" diversion serves as an effective upstream monitoring point with which to assess effects on springs in the upper watershed feeding the diversion. If flow stops as a result of pumping the Alta Vista well, then MWSD should revise the pumping schedule.

3. Monitor water levels in test wells 2004-3 and 2004-5 as additional data for a better understanding of the fractured bedrock aquifer, and to help quantify what other activities or processes may be affecting water levels.

4. Continuously monitor ground-water levels and specific conductance at the mouth of Daffodil Canyon in well 2004-2 to assess pumping effects on Daffodil Canyon. If drawdown effects are documented per the thresholds of significance outlined in Section 3.3.3, then adjust pumping appropriately, and (b) assess whether and when monitoring in or near Kanoff Creek may be warranted.

5. At least initially, monitoring Kanoff Creek is not indicated.

6. Monitoring and pumping records shall be documented in an annual report and made available for public review.

Where not otherwise specified, measurements at these locations should be made in mid-June, late August and late September, under the direction of a certified engineering geologist or professional engineer with active State of California registration, using a sampling and analysis plan to be approved by the District.

3.4 Water Rights

Documents presented in Appendix D summarize MWSD's pre-1914 water rights to flow in and beneath Montara Creek, pre-dating SWRCB jurisdiction. Assuming the chain of title can be traced back to Montara Realty Co., MWSD has rights to 100 miners' inches, equivalent to 1,122 gallons per minute -- about 2.4 cfs or nearly 5 acre-feet per day. This right more than meets any proportion of well 2004-4's production that may ultimately diminish flow in Montara Creek. The rights to divert, however, do not release MWSD from obligations to avoid, minimize, or mitigate environmental effects of excessively pumping from the granitics.

3.5 Potential Influences on the Downgradient MTBE Source

Most recharge to pumping well 2004-4 comes from areas to the north and east of the well, and especially from area nearest the well (Figure 5). The MTBE source is 2000 feet to the south (traverse or downgradient) and is reportedly contained by a pump-and-treat system.

By mitigating for drawdown responses to wetland and riparian vegetation near the well, MWSD will almost certain avoid pumping from the area affected by MTBE.

3.6 Reliability of Yield and Potential Effects on Ground-Water Storage

Unlike alluvial aquifers within the stream valleys, the lateral boundaries of the bedrock aquifer are independent of surface watershed areas, and therefore can have much broader recharge areas. While the areas which can recharge this well under varying conditions are not fully known, it is clear that a large volume of mountain extending well beyond the watersheds on either side of the Alta Vista Road ridge potentially contributes storage and supply tapped by well 2004-4. Both the volume and the extent of the are magnified by the scale and the depth of the joints – 724 feet below ground surface and 200 feet below sea level – from which this well is supplied. In contrast, wells and springs drawing upon shallower joints are believed to draw primarily from more-localized sources. Independent evidence supporting a large, interconnected contributing area is nearly uniform specific conductance (an index of salinity) measured when both constructing and pumping the well. Previous work has shown that in Santa Cruz Mountains granitic aquifers with limited storage, specific conductance will rise markedly as a well is constructed, as it is pumped for long periods, or over time during early summer; conversely, larger, integrated aquifers will maintain a nearly steady specific conductance (c.f., Hecht, 1978), as is the case with well 2004-4. The steady specific conductance values during testing and the spatially uniform values recorded in other nearby source indicate that this well draws from a large, integrated aquifer.

3.6.1 Recharge sustainability. The potential to recharge the largely-unweathered deep granitic rocks is magnified by presence of permeable and water-holding rock virtually throughout the Montara Mountain batholith. Recharge to the fractures slowly and nearly-continuously percolates from overlying weathered granitics, alluvium and colluvial wedges. This is reflected in the larger, longer-sustained baseflows of seeps, springs, and streams emanating from these rocks. Recent research (e.g., Owens and others, 2000) indicates that baseflows from watersheds underlain by Montara Mountain granitic rocks are often three to five times larger than those in adjoining streams draining Franciscan or Purisima or early-Tertiary aquifers, supporting earlier work[13] (c.f., Huckins, 1988) showing proportionately

[13] Perhaps the most-easily understood evidence for much greater recharge rates and sustained baseflows in granitic rocks can be found in the region's history. The original water source for the community of Half Moon Bay was Apanolio Creek, on the south side of the Montara batholith. The

much greater and more reliable (a) recharge to the Montara granitics and (b) yield to the streams sustaining flow during dry periods.

With this background, it is possible to compare the yield of Well 2004-4 with the areas that likely to recharge the propose volumes to be extracted. The proposed pumping rate of 150 gpm is equivalent to slightly more than 240 acre-feet per year if pumped continuously. A more likely pumping scenario is to operate the pumps 50 percent of the time, probably on the basis of 12 hours on and 12 hours off, resulting in a yield of 120 acre feet per year. Given a conservative estimate for annual recharge averaging 6 inches, then the estimated recharge area would be 240 acres; a more liberal annual rate averaging 12 inches would require only 120 acres. For perspective, Martini Creek watershed (catchment) above Old San Pedro Trail bridge is about 524 acres, and Daffodil Canyon watershed is approximately 131 acres.

In reality, few wells anywhere in the state draw upon recharge areas exclusive to the well. In the case of well 2004-4, the available area without other wells could sustain the anticipated yield, but other areas and sources likely also contribute. As well 2004-4 is pumped long term, it may draw recharge into the zones shared with other wells, streams and diversions. The mitigation and monitoring plan proposed for effects to spring and wetland responses in Section 3.3.3 (above) should be adequate to minimize effects below any thresholds of significance.

3.7 Potential Effects on Ground-Water Outflow and for Sea-Water Intrusion

Sea-water intrusion is physically impossible in a well where water levels are not expected to fall below sea level. The pumping water level in well 2004-4 is estimated at an elevation of 190 feet if pumped at 150 gpm.[14] Further, the well is separated from the ocean by a large, sustained mound of ground water, including aquifers holding water at static levels of 100 feet above sea level or more. Additionally, the north-south strike of the main fracture(s) and their eastward dip (and away from the coast) constrains sea-water intrusion (see Figures 3 through 6).

Spring Valley Water Company – the original purveyor to San Francisco and the Peninsula Communities, and subsequently taken over by the San Francisco Water Department – obtained water rights on other small streams emanating from Montara Mountain, such as Frenchmans Creek and Loucks Creek, not bothering with most streams of similar size originating in other rock types.

[14] Elevation of well 2004-4 is about 530 feet and static (non-pumped) water level is at 234 feet below ground surface (Table 1). The specific capacity of the well is 1.4 gpm per foot of drawdown, and when pumped at 150 gpm, drawdown is 107 feet. Elevation of the water when pumped at 150 gpm is 530 minus 234 minus 107, which equals 189 feet.

3.8 Potential Impacts from Seismic Activity

Increases or decreases to well yields and/or static water levels are observed following large earthquakes, suggesting changes to fracture porosity and joint orientation of the bedrock aquifer. For example, following the 1989 Loma Prieta earthquake, well yields, water levels and spring flows were altered in the Santa Cruz Mountains at many locations (Briggs, 1992; Rojstaczer and Wolf, 1992). Turbidity may also be introduced following such events, particularly in wells such as 2004-4, completed as an open bedrock borehole without screened casing and a sand (filter) pack.

Well 2004-4 is cased through weathered granitics from the ground surface to competent granitic rock at 370 feet, stabilizing this section of well from likely collapse or slough from the walls of the well. Geophysical logging of the open borehole below 370 feet down to 714 feet, showed sparsely-fractured competent granitic rock, and confirming suggestions from the geologists' field logging and the slow, uniform drilling rates that casing the well may not be either needed or warranted. Placing the pump within this section of massive granitics is recommended to minimize any potential for borehole collapse, and reduce pumping interruptions and costly pump replacement complications. The total depth of well 2004-4 is 780 feet, providing a conservative 50 feet of borehole below the water-yielding fractures to collect sand and sloughed material in the coming years.

Well 2004-4 provides improvements to emergency water supplies given an interruption of existing supplies on mid-coast San Mateo County. The well does not appear to be yield limited, and provides water of potable quality. Since it draws from a ground-water source deeper and further toward the mountain crest than most in the region, it may provide short-term high yields during times of emergency – during fire demands or when other supplies may be contaminated or non-producing.

Midcoast residents living beyond the boundaries of MWSD may also potentially benefit under such conditions, gaining a significant local source of supply in case of seismic-related interruption of water supplies imported from Hetch Hetchy or Pilarcitos Lake.

3.9 Erosion and Surface Subsidence

3.9.1 Erosion Associated with Construction of the Project. The erosion hazard, which can be high in these soils and in the weathered granitic rocks at the site of well, can be reduced to below significance using demonstrated erosion-control methods when the well is serviced or maintained.

3.9.2 Potential for Surface Subsidence from Long-Term Pumping. No significant surface subsidence impacts are anticipated from pumping well 2004-4 at 150 gallons per minute (gpm) or greater, because geologic and geophysical data establish that the well is constructed completely in granitic rocks. Granitic rocks are not reported to be susceptible to ground subsidence. Ground subsidence has occurred in the Santa Clara Valley, and elsewhere in California, where compressible clays and other sedimentary rocks are subjected to much greater drawdowns (c.f., Poland, 1972).

4. CONCLUSIONS AND RECOMMENDATIONS

Unlike many other bedrock wells in midcoast San Mateo County, well 2004-4 is very high yielding and draws ground water from deep, regional joints in Montara Mountain. The well draws from the unweathered granitic rock of the Montara batholith, an aquifer that is only slightly developed in the Montara/Moss Beach area. Several independent lines of evidence indicate that well appears to draw on a large body and/or interconnected sources of ground water within the mountain. Nearly all of the contributing area has little or no potential sources of contamination.

Water quality is excellent: 160 mg/L total dissolved solids; iron and manganese not detected; and satisfying Title 22 drinking water standards. Yields were sustained throughout a five-day aquifer test conducted at 300 gpm, with water levels gradually stabilizing during the test.

As with other community water-supply wells, reliability of yield is initially established by conducting a suite of tests mandated by the California Department of Health Services, including a 72-hour aquifer test. Well 2004-4 exceeded these tests. Measurements of yield, drawdown, water quality, and temperature are indicative that this well draws upon a large volume of fracture rock beneath Montara Mountain. The well tests showed no evidence of barriers or boundaries which might restrict the volume of yield from the well. Eventually, the reliability of well 2004-4 will be established through its use over time, as with all wells of its class.

Well 2004-4 can provide improvements to emergency water supplies given an interruption of existing supplies to midcoast San Mateo County.

Independent lines of evidence indicate that local wells will not show significant or adverse drawdown effects by long-term pumping of well 2004-4 at the proposed rate of 150 gallons per minute. Geologic and geophysical logging of the borehole and water quality analyses indicate that shallow (<400-foot) wells used by residences along Alta Vista Road draw from a weathered-granitic aquifer, yielding water of different quality from that pumped from the well. The well was completed in a manner that isolates the deep ground water source from shallow sources, as to minimize (or rule out) well-head impacts. The 5-day pumping test at

300 gallons per minute showed no drawdown impacts to residential well owners along Alta Vista Road, drawing their water from the shallow bedrock source.

Results of general mineral analyses suggest that, similar to well 2004-4, baseflow in regional streams originate from bedrock fracture flow, likely captured by open joints in the bedrock that surface downgradient at the spring. The proposed pumping rate is similar to natural yields of clusters of springs throughout the area.

One way of responsibly approaching the effects of well drawdown to the springs, riparian vegetation and wetlands in the vicinity of the well would be to limit drawdown at an indicator site to a level known to not be harmful to riparian species. The closest site to well 2004-4 is the relatively large ground-water discharge area defining the upper extent of the perennial portion of Montara Creek about 400 feet south-southeast of well 2004-4. Such guidelines were developed for similar granitic soils and alluvium along the Carmel River by the Monterey Peninsula Water Management District, which has used them successfully over the past 18 years. The guidelines have short-term as well as seasonal thresholds of significance for drawdown. Given the highest drawdown rate occurs following the onset of pumping, the rate of pumping should be ramped up gradually after June 1 to avoid exceeding the 7-day threshold of significance, otherwise nominal effects are anticipated prior to this when soil water is readily available. An adaptive management program is proposed, beginning with applying the guidelines, monitoring responses, and using the results to evaluate whether further drawdown might be tolerated. To implement this program, we principally recommend installing shallow monitoring wells near the spring and creek, and developing a wetland and riparian vegetation monitoring scheme to assess drawdown responses while pumping well 2004-4 at the proposed 150 gpm. Additional monitoring is also proposed for Daffodil Canyon and Kanoff Creek watersheds.

There is no potential for well 2004-4 to induce seawater instruction. This is physically impossible in a well where water levels are not expected to fall below sea level. The water-level elevation in well 2004-4 is estimated to be around 190 feet above sea level if pumped at 150 gpm. The well is also separated from the ocean by a large, sustained mound of ground water, and a unique set of conditions associated with the orientation of principal water-yielding joints supplying ground water to the well minimize the possibility for sea-water intrusion to a negligible level.

Changes to the yield and/or static water level are possible following large earthquakes, and turbidity may also be introduced. The well has been designed to accommodate a certain amount of displacement and caving while sustaining production.

Operation of the well is not expected to draw any water from a known MTBE-affected site substantially downgradient of well 2004-4. No other contamination sites are known from its inferred recharge area.

No surface subsidence is anticipated from pumping well 2004-4 at 150 gpm.

Erosion hazards can be high in the soils and weathered granitic rocks at the site of well. These should be reduced to below significance using demonstrated erosion-control methods and a regular maintenance schedule.

5. LIMITATIONS

This report was prepared in general accordance with the accepted standard of practice in surface-water and ground-water hydrology existing in Northern California for projects of similar scale at the time the investigations were performed. No other warranties, expressed or implied, are made.

As is customary, we note that readers should recognize that interpretation and evaluation of subsurface conditions and physical factors affecting the hydrologic context of any site is a difficult and inexact art. Judgments leading to conclusions and recommendations are generally and customarily made with an incomplete knowledge of the conditions present. More extensive or extended studies, including additional and more complete aquifer tests, can reduce the inherent uncertainties associated with such studies. We note, in particular, that many factors affect local and regional ground-water levels. If the client wishes to further reduce the uncertainty beyond the level associated with this study, Balance should be notified for additional consultation.

We have used standard environmental information -- such as rainfall, topographic mapping, geologic mapping and geophysical logs -- in our analyses and approaches without verification or modification, in conformance with local custom. New information could influence recommendations, perhaps fundamentally. As updated information becomes available, the interpretations and recommendations contained in this report may warrant change. To aid in revisions, we ask that readers or reviewers advise us of new plans, conditions, or data of which they are aware.

Concepts, findings and interpretations contained in this report are intended for the exclusive use of Montara Water and Sanitary District under the conditions presently prevailing except where noted otherwise. Their use beyond the boundaries of the site could lead to environmental or structural damage, and/or to noncompliance with water-quality policies, regulations or permits.

6. REFERENCES

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TABLES

Table 1. Well 2004-4 drilling and construction descriptors and yield test results
Montara, San Mateo County, California

Site locators	
Borehole number	BH-9b
Assessors parcel number	036-180-030
Latitude, NAD27	N37.5502
Longitude, NAD27	W122.4957
Elevation, feet	530
Drilling and well construction descriptors	
Date drilling began	5/19/2004
Date of well completion	7/7/2004
Depth of static water, feet	234
Air lift test, gpm	200+
Specific conductance, umhos/cm @ field temperature	224
Temperature, C	19
Diameter of well casing, inches	12
Depth of seal, feet	370
Screened intervals, feet	9" noncased hole
Depth of yield-producing open joints, feet	724
Depth of borehole, feet	780
Yield testing	
Date pumping began	11/2/2004
Flow rate, gpm	300
Pumping duration, hours	120
Total volume of water pumped, gallons	2,220,000
Total volume of water pumped, acre-feet	51
Static depth to water level prior to test, feet	232.05
Depth to water at end of pumping, feet	447.00
Drawdown at end of pumping, feet	214.95
Specific capacity (Cs), gpm per foot of drawdown	1.4
Aquifer permeability based on pumping drawdown data (Transmissivity)	not applicable
Date pumping ended and recovery began	11/7/2004
Duration for 100 percent recovery, hours	220
Aquifer permeability based on residual drawdown data during recovery:	not applicable

Notes:

Standard methods for calculating aquifer transmissivity (using Theis equation) are not applicable at this well because nearly all of the ground-water yield is supplied from few open joints starting at 724 feet from ground surface; many of the method assumptions were not met.

Table 2. Summary of field measurements and water quality analyses, Montara Water and Sanitary District, San Mateo County, Califorina

PARAMETER	UNITS	DETECTION LIMIT	MCL	Water Well Samples									Surface Water Samples		
DESCRIPTORS															
Sample I.D.				040922:1900	041118:1100	040917:1215	040922:1655	041107:1600	041007:1045	041007:1338	041007:1550	041118:1015	041007:1616	041126:1720	041126:1650
Site				Well 2004-1 (BH-1)	Well 2004-2 (BH-3)	Well 2004-3 (BH-9)	Well 2004-4 (BH-9B)	Well 2004-4 (BH-9B)	Well 2004-5 (BH-11)	McNee Ranch Domestic Well	Ocean View Stables Well	775 Alta Vista Rd Domestic Well	Martini Creek Gage	Daffodil Canyon near BH-3	Montara Cr Raw Water Diversion
Assessors parcel number				036-330-040	036-320-100	036-180-030	036-180-030	036-180-030	036-180-110	036-330-030	036-330-040	036-143-030	036-330-040	036-330-040	036-370-030
Latitude, NAD27	degrees			N37.5519	N37.5505	N37.5512	N37.5502	N37.5502	N37.5478	N37.5537	N37.5534	N37.5469	N37.5541	N37.5504	
Longitude, NAD27	degrees			W122.5107	W122.5077	W122.4951	W122.4957	W122.4957	W122.4957	W122.5067	W122.5068	W122.4978	N122.5057	W122.5072	
Elevation, NGVD29	feet			60	100	560	530	530	350	100	100	420	100	120	
Lab used				Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control	Soil Control
Sample collected by				gp	jp	gp, jp	gp	mw, va	gp	jp	mw	jp	mw	jp	jp
Sample filtering				yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
FIELD MEASUREMENTS															
Date	MM/DD/YY			9/22/2004	11/18/2004	8/17/2004	9/22/2004	11/7/2004	10/7/2004	10/7/2004	10/7/2004	11/18/2004	10/7/2004	11/26/2004	11/26/2004
Time	HH:MM			19:00	11:00	12:15	16:55	16:00	10:45	13:38	15:50	10:15	16:16	17:20	16:50
Specific conductance (@ 25 C°)	umhos/cm			511	347	248	264	264	318	368	--	--	219	--	--
Conductance (@ field temp)	umhos/cm			391	333	236	235	230	281	320	--	--	170	--	--
Temperature	deg C			13.5	22.6	22.1	19.4	18.6	19.1	18.5	--	--	14	--	--
WATER QUALITY INDICATORS															
Alkalinity (total)	mg/L CaCO3	1		82	68	60	68	65	120	92	190	82	57	64	49
Hardness (total)	mg/L CaCO3	5		110	61	73	80	75	130	110	260	130	73	79	63
pH	pH Units	0.1	10.6	8.1	8.1	7.7	7.7	7.9	7.2	7.5	6.6	7.6	7.2	7.5	7.6
Specific conductance (@ 25 C°)	umhos/cm	1	1600	450	340	250	230	250	400	370	670	460	240	250	190
Total dissolved solids (TDS)	mg/L	10	1000	290	220	160	150	160	260	240	430	300	150	160	125
GENERAL MINERALS															
Bicarbonate (as CaCO3)	mg/L	1		82	68	60	68	65	120	92	190	82	57	64	49
Calcium (Ca)	mg/L	0.5		32	19	24	27	25	35	33	69	28	22	24	19
Carbobate (as CaCO3)	mg/L	1	120	0	0	0	0	0	0	0	0	0	0	0	0
Chloride (Cl)	mg/L	1	250	92	56	31	32	32	48	52	82	85	32	37	26
Iron (Fe)	mg/L	0.05	0.3	0	0	0.18	0.091	0	0	0	4.8	0	0.069	0.33	0.21
Magnesium (Mg)	mg/L	0.5		7.3	3.3	3.2	3	3	11	6.8	22	14	4.4	4.7	3.8
Manganese (Mn)	mg/L	0.02	0.05	0.037	0.03	0	0	0	0	0	0.34	0	0	0.032	0
Potassiuim (K)	mg/L	0.5		0.93	1.1	0.65	0.53	0.62	0.6	1.1	0.94	0.76	0	0	0
Sodium (Na)	mg/L	0.5		54	44	26	23	22	45	34	66	38	24	25	21
Sulfate (SO4)	mg/L	1	250	15	8.4	10	9.8	9.1	12	10	46	14	7.9	7.1	7.8
TITLE 22 PRIMARY STANDARDS, INORGANIC															
Aluminum (Al)	mg/L	0.05	1	0	0	0.15	0	0	0			0	--	--	--
Antimony (Sb)	mg/L	0.006	0.006	0	0	0	0	0	0			0	--	--	--
Arsenic (As)	mg/L	0.002	0.010	0	0	0.14	0.0088	0.0085	0			0	--	--	--
Barium (Ba)	mg/L	0.1	1	0	0	0	0	0	0			0	--	--	--
Beryllium (Be)	mg/L	0.001	0.004	0.0025	0	0	0	0	0			0	--	--	--
Cadmium (Cd)	mg/L	0.001	0.005	0	0	0	0	0	0			0	--	--	--
Chromium (Cr)	mg/L	0.001	0.05	0.0013	0	0.014	0	0	0.0024			0	--	--	--
Fluoride (F)	mg/L	0.1	1	1.1	1.8	0.71	0.63	0.61	0.85	1.1	0.85	1.2	0.39	0.57	0.45
Mercury (Hg)	mg/L	0.0002	0.002	0	0	0	0	0	0			0	--	--	--
Nickel (Ni)	mg/L	0.01	0.1	0	0	0	0	0	0			0	--	--	--
Nitrate as (NO3)	mg/L	1	45	0	0	0	1.3	1.4	0	1.8	0	1.8	0	0	0
Selenium (Se)	mg/L	0.005	0.05	0	0	0	0	0	0			0	--	--	--
Thallium (Tl)	mg/L	0.001	0.002	0	0	0	0	0	0			0	--	--	--
OTHER CONSTITUENTS															
Boron (B)	mg/L	0.1		0	0	0	0	0	0			0	--	--	--
Copper (Cu)	mg/L	0.05	1	0	0	0	0	0	0			0	--	--	--
Lead (Pb)	mg/L	0.005	0.015	0	0	0	0	0	0			0	--	--	--
Sliver (Ag)	mg/L	0.01		0	0	0	0	0	0			0	--	--	--
Zinc (Zn)	mg/L	0.05	5	0.054	0	0.081	0.054	0	0			0	--	--	--
Gross Alpha	pCi/L		15		0.405			1.71	0.494				--	--	--
LAB CHECK															
Major Cations (Ca+Mg+K+Na+Fe+Mn)	meq/L	--	--	4.57	3.16	2.61	2.61	2.47	4.62	3.71	8.33	4.22	2.51	2.68	2.18
Major Anions (HCO3+CO3+Cl+SO4+F+NO3)	meq/L	--	--	4.60	3.21	2.32	2.52	2.45	4.05	3.60	7.11	4.42	2.23	2.50	1.90
Ion Balance (Cations/Anions)	--	--	--	0.99	0.99	1.13	1.04	1.01	1.14	1.03	1.17	0.96	1.13	1.07	1.15

NOTES

Observer key: mw = Mark Woyshner; jp = Jason Parke; gp = Gustavo Porras; va = Vic Abadie

Lab results: 0 = not detected; blank value = not tested

MCL = Title 22 Maximum Contaminant Level as of June 12, 2003; the MCL of Lead is the Regulatory Action Level

Table 3. Depths of wells along Alta Vista Road
Montara, San Mateo County, California

Address	Well Depth (feet)	Seal (feet)	Gravel Pack (feet)	Perforations (feet)
1020 Alta Vista Road	200	42	42 to 200	45 to 200
775 Alta Vista Road	300	50	50 to 300	220 to 300
770 Alta Vista Road	260	20	20 to 260	180 to 260
732 Alta Vista Road	310	20	20 to 310	170 to 210; 250 to 310
957 Vallesitos Road	260	20	20 to 260	180 to 260
957 Vallesitos Road	290	20	20 to 290	190 to 290

Notes:
Well information take from California Department of Water Resources water well driller's report.

FIGURES

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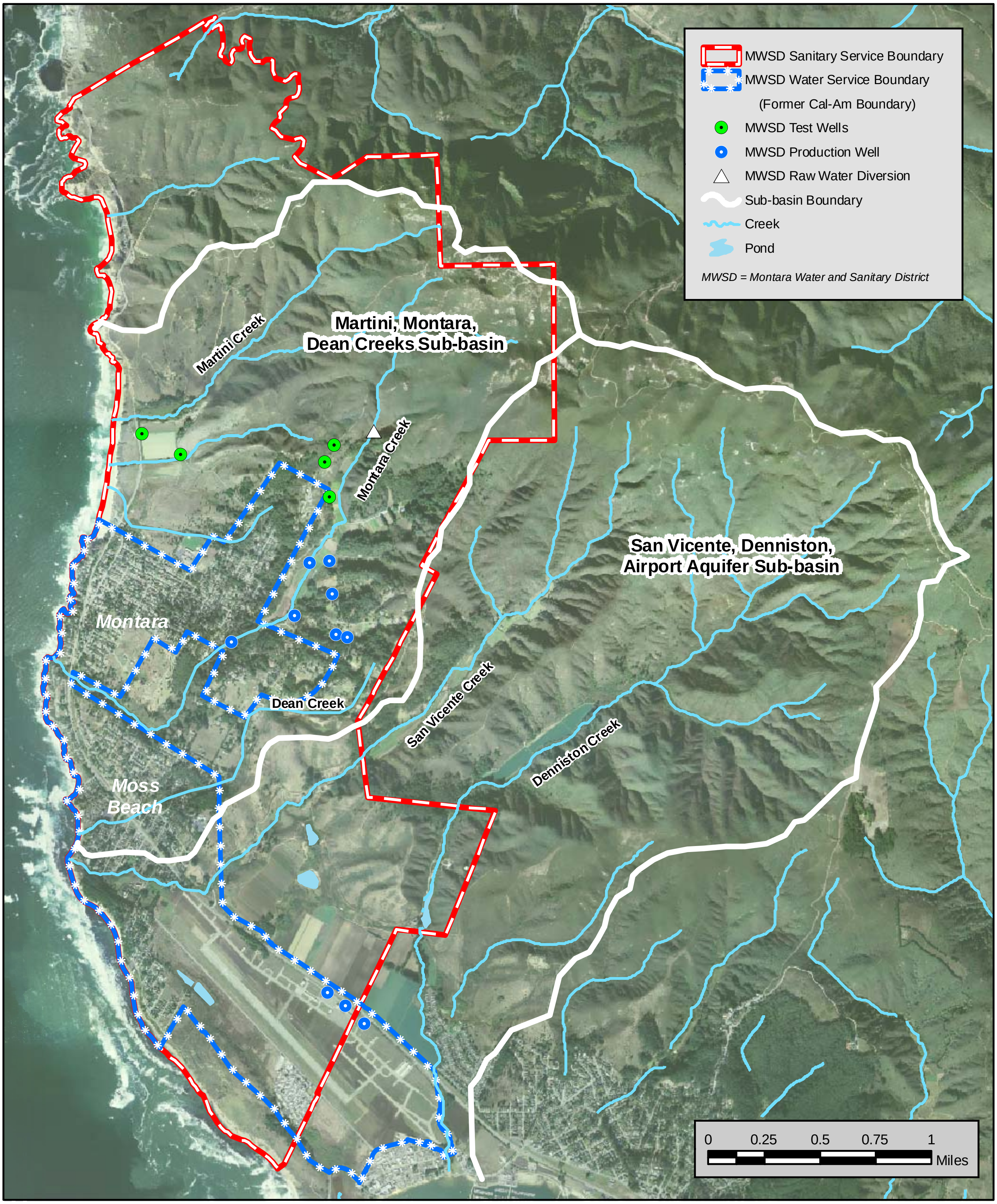
Figure 1. Site location map, Montara, San Mateo County, California

Balance Hydrologics, Inc.

Hillshade and land cover from USGS (http://seamless.usgs.gov/)
Major roads and major cities from ESRI Data CD, 2004

0 3 6 9 12 Miles

N



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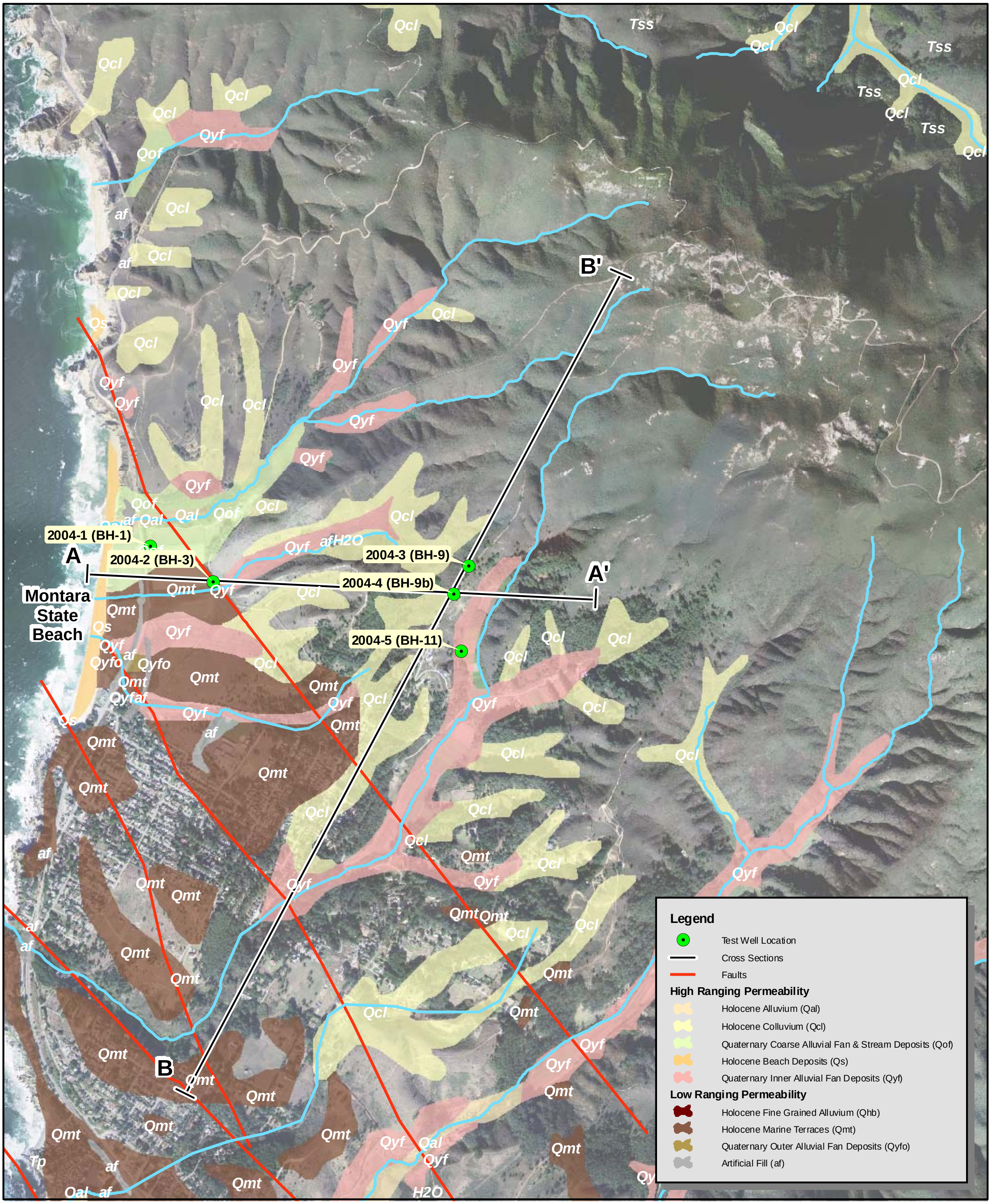
Balance Hydrologics, Inc.

Figure 2. Locations of Montara Water and Sanitary District production wells, raw water diversion, service boundaries, and related Midcoast San Mateo County Sub-basins.

Boundary source: LAFCO
Aerial photo source: USGS, captured 2/27/2004



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Balance Hydrologics, Inc.

Figure 3. Geology map and location of test wells and cross-sections, Montara, San Mateo County, California

Aerial photo from USGS, captured 2/27/2004. Geology data from Geologic Map of San Mateo County, Ca, Brabb & Pampeyan, 1983.

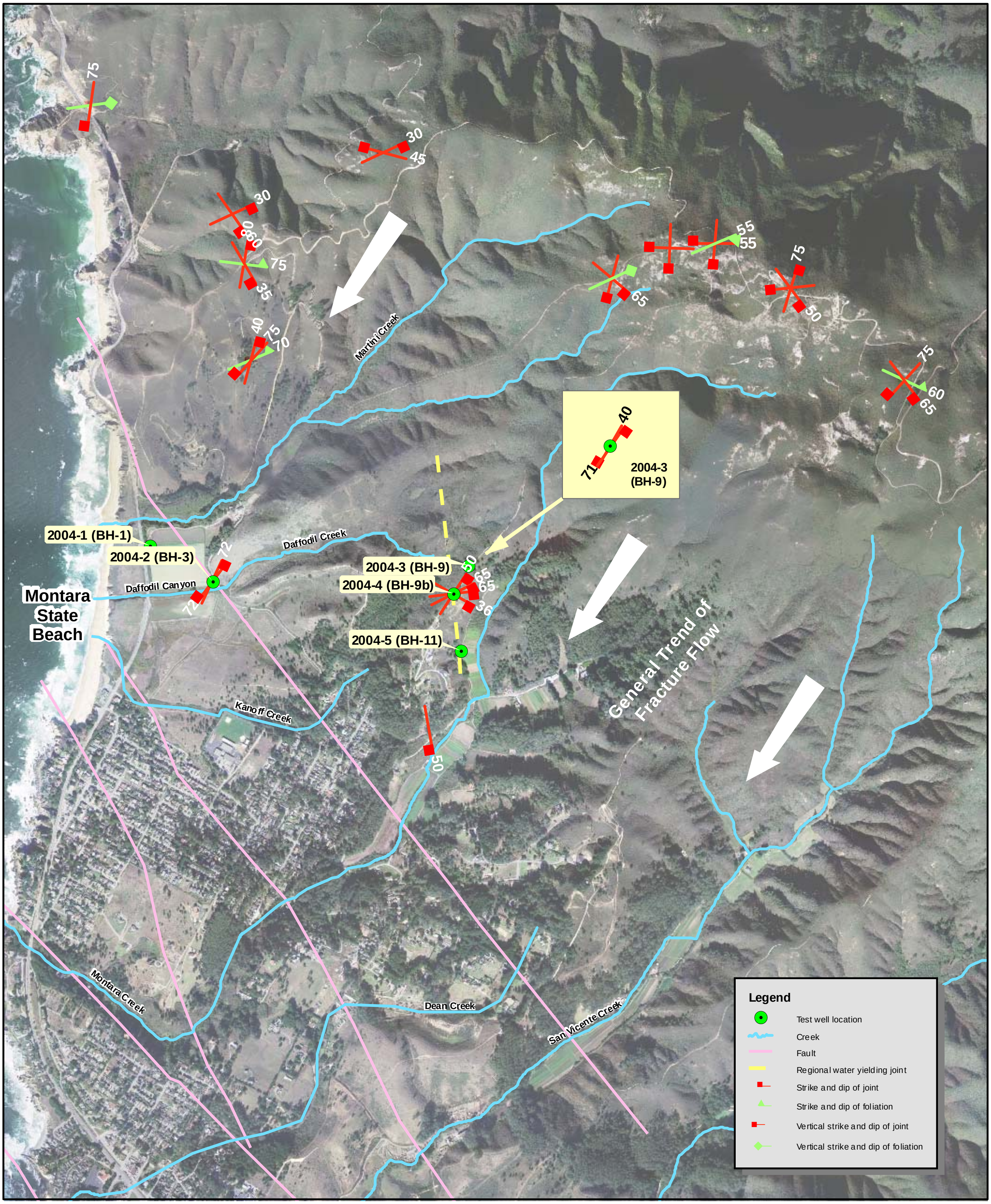

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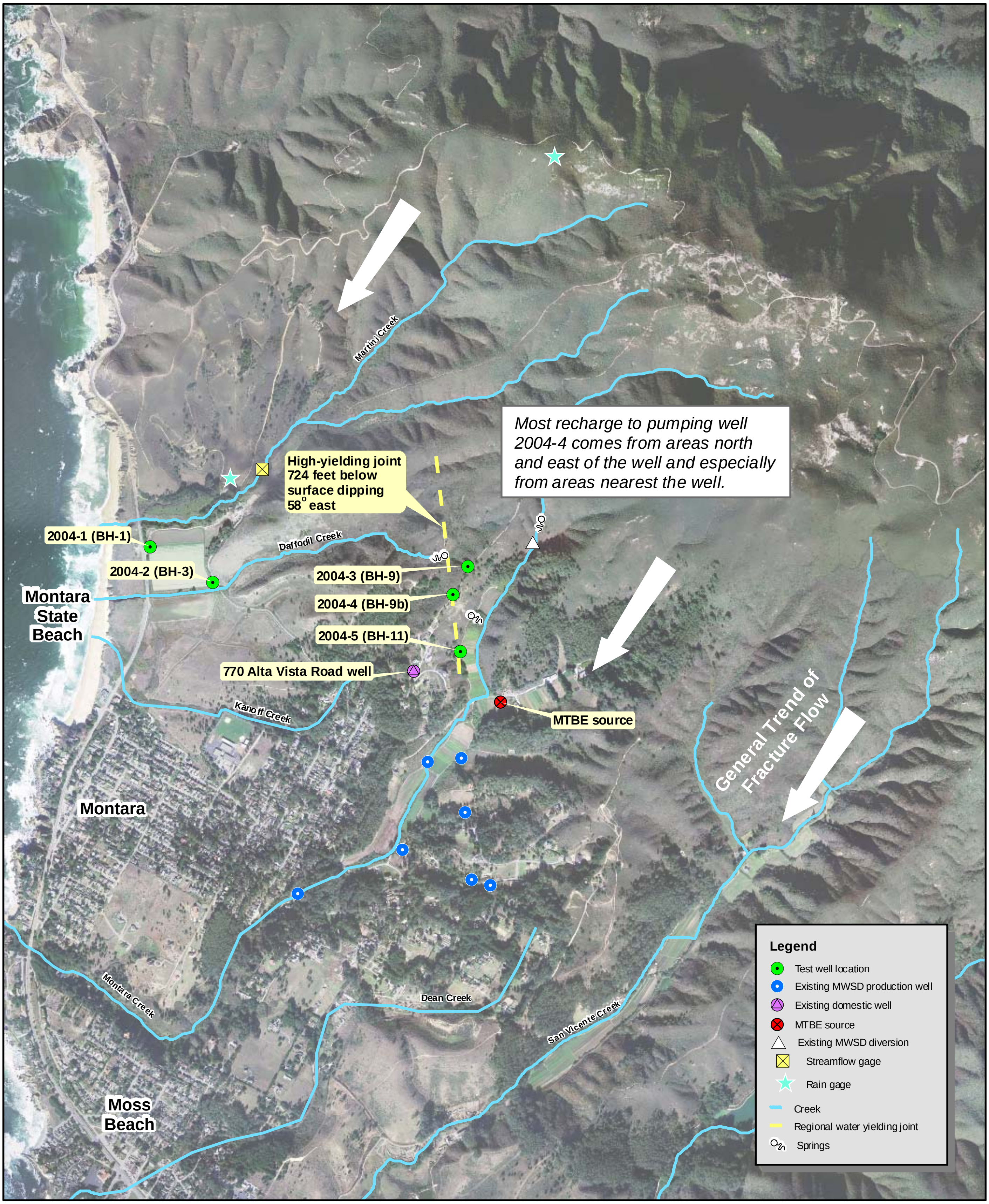
Figure 4. Fracture and joint orientations measured at BH-3, BH-9, and BH9b, and locations of mapped joint systems and foliations, Montara, San Mateo County, California

Sources: (1) ATV logs, Norcal 2004
(2) Preliminary Geologic Map, Brabb and Pampeyan, 1972
(3) Aerial photo from USGS, captured 2/27/2004.

0 1,000 2,000 3,000 4,000 Feet

N



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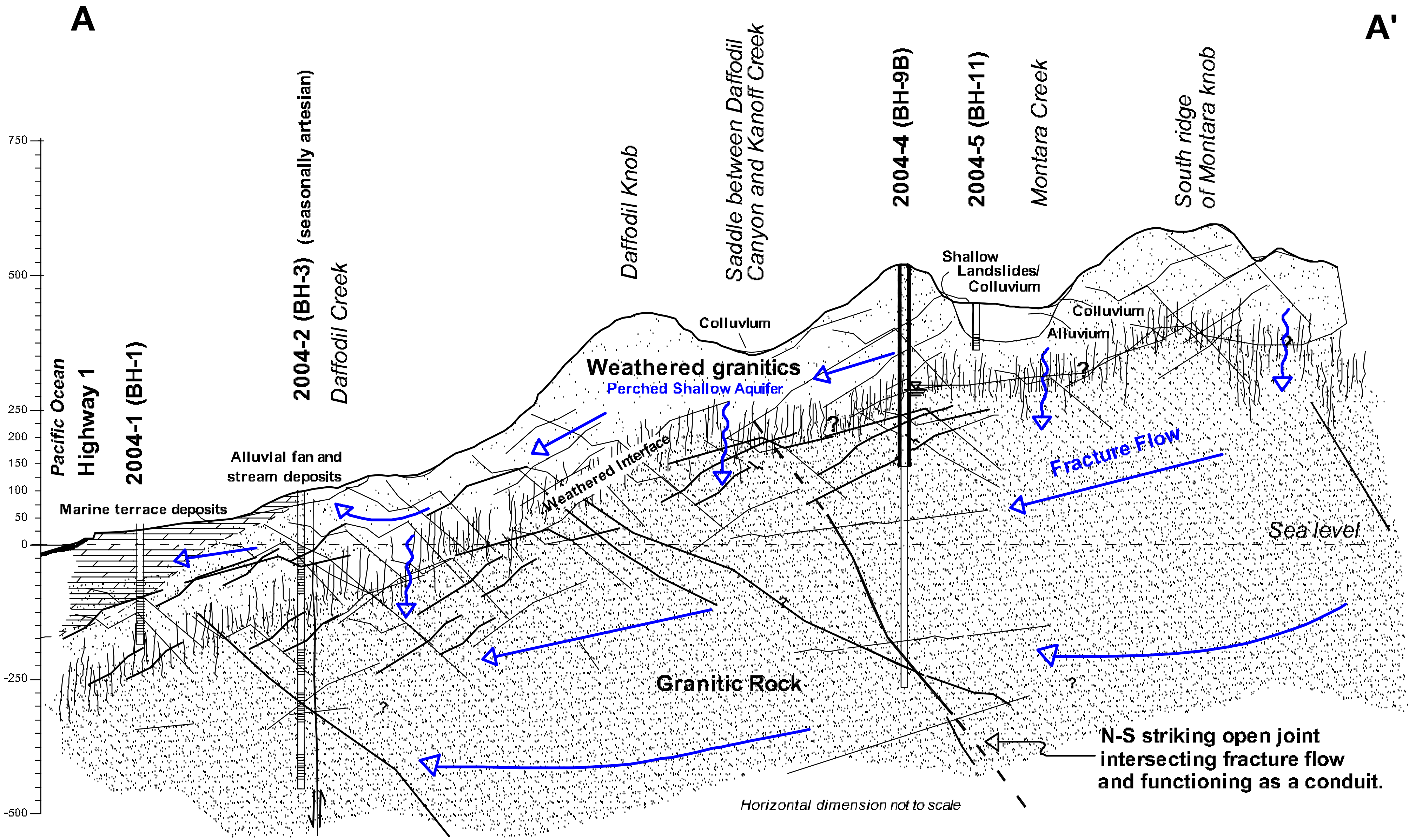
Balance Hydrologics, Inc.

Figure 5. Hydrology map and locations of MWSD wells relative to MTBE source, Montara, San Mateo County, California

Source: Aerial photo from USGS, captured 2/27/2004.

0 1,000 2,000 3,000 4,000 Feet

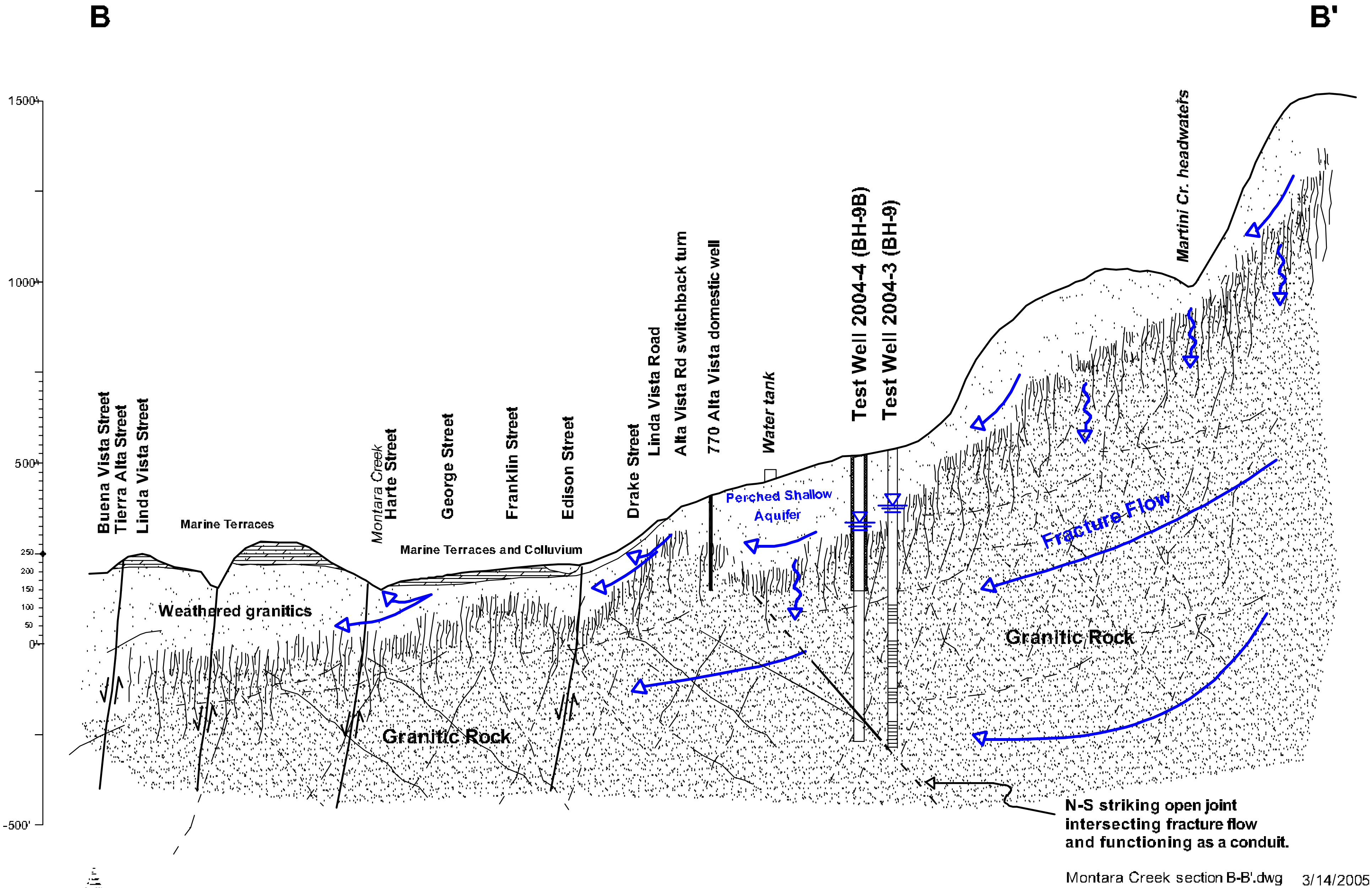
N



Montara sec A-A'.dwg 3/14/2005

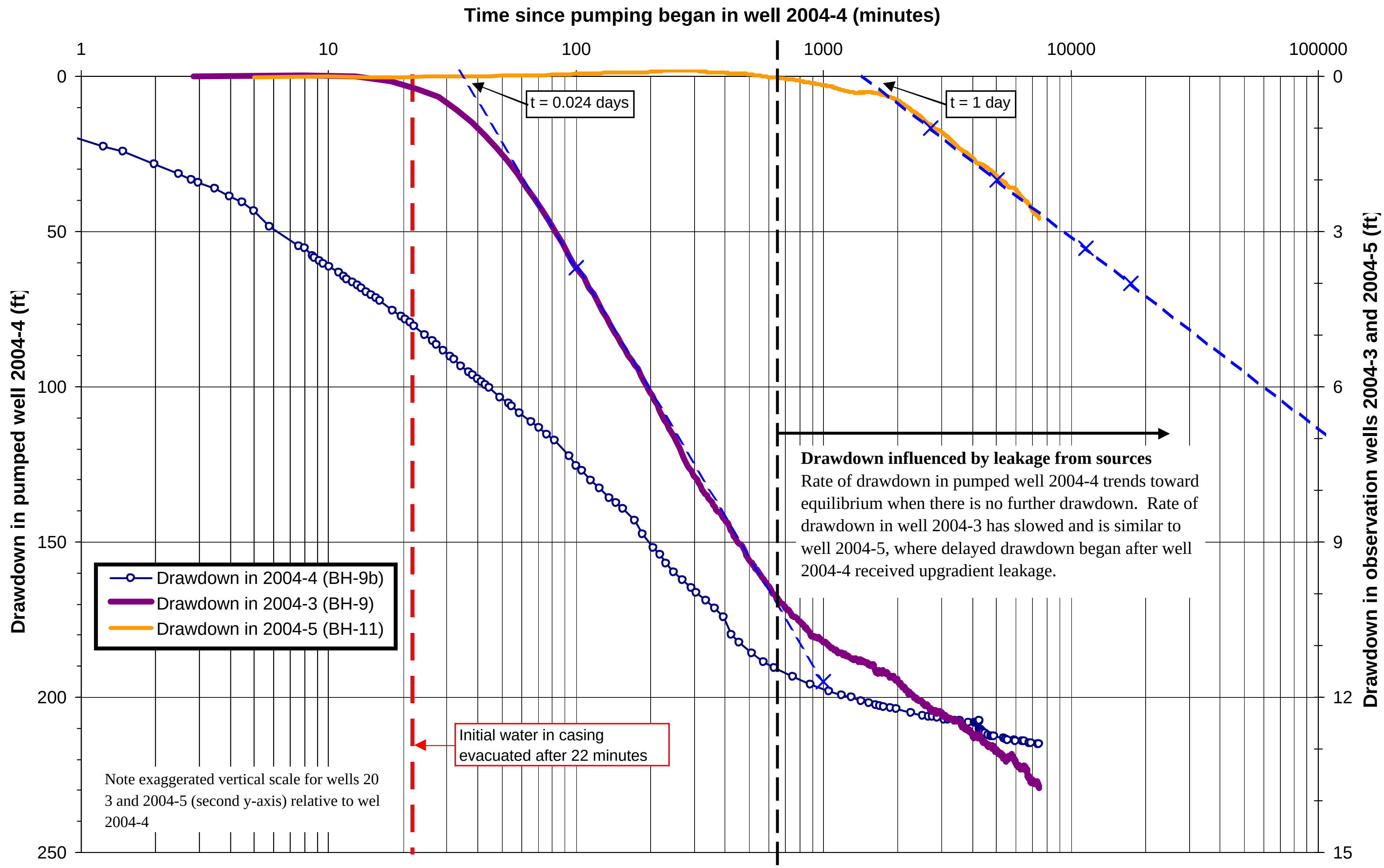
Balance Hydrologics, Inc.

Figure 6. Hydrogeologic cross-section A-A', Montara, San Mateo County, CA.



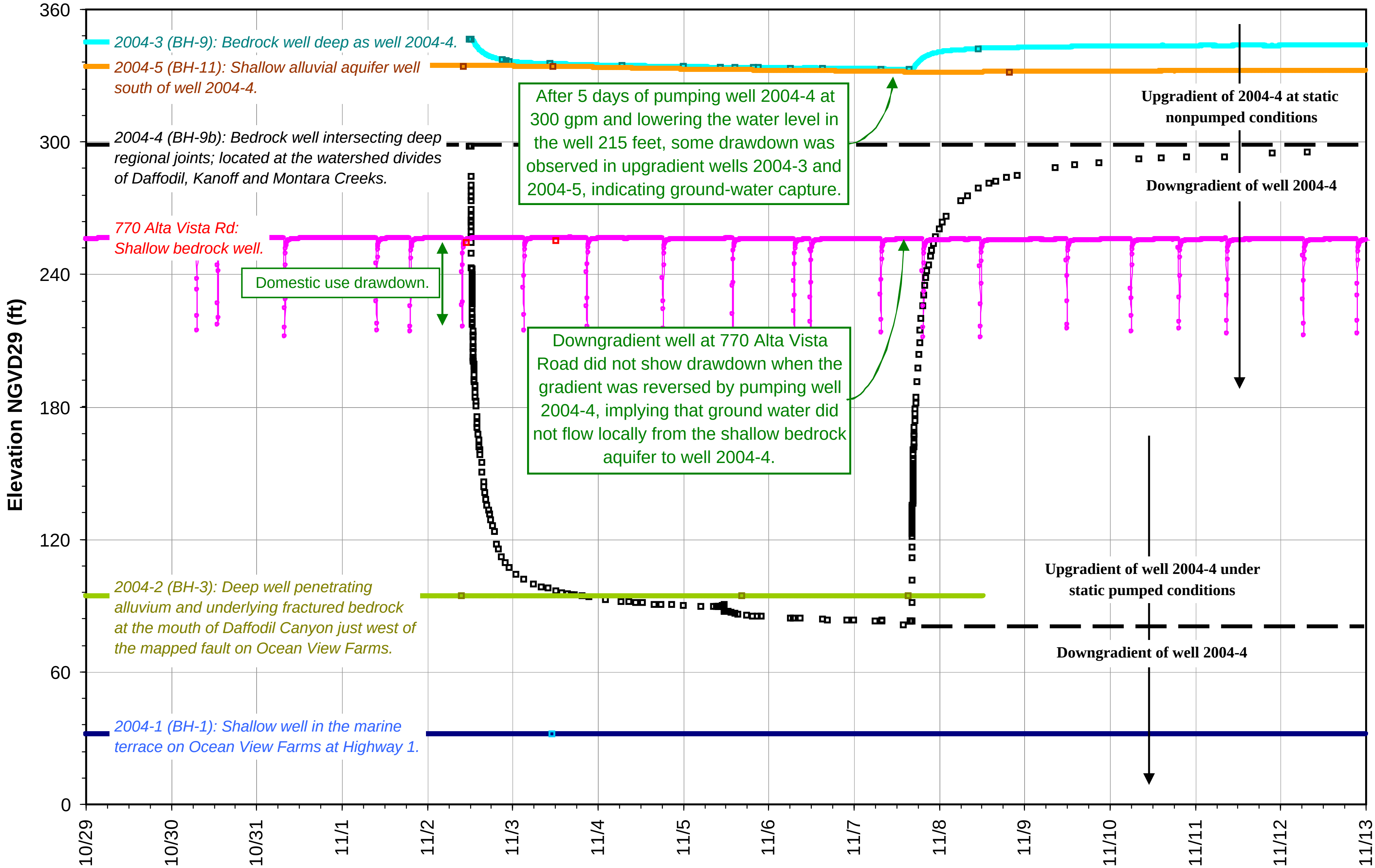
Balance Hydrologics, Inc.

Figure 7. Hydrogeologic cross-section B-B' from Buena Vista St in Moss Beach, along Cedar/ Elm St and Alta Vista Rd, Montara, San Mateo County, CA.



Balance Hydrologics, Inc.

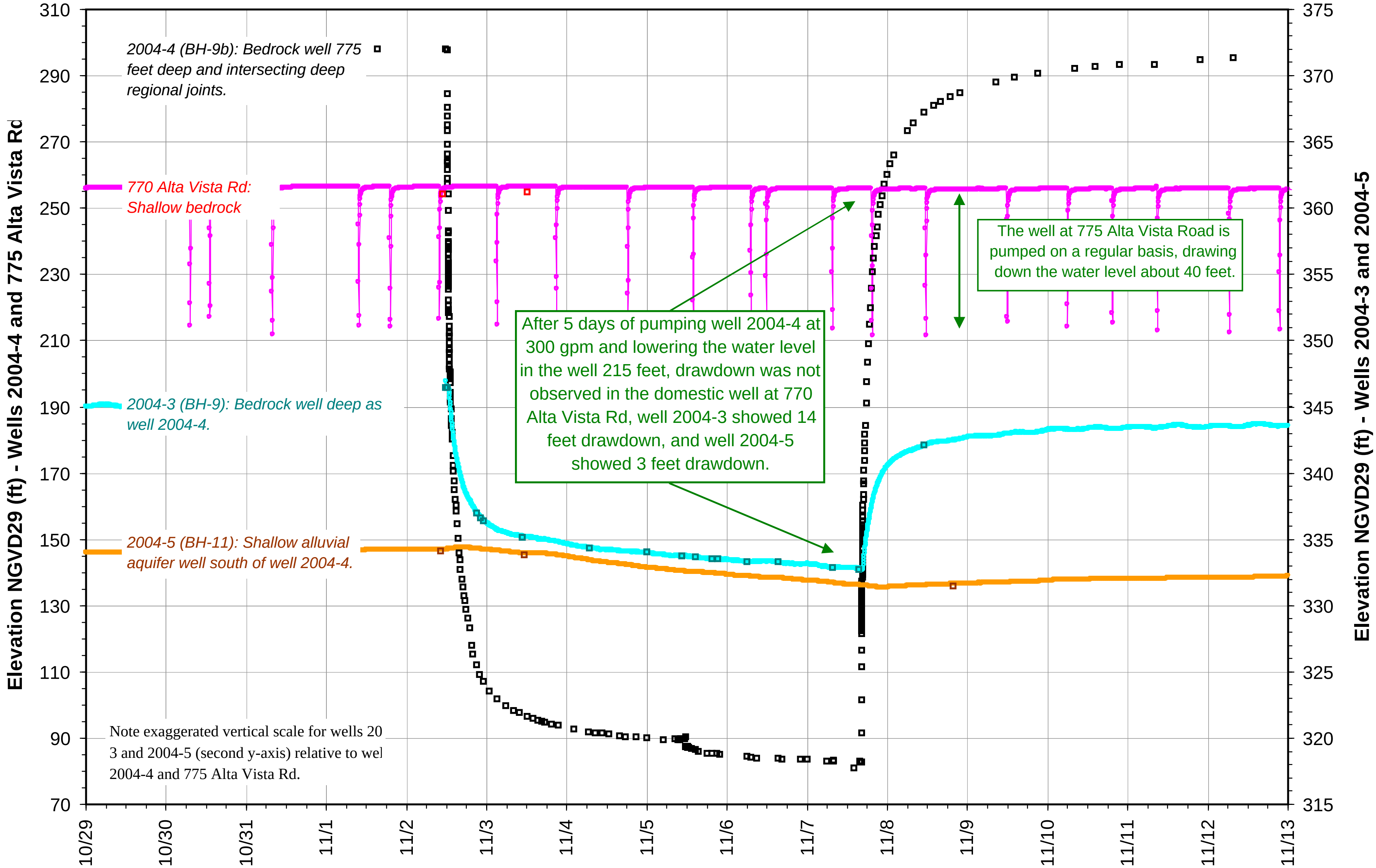
Figure 8. Water-level drawdown in pumped well 2004-4 (BH-9b) and observation wells 2004-3 (BH-9) and 2004-5 (BH-11) during constant-rate pumping test, November 2 to 12, 2004, APN 036-180-030, San Mateo County, California.



Balance Hydrologics, Inc.

Figure 9. **Water-level elevations in Montara Water and Sanitary District test wells and domestic well at 770 Alta Vista Road, October 29 to November 13, 2004, while conducting a 300-gpm constant-rate pumping test at well 2004-4, San Mateo County, California.**

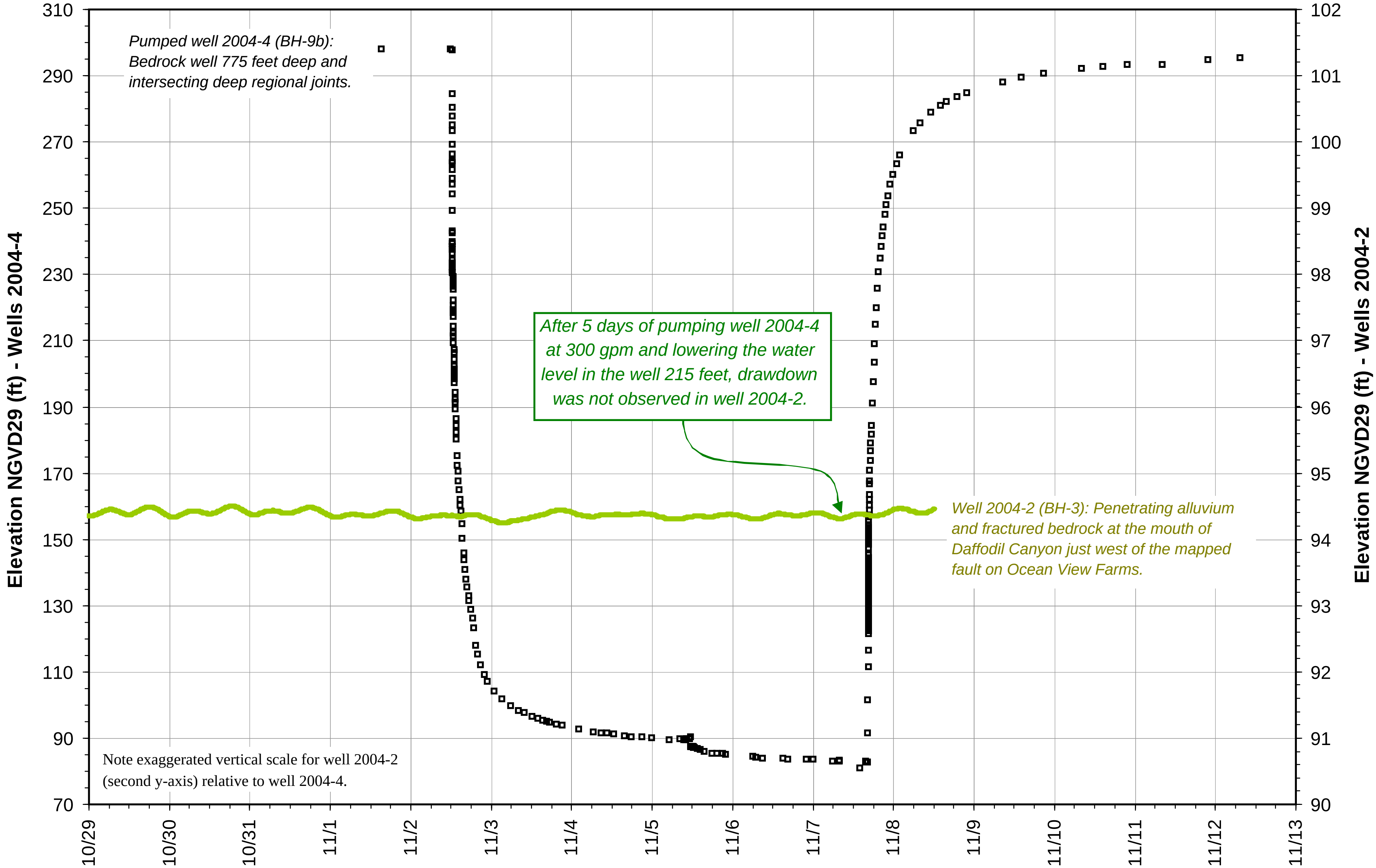
Note: Manual measurements are indicated as square symbols, other measurements were automated.



Balance Hydrologics, Inc.

Figure 10. Water-level elevations in Montara Water and Sanitary District test wells 2004-3, 2004-4, 2004-5, and domestic well at 770 Alta Vista Road, October 29 to November 13, 2004, while conducting a 300-gpm constant-rate pumping test at well 2004-4, San Mateo County, California.

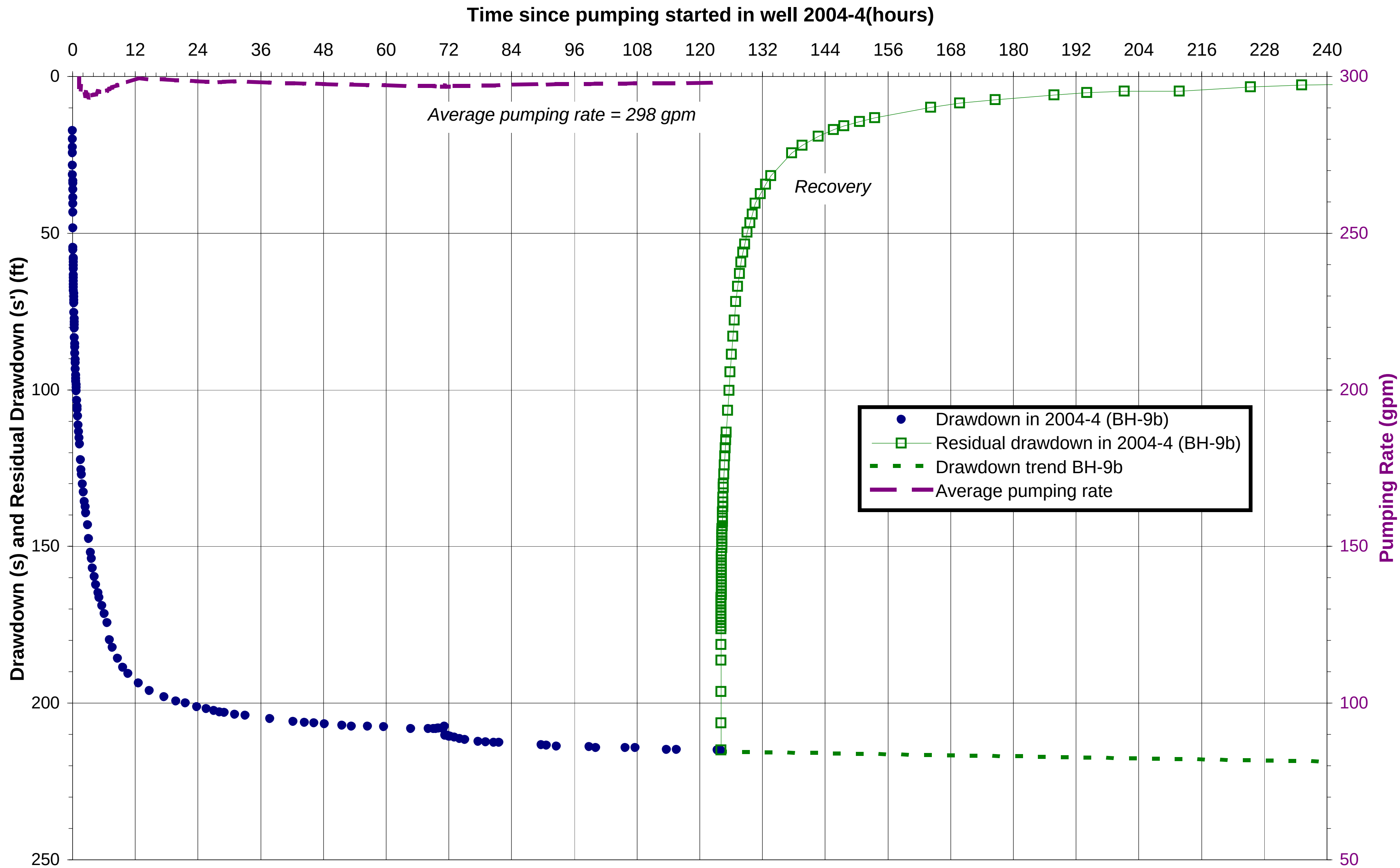
Note: Manual measurements are indicated as square symbols, other measurements were automated.



Balance Hydrologics, Inc.

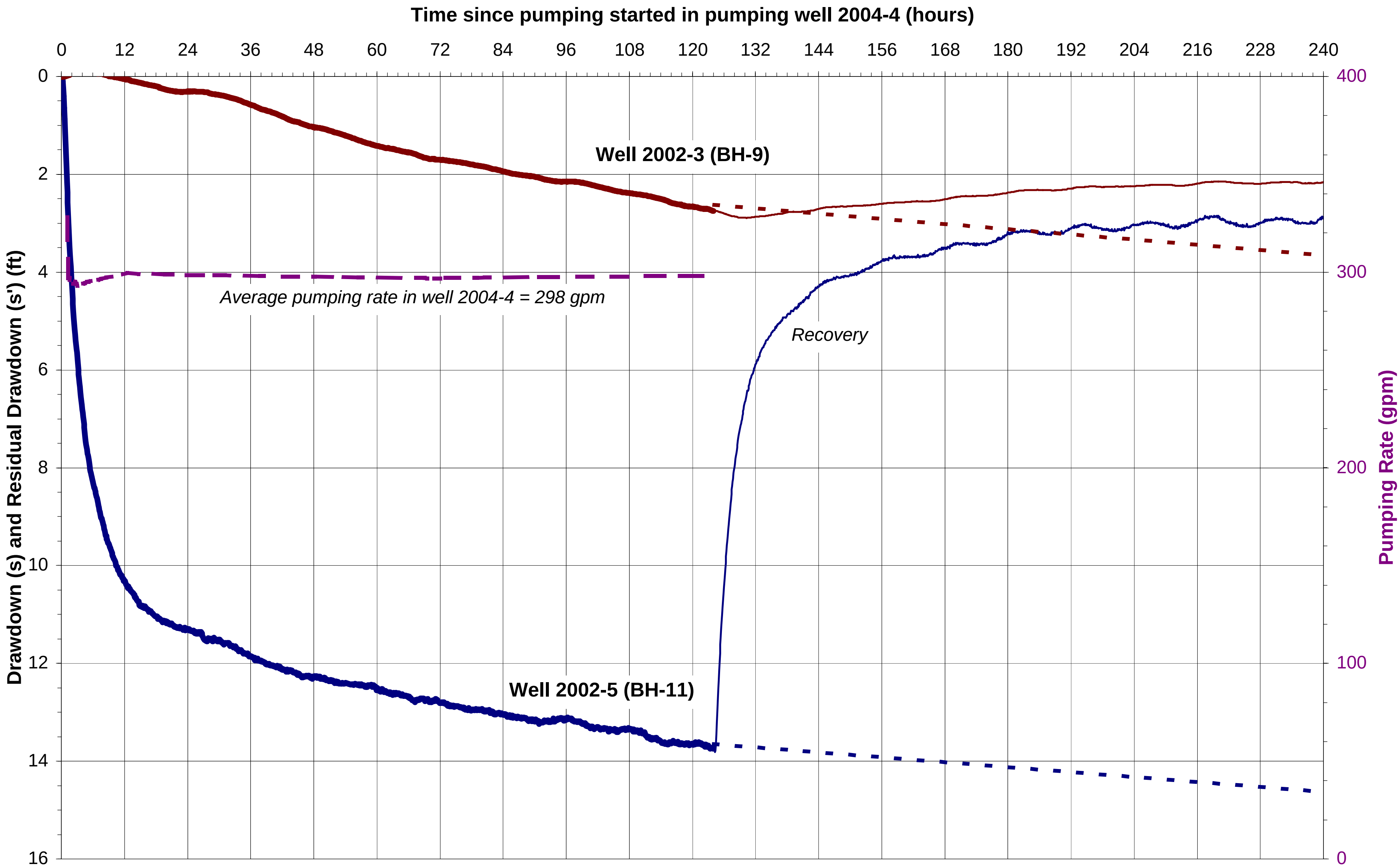
Figure 11. Water-level elevations in Montara Water and Sanitary District test wells 2004-2 and 2004-4, October 29 to November 13, 2004, while conducting a 300-gpm constant-rate pumping test at well 2004-4, San Mateo County, California.

204119_PT&elev_data_allv3_mwedits.xls, BH-9b Chart3



Balance Hydrologics, Inc.

Figure 12. **Drawdown and recovery in well 2004-4 (BH-9b), during constant-rate pumping test, November 2 to 12, 2004, APN 036-180-030, San Mateo County, California.**

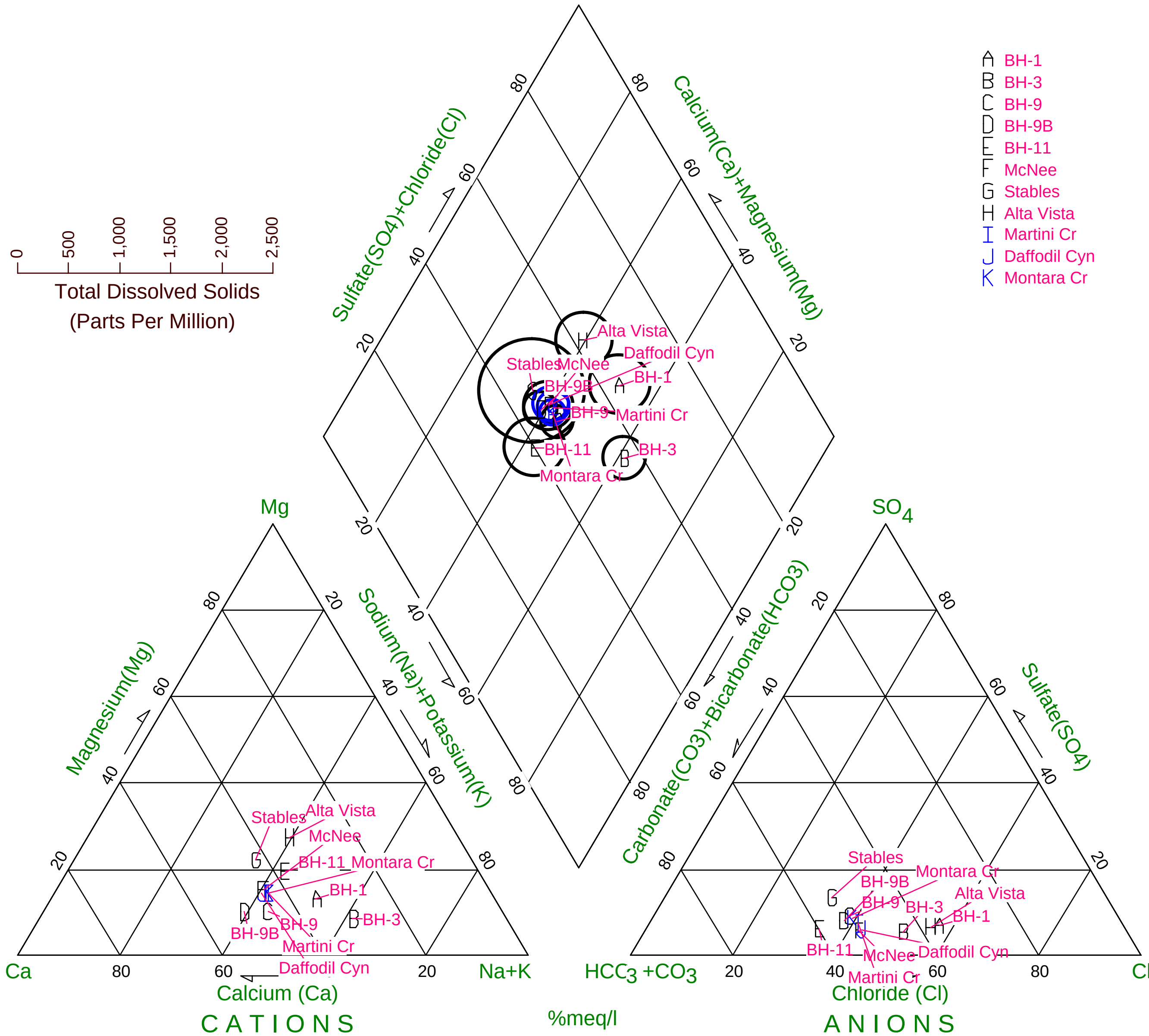


Balance Hydrologics, Inc.

Figure 13. Drawdown and recovery in wells 2004-3 (BH-9) and 2004-5 (BH-11) during constant-rate pumping test, November 2 to 12, 2004 , APN 036-180-030, San Mateo County, CA.

Montara Water and Sanitary District

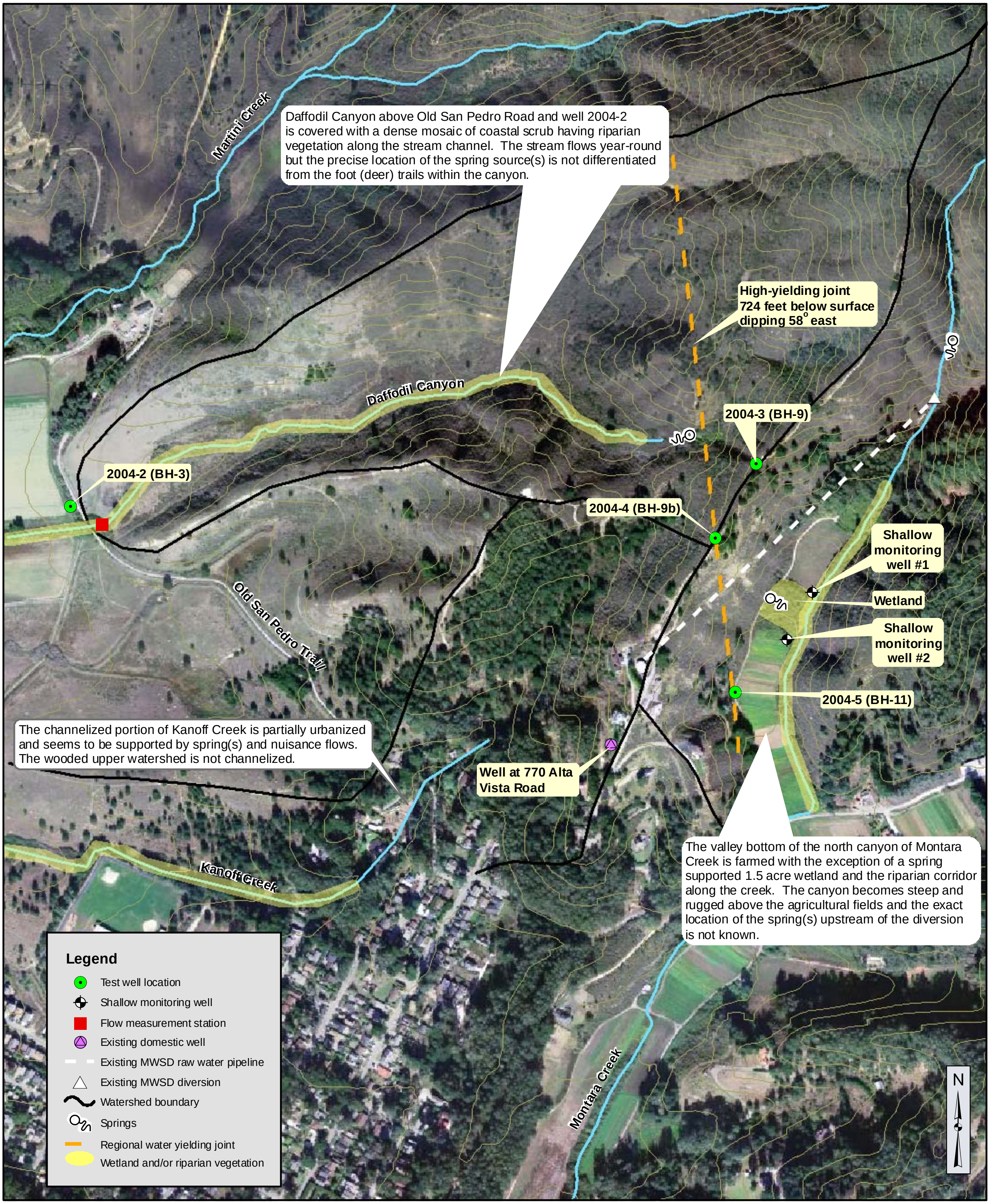
San Mateo County, California



This diagram shows cations in the ternary graph on the left and anions on the right graph. The diamond graph in the center illustrates both cations and anions. Hardness dominated water plots to the left and top of the diamond graph, soft monovalent-salt dominated water to the right, and soft alkaline water towards the bottom. The radius of circle around the plotted points represents the concentration of dissolved solids, calibrated to the scale shown.

Balance Hydrologics, Inc.

Figure 14. Piper diagram illustrating different ionic signatures of water samples collected from test wells during yield tests, and from regional wells and surface waters, Montara, San Mateo County, California.



W:\Projects\204041\204041_Montara\Fig15_wells_July14_05.mxd

Balance Hydrologics, Inc.

Figure 15. Location of proposed Alta Vista production well (2004-4) relative to local springs, creeks, wetland and riparian habitats, Montara, San Mateo County, California

Most recharge to well 2004-4 comes from areas north and east of the well and especially from areas nearest the well (see figure 5).

Source: Aerial photo from USGS, captured 2/27/2004.

0 500 1,000 1,500 Feet

APPENDICES

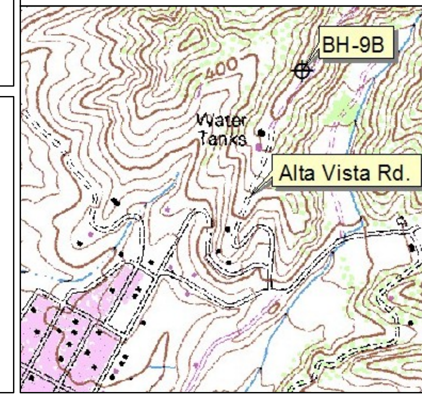
APPENDIX A

Geological and geophysical logs of borehole 9b and construction diagram of well 2004-4, APN 036-180-030, San Mateo County, California

Balance Hydrologics, Inc.

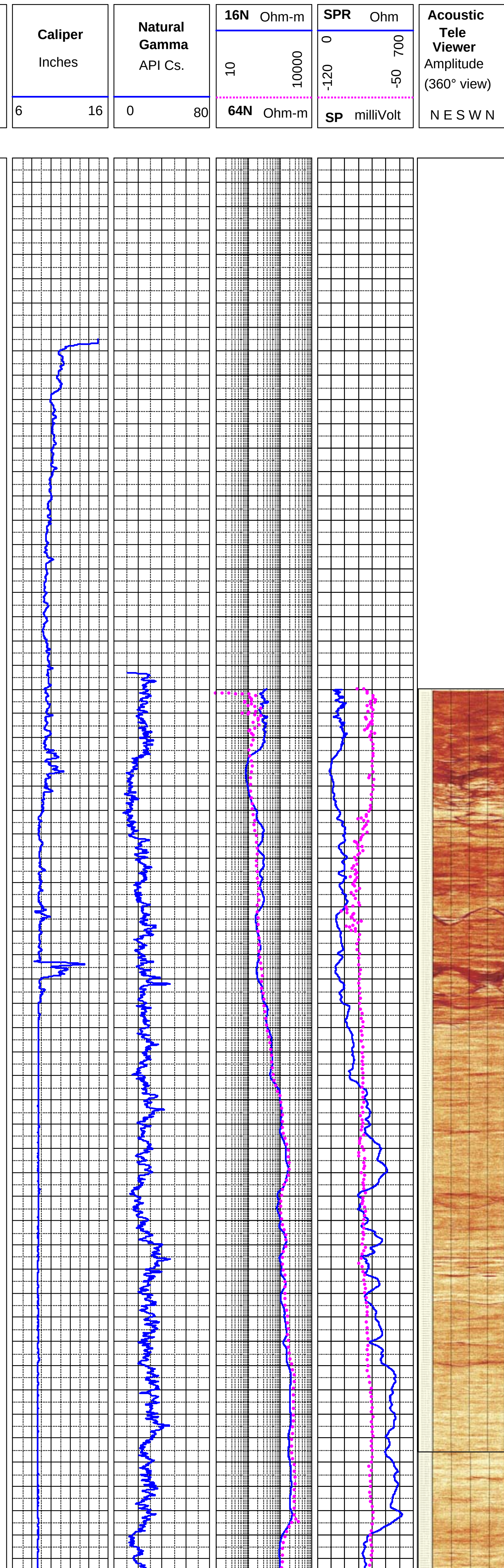
Appendix A: Well log and construction diagram, hydrogeologists' observations and geophysical logs at BH-9b (well 2004-4).

BH-9B Location

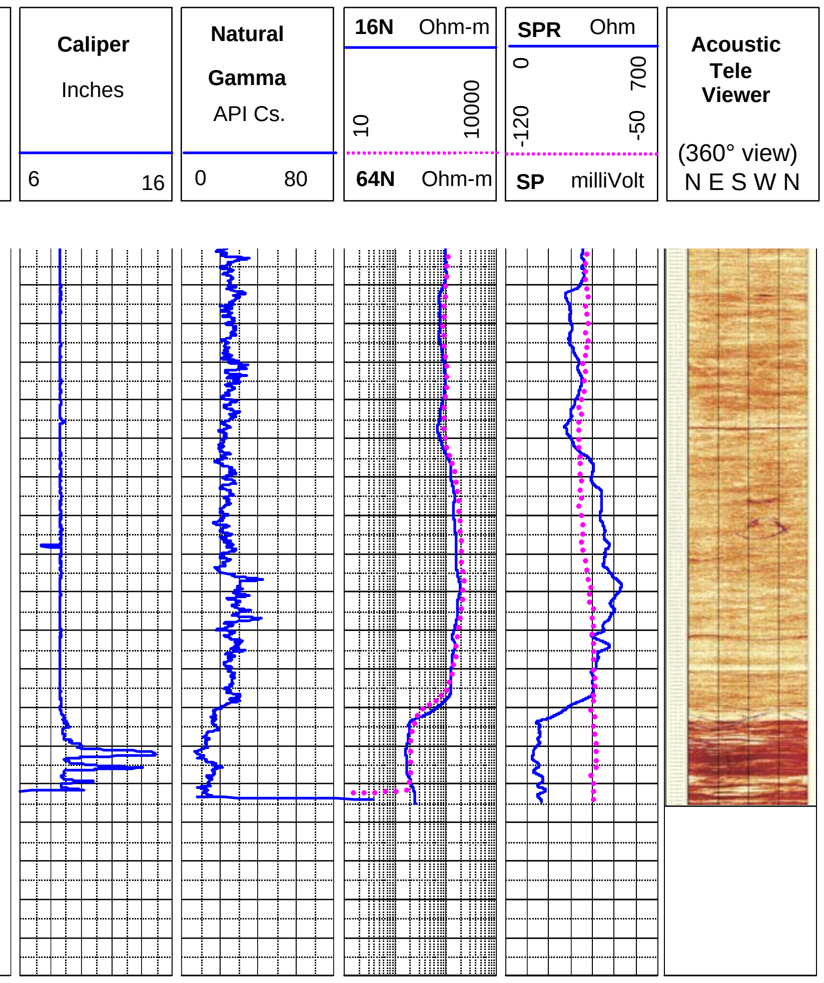


APN:	**036-180-030**	Driller:	**Steven Estebon, Maggiora Bros. Drilling**
Location:	**Alta Vista Rd., Montara, CA**	Drilling rig:	**Ingersoll Rand 1150/350**
Latitude, Longitude:	**N37.5502, W122.4957 NAD27**	Driling bits:	**8¾ in. air rotary, 8¾ in. air hammer, 16 in. rotary ream**
Ground surface elevation:	**530 feet**		**Cutting samples taken every 5 feet**
Start drilling date:	**May 19, 2004**	Depth of borehole:	**780 feet**
Well completion date:	**July 7, 2004**	Depth of casing:	**370 feet**
Borehole geologists:	**Jason Parke, Gustavo Porras, Vic Abadie**	Diameter of casing:	**12 inches, I.D.**
Geophysical log:	**Bill Henrich, Norcal Geophysics, June 1, 2004**		**9 inch non-cased borehole below 370 feet**

Depth feet	Lithology	Hydrology	Well Construction	Remarks
0	CLAYEY SAND: 0 to 15 ft.: Orangish brown, poorly sorted, mostly feldspar, cohesive sandy clay (SC)			0-180+ ft: neat concrete/bentonite seal 2 inches around casing 0-14ft: May 19 started drilling with 8 3/4 inch, air rotary 14-274 ft: May 21 approx. drilling rate is 30 ft/hr 37 feet of 10-inch casing is installed as temporary conductor casing
15–235	WEATHERED GRANITICS: 15 to 235 ft. - Montara Mountain Granitic Rock: Decomposed angular to subrounded light brown quartz diorite; 20 ft: orangish yellow brown mostly feldspar 5% clay 55 ft: 50% orangish yellow brown feldspar, 30-40% quartz 75 ft: increasing clay content 85 ft: brownish color 10% hornblende 115 ft: brownish orangish brown 50-60%feldsp 30%qtz, 10% hornblende 145 ft: cont. increasing clay content 210 ft: orangish brown increasing dampness, 5-10% clay	235 ft: first water, static water level		
235–780	GRANITICS: 235 to 780 ft. - Montara Mountain Granitic Rock: Fractured angular to subangular greenish grey quartz diorite 235 ft: 50% feldspar, 30-40% greenish gray hornblende, 15% quartz 240 to 285 ft: Hornblende greater than 40% of rock 245 ft: 80% greenish gray hornblende 295 ft: 60% feldspar, 10% quartz, 30-25% hornblende 315 ft: 75-80% greenish gray hornblende, 20% feldspar and quartz, 5% hornblende 420 ft: 40-50% black and greenish gray hornblende, 40-45% feldspar, 5-10% quartz 545 ft: 40-60% feldspar, 30-40% greenish gray hornblende, 5-10% quartz	240 ft: 10 gpm drilling 260 ft: 15 gpm (est) drilling 300 ft: 25 gpm drilling 340 ft: 30 gpm drilling 380 ft: 30 gpm drilling 440 ft: 26 gpm drilling		260 ft: specific conductance 252 micro-mhos/cm at 20C 274-417 ft: May 24 approx. drilling rate is 30 ft/hr 300 ft: specific conductance 220 micro-mhos/cm at 18C 310 ft: approx. drilling rate is 300 ft/hr 332 ft: approx. drilling rate is 100 ft/hr 360 ft: approx. drilling rate is 30 ft/hr 0-370 ft: Jun. 5 to 16, reamed to 16-inch dia.; Jun. 17, installed 12-inch steel conductor casing; Jun. 30, poured concrete seal; July 2 to 7, cleaned borehole to 743 ft. and advanced to 780 ft. 417-577 ft: May 25 approx. drilling rate is 30 ft/hr 505 ft: approx. drilling rate is 15 ft/hr 565 ft: approx. drilling rate is 50 ft/hr 577-697 ft: May 26 approx. drilling rate is 30 ft/hr

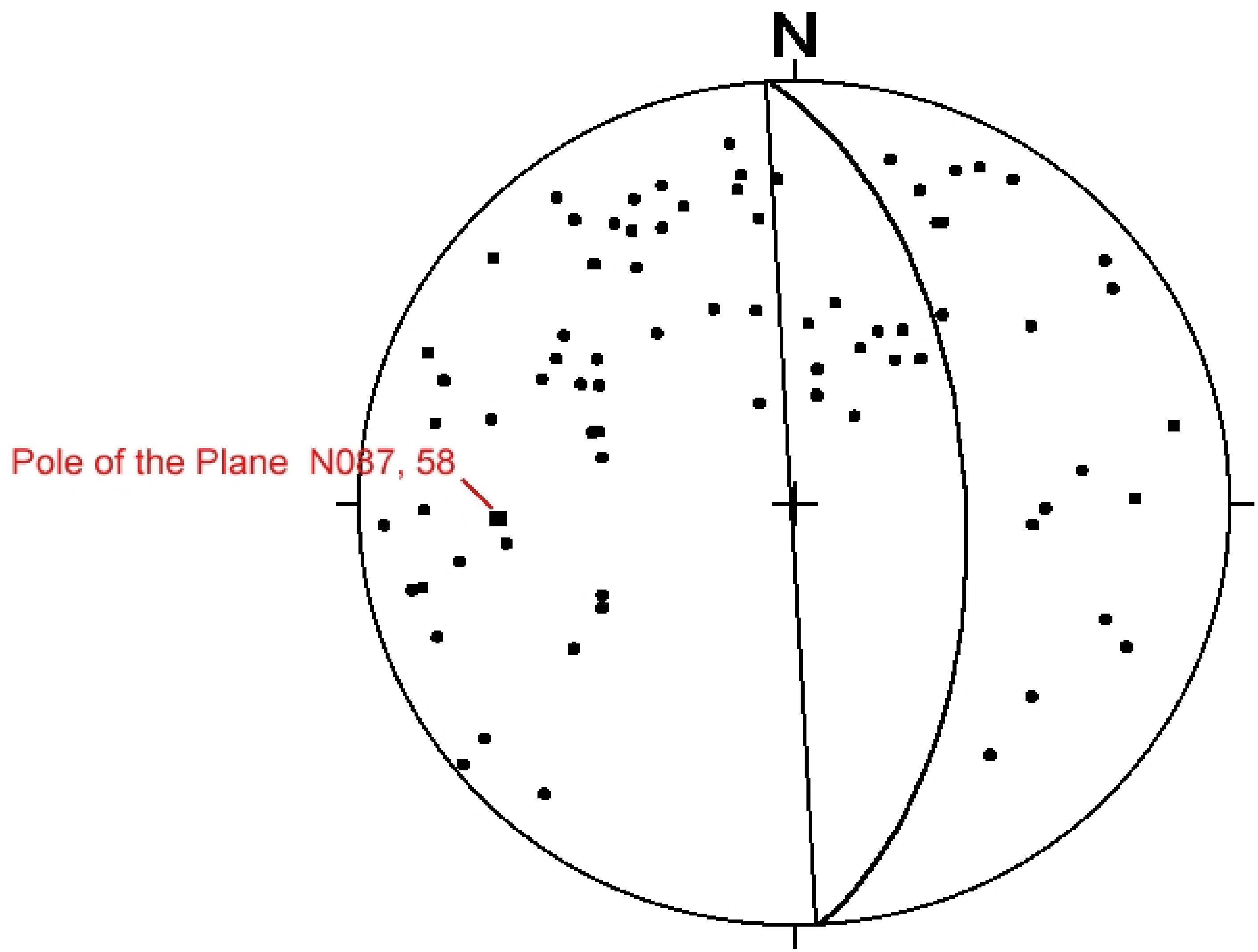


Depth feet	Lithology	Hydrology	Well Construction	Remarks
-600	Continue - Montara Mountain Granitic Rock: Fractured quartz diorite			620 ft: approx. drilling rate is 30 ft/hr
-650		660 ft: 60 gpm drilling		
		680 ft: 44 gpm drilling		680 ft: specific conductance 232 micro-mhos/cm at 18C
-700	705 ft: Weathered orangish DG 60-70% Feldspar, 20-30% hornblende, 10-15% quartz			697-743 ft: May 27 approx. drilling rate is 15 ft/hr
	715 ft: 80-90% Hornblende, 10% Feldspar	720 ft: 88 gpm drilling		724 ft. open joint dip 58 deg N087E
	720 ft: Saussuritization of hornblende, zoisite			727 ft. open joint dip 40 deg N111E
	743 ft: Weathered orangish DG 60-70% Feldspar, 20-30% hornblende, 10-15% quartz	740 ft: 193 gpm drilling		740 ft: specific conductance 224 micro-mhos/cm at 19C
-750	755 ft: 80-90% Hornblende, 10-20% Feldspar	760-780 ft: +300 gpm (est) drilling		
	Bottom of well at 780 ft.			780 ft: Drilling finished on July 6 at 13:00

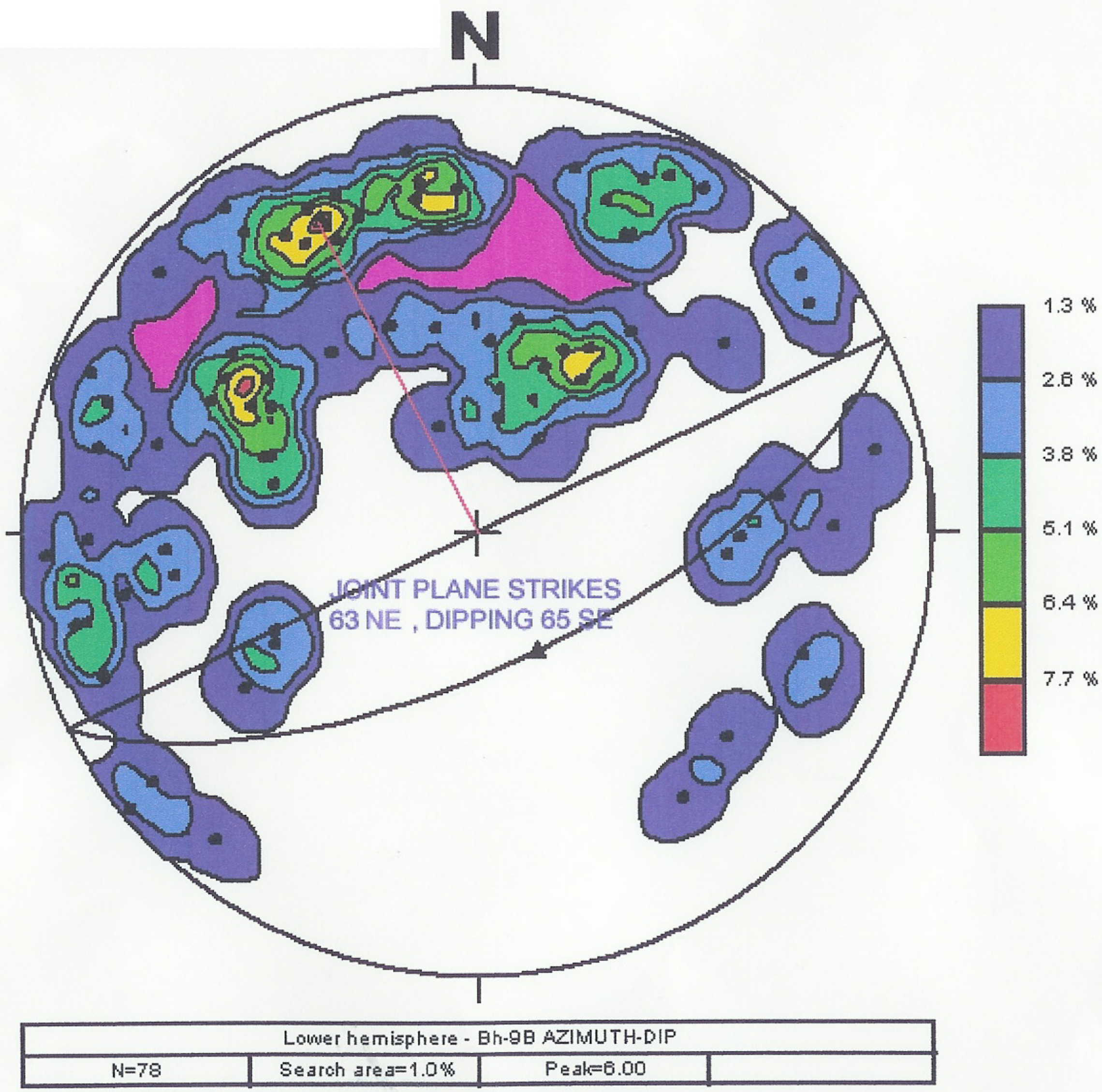


APPENDIX B

Stereo-net plot of fracture orientation populations identified from borehole 9b acoustic televiewer imaging survey results, APN 036-180-030, San Mateo County, California



Appendix B. **Schmidt-net plot of discontinuities in BH-9b, APN 036-180-030, San Mateo County, California.**
The high water-yielding open joint at 724 feet has a dip azimuth of N87°E and a magnitude of 58°. It strikes N3°W. The joint plane and pole to the plane (projected perpendicular to the lower hemisphere) is identified in the plot. Acoustic televiewer survey and data interpretation performed by Norcal Geophysics.



NORCAL GEOPHYSICAL CONSULTANTS, INC.

Appendix B. Concentration contours on Schmidt-net plot of discontinuities in BH-9b, APN 036-180-030, San Mateo County, California. The highest concentration has a dip azimuth of S27°E and a magnitude of 65°. It strikes N63°E. The joint plane and pole to the plane (projected perpendicular to the lower hemisphere) is identified in the plot. Acoustic televiewer survey and data interpretation performed by Norcal Geophysics.

Appendix B: Geophysical interpretation by Norcal Geophysics of discontinuities identified in borehole 9b using acoustic televiewer, June 1, 2004, Montara, San Mateo County, California

Discontinuity number	**Depth from ground surface** (feet)	**Dip azimuth** (degrees from true north)	**Dip magnitude** (degrees from true horizontal)	**Fit of plane** 1-P0/100	**Number of points to fit plane** n	**Quality** Q	**Feature classificatior** K	**Upper depth** (feet)	**Lower depth** (feet)	**Borehole diameter** (feet)	**Borehole axis azimuth** (degrees from true north)	**Borehole axis deviation** (degrees from vertical)	**Comment**
1	735.672	104	37.7	1	0	*	2	735.381	735.963	0.764	240	0.55	Fracture open
2	733.521	127	56.1	0.953	9	B	2	732.97	734.071	0.764	290.81	0.85	Fracture
3	730.931	61	42	0.946	11	C	2	730.605	731.256	0.764	204.5	1.94	Fracture open
4	727.187	111	39.8	0.886	12	D	2	726.864	727.51	0.764	193	2.39	Fracture open
5	***724.341***	***87***	***57.8***	***0.954***	***11***	***B***	***2***	***723.736***	***724.945***	***0.764***	***181.94***	***1.22***	***Fracture open; high yieding***
6	719.847	323	63.5	0.988	8	A	2	719.092	720.603	0.764	219.42	1.26	Fracture discontinuous
7	719.527	106	61.7	0.983	6	A	2	718.842	720.212	0.764	226.56	1.55	Fracture discontinuous
8	719.488	310	60.2	0.986	8	A	2	718.818	720.159	0.764	225.14	1.46	Fracture discontinuous
9	718.421	82	56.5	0.992	10	A	2	717.868	718.974	0.764	217.22	1.6	Fracture discontinuous
10	714.475	110	41	0.956	14	B	2	714.133	714.817	0.764	171.49	1.64	Fracture
11	714.164	77	79.3	0.96	14	B	2	712.159	716.168	0.764	168.11	1.88	Fracture discontinuous
12	712.889	110	74.7	0.952	8	B	2	711.425	714.353	0.764	174.91	1.59	Fracture discontinuous
13	710.287	201	68.5	0.979	8	A	2	709.327	711.315	0.764	191.69	1.12	Fracture discontinuous
14	701.966	217	46.8	0.941	11	C	2	701.543	702.39	0.764	201.46	1.19	Fracture
15	692.42	232	58.1	0.922	15	C	2	691.765	693.076	0.764	204.96	1.92	Fracture
16	682.152	127	47.5	0.988	5	A	2	681.734	682.57	0.764	208.65	0.91	Fracture discontinuous
17	674.487	147	56.3	0.978	6	A	2	673.903	675.071	0.764	197.63	0.79	Fracture discontinuous
18	670.605	40	78.6	0.975	13	A	2	668.951	672.258	0.764	220.01	1.56	Fracture discontinuous
19	667.326	51	87.8	0.973	11	B	2	661.172	665.121	0.764	213.58	1.44	Fracture discontinuous
20	664.033	208	79.4	0.958	24	B	2	663.487	666.658	0.764	215.25	2.35	Fracture discontinuous
21	654.323	213	80.8	0.976	27	A	2	656.136	657.204	0.764	218.86	1.64	Fracture discontinuous
22	637.709	161	20.5	0.981	10	A	2	637.561	637.857	0.764	155.84	0.72	Vein
23	499.722	141	62.4	0.976	20	A	2	498.982	500.461	0.764	211.24	0.81	Fracture
24	491.443	271	48	0.944	9	C	2	491.015	491.871	0.764	199.75	0.88	Fracture
25	480.067	171	67.8	0.965	14	B	2	480.05	481.053	0.764	144.13	1.15	Fracture discontinuous
26	473.983	269	67	0.971	16	B	2	473.083	474.884	0.764	180.79	1.62	Fracture
27	462.428	117	54.9	0.922	17	C	2	461.9	462.957	0.764	252.22	1.04	Fracture
28	455.657	191	21.4	0.988	7	A	2	455.49	455.824	0.764	193	2.25	Fracture
29	455.47	213	20.3	0.986	8	A	2	455.313	455.627	0.764	201.26	2.1	Fracture
30	452.124	142	42.6	0.978	7	A	2	451.762	452.486	0.764	185	1.16	Fracture
31	443.479	191	40.1	0.955	12	B	2	443.146	443.813	0.764	171.17	1.11	Fracture
32	442.131	177	66	0.974	14	A	2	442.194	443.038	0.764	175.69	1.19	Fracture discontinuous
33	434.48	150	63.7	0.961	15	B	2	434.218	435.243	0.764	255.54	0.78	Fracture discontinuous
34	433.84	170	75.6	0.943	11	C	2	432.329	434.155	0.764	244.61	0.76	Fracture discontinuous
35	428.873	120	47.3	0.948	17	B	2	428.468	429.277	0.764	239.3	1.28	Fracture
36	402.631	158	41.3	0.986	10	A	2	402.291	402.97	0.764	234.38	1.22	Fracture
37	389.383	263	56	0.989	6	A	2	388.803	389.964	0.764	204.86	1.16	Fracture
38	360.644	202	32.7	0.937	10	C	2	360.392	360.896	0.764	158.23	0.96	Fracture
39	360.62	231	80.7	0.985	9	A	2	358.188	360.281	0.764	160.03	1.04	Fracture discontinuous
40	360.067	189	26.5	0.958	9	B	2	359.87	360.264	0.764	144.48	1.16	Fracture
41	358.114	211	39.7	0.933	22	C	2	357.782	358.446	0.764	216.24	1.34	Fracture discontinuous
42	357.435	205	37.2	0.97	15	B	2	357.138	357.731	0.764	212.96	0.6	Fracture discontinuous
43	356.626	214	33.8	0.981	10	A	2	356.416	356.885	0.764	234.69	0.45	Fracture discontinuous
44	355.277	184	35.3	0.967	11	B	2	355.001	355.554	0.764	199.71	0.66	Fracture
45	353.635	169	38.5	0.975	10	A	2	353.309	353.74	0.764	188.63	2.09	Fracture discontinuous

Discontinuity number	Depth from ground surface (feet)	Dip azimuth (degrees from true north)	Dip magnitude (degrees from true horizontal)	Fit of plane 1-P0/100	Number of points to fit plane n	Quality Q	Feature classificatior K	Upper depth (feet)	Lower depth (feet)	Borehole diameter (feet)	Borehole axis azimuth (degrees from true north)	Borehole axis deviation (degrees from vertical)	Comment
46	351.194	160	64.1	0.974	13	A	2	350.692	351.992	0.764	201.74	0.43	Fracture discontinuous
47	350.777	177	65.9	0.935	21	C	2	349.967	351.626	0.764	226.27	0.32	Fracture discontinuous
48	349.729	173	57.6	0.929	27	C	2	349.105	350.354	0.764	215.9	1.28	Fracture
49	345.511	89	74.2	0.949	19	B	2	344.198	346.825	0.764	200.42	1.09	Fracture
50	344.821	113	80.6	0.965	18	B	2	342.468	344.698	0.764	193.52	1.04	Fracture discontinuous
51	339.434	258	78	0.947	23	B	2	338.774	341.46	0.764	235.29	1.39	Fracture discontinuous
52	330.718	148	67.2	0.967	13	B	2	329.754	331.683	0.764	158.2	1.19	Fracture
53	314.512	275	45.6	0.896	22	D	2	314.114	314.91	0.764	218.52	1.07	Fracture
54	312.991	87	83.8	0.954	23	B	2	310.268	315.715	0.764	251	1.89	Fracture discontinuous
55	305.196	220	37	0.945	14	C	2	304.901	305.492	0.764	167.28	1.2	Fracture
56	304.65	294	72.1	0.942	16	C	2	303.5	305.154	0.764	174.77	0.99	Fracture discontinuous
57	301.713	69	76.9	0.943	16	C	2	300.177	301.874	0.764	223.37	0.92	Fracture discontinuous
58	280.617	56	51.4	0.951	14	B	2	280.291	281.086	0.764	180.84	0.88	Fracture discontinuous
59	280.197	291	65.3	0.969	17	B	2	279.945	281.011	0.764	146.52	0.57	Fracture discontinuous
60	278.586	77	76.7	0.961	11	B	2	277.081	278.325	0.764	248	0.94	Fracture discontinuous
61	274.733	207	63.9	0.943	16	C	2	274.3	275.495	0.764	206.2	1	Fracture discontinuous
62	273.768	235	78	0.962	11	B	2	272.518	274.496	0.764	228.24	1.33	Fracture discontinuous
63	272.684	52	79.4	0.972	11	B	2	270.951	272.47	0.764	231.84	1.74	Fracture discontinuous
64	272.213	64	40.8	0.971	8	B	2	271.895	272.531	0.764	213.15	1.16	Fracture discontinuous
65	269.044	122	54.5	0.975	12	A	2	268.742	269.613	0.764	148.96	1.88	Fracture discontinuous
66	268.828	122	44	0.974	13	A	2	268.842	269.221	0.764	146.11	1.93	Fracture discontinuous
67	267.569	155	61.4	0.996	6	A	2	268.008	268.282	0.764	159.34	0.41	Fracture discontinuous
68	265.827	130	79.5	0.957	15	B	2	266.175	267.826	0.764	246.81	0.77	Fracture discontinuous
69	265.2	143	80	0.968	14	B	2	265.942	267.269	0.764	256.56	1.09	Fracture discontinuous
70	263.63	158	70.3	0.976	13	A	2	263.758	264.678	0.764	273.41	0.76	Fracture discontinuous
71	263.253	153	70	0.982	12	A	2	263.143	264.302	0.764	239.23	0.53	Fracture discontinuous
72	262.829	170	64.8	0.974	13	A	2	262.657	263.658	0.764	177.68	0.43	Fracture discontinuous
73	259.689	205	76.1	0.961	19	B	2	259.606	261.28	0.764	180.58	0.48	Fracture discontinuous
74	258.333	206	63.2	0.957	18	B	2	257.763	259.126	0.764	155.86	1.6	Fracture discontinuous
75	254.615	103	73.7	0.926	20	C	2	254.035	255.934	0.764	174.07	0.54	Fracture discontinuous
76	252.718	143	73	0.932	19	C	2	251.78	253.926	0.764	122.7	0.72	Fracture discontinuous
77	248.764	80	67.1	0.971	14	B	2	248.579	249.657	0.764	182.13	1.45	Fracture discontinuous
78	238.886	195	73.3	0.935	19	C	2	238.178	240.221	0.764	183.9	0.74	Fracture discontinuous

Note: Refer to accompanying explanation sheet for column descriptions.

Discontinuity Table Explanation

We classified discontinuities into two main types namely fractures and foliation. Of the discontinuities interpreted, most were continuous (360 degrees) across the "unwrapped" BHTV image plot, however, in complexly fractured zones or where discontinuities contain a apparent high dip angle (70 degrees or greater), only segments of the discontinuity were observed. We subdivided these discontinuities as either discontinuous or segmented. Due to the complexity and extreme segmentation of discontinuity traces in some fracture zones, not all possible fractures were subject to tabulation and interpretation. This is to say that the number of interpreted fractures in our analysis will not always correlate to the fracture frequency as determined from rock core analysis for reasons of significance, detection, cementation (in the case of BHTV logs) and undetected breakage of core at the surface. The results of our discontinuity interpretation are presented as a series pf tables. The tables contain column headers which identify various parameters and descriptions from the interpretation. A explanation of column headers is as follows:

COLUMN (from left to right)	CONTENTS
1	discontinuity number (1….N)
2	*Depth*: center depth in meters of interpreted feature (fracture in the majority of cases)
3	*1-Po/100*: This parameter ranges from 0 thru 1.0 according to how well the calculated plane fits the digitized points on a discontinuity trace.
4	*Azimuth*: calculated true dip direction (0-360 degrees) of the plane contained in the discontinuity trace corrected for borehole deviation
5	*Dip*: calculated dip magnitude (0-90 degrees) of the plane contained in the discontinuity trace corrected for borehole deviation
6	***n***: number of points manually selected along the discontinuity trace
7	*Q*: a quality parameter A, B, C, D
8	*K*: classification of interpreted feature (fracture or bedding)
9	*Upper Depth*: lowest position of the interpreted plane contained inside a discontinuity trace in meters
10	*Lower Depth*: highest position of the interpreted plane contained inside a discontinuity trace in meters

11 *Well Diam*: borehole diameter (in feet)

Well Deviation

12 *Azimuth*: bearing in degrees of the borehole axis

13 *Dev*: inclination in degrees of the borehole axis from vertical

14 *Thickness*: true thickness of fracture or bed. Not analyzed

15 *Comment*: Geologic classification of discontinuity with modifiers

APPENDIX C

Analytical laboratory reports of water samples collected during yield tests, Montara, San Mateo County, California

ANALYTICAL CHEMISTS
and
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Approved by State of California

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Tel: 831 724-5422
FAX: 831 724-3188

186890-2-4205

Balance Hydrologics Inc.
841 Folger Avenue
Berkeley CA 94710-2800

29 SEP 04

MATERIAL: Water sample received 23 September 2004
IDENTIFICATION: Project #204119, Well BH9B
Sample ID: 2041190409221655/1658
REPORT: Quantitative chemical analysis is as follows expressed as milligrams per liter (parts per million):

			PUBLIC HEALTH DRINKING WATER LIMITS[1]
pH value (units)		7.7	10.6
Conductivity (micromhos/cm)		230	1600
Carbonate Alk.	(as $CaCO_3$)	0	120
Bicarbonate Alk.	(as $CaCO_3$)	68	-
Total Alkalinity	(as $CaCO_3$)	68	-
Total Hardness	(as $CaCO_3$)	80	-
Total Dissolved Solids		150	1000
Nitrate	(as NO_3)	1.3	45
Chloride (Cl)		32	250
Sulfate (SO_4)		9.8	250
Fluoride (F)		0.63	1.0
Calcium (Ca)		27	-
Magnesium (Mg)		3.0	-
Potassium (K)		0.53	-
Sodium (Na)		23	-
Total Iron(Fe)		0.091	0.3
Manganese (Mn)		< 0.02	0.05

[1]California Administrative Code; Title 22

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY
WATSONVILLE
CALIFORNIA
95076
USA

Tel: 831 724-5422
FAX: 831 724-3188

186890-2-4205

Balance Hydrologics Inc.
841 Folger Avenue
Berkeley CA 94710-2800

29 SEP 04

MATERIAL: Water sample received 23 September 2004
IDENTIFICATION: Project #204119, Well BH9B
Sample ID: 20411904092216555/1658
REPORT: Quantitative chemical analysis is as follows expressed as milligrams per liter:

			PUBLIC HEALTH DRINKING WATER LIMITS[1]
Arsenic	(As)	0.0088	0.05
Barium	(Ba)	< 0.10	1.0
Boron	(B)	< 0.10	-
Cadmium	(Cd)	< 0.001	0.005
Chromium	(Cr)	< 0.001	0.05
Copper	(Cu)	< 0.05	1.0
Cyanide	(CN)	< 0.05	0.2
Lead	(Pb)	< 0.005	0.05
Mercury	(Hg)	< 0.0002	0.002
Selenium	(Se)	< 0.005	0.05
Silver	(Ag)	< 0.010	0.1
Zinc	(Zn)	0.054	5.0
MBAS	(Surfactants)	< 0.025	0.5
Aluminum	(Al)	< 0.05	1.0
Antimony	(Sb)	< 0.006	0.006
Beryllium	(Be)	< 0.001	0.004
Nickel	(Ni)	< 0.01	0.1
Thallium	(Tl)	< 0.001	0.002
Nitrite	(as NO_2)	< 0.5	-

[1] California Administrative Code; Title 22

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186890-2-4205

Balance Hydrologics Inc.
841 Folger Avenue
Berkeley CA 94710-2800

29 SEP 04

MATERIAL:	Water sample received 23 September 2004
IDENTIFICATION:	Project #204119, Well BH9B
	Sample ID: 2041190409221655/1658
REPORT:	General Physical Analysis is as follows:

TEMPERATURE (°C)	COLOR (Co/Pt) (Units)	ODOR (Threshold (Number)	TURBIDITY (NTU)	pH value (units)
-	< 3	< 1	1.0	7.7

-not determined
Odor test performed at 60°C

ANALYTICAL CHEMISTS

October 11, 2004

Lab ID : SP 409895
Customer : 2020008

Soil Control Lab
42 Hangar Way
Watsonville, CA 95076

Laboratory Report

Introduction: This report package contains total of 4 pages divided into three sections:

Case Narrative (2 Pages) : An overview of the work performed at FGL.
Chemical Results (1 Page) : Results for each sample submitted.
Quality Control (1 Page) : Supporting Quality Control (QC) results.

This report package pertains to the following sample:

Sample Description	Date Sampled	Date Received	FGL Lab Sample ID #	Matrix
Well BH9B	09/22/2004	09/24/2004	SP 409895-01	DW

Sampling and Receipt Information: The sample was received, prepared and analyzed within the method specified holding times. All samples arrived at 6 °C. All samples were checked for pH if acid or base preservation required (except for VOAs). For details of sample receipt information, please see the attached Chain of Custody and Condition Upon Receipt Forms.

Quality Control: All samples were prepared and analyzed according to the following tables:

Radio Chemistry QC

900.0	09/30/2004:A207 All preparation quality controls are within established criteria, except: The following note applies to Gross Alpha: 435 Sample matrix may be affecting this analyte. Data was accepted based on the LCS or CCV recovery.
	10/07/2004:A - GP213 All analysis quality controls are within established criteria.

Case narrative continued on next page...

Corporate Offices & Laboratory
P.O. Box 272 / 853 Corporation Street
Santa Paula, CA 93061-0272
TEL: (805) 392-2000
FAX: (805) 525-4172
CA NELAP Certification No. 01110CA
CA ELAP Certification No. 1573

Office & Laboratory
2500 Stagecoach Road
Stockton, CA 95215
TEL: (209) 942-0181
FAX: (209) 942-0423
CA ELAP Certification No. 1563

Field Office
Visalia, California
TEL: (559) 734-9473
FAX: (559) 734-8435
Mobile: (559) 737-2399

October 11, 2004

Lab ID : SP 409895
Customer : 2020008

Soil Control Lab

Certification: I certify that this data package is in compliance with NELAC Standards, both technically and for completeness, except for any conditions listed above. Release of the data contained in this data package is authorized by the Laboratory Director or his designee, as verified by the following signature.

FGL ENVIRONMENTAL

KAD:cl

Kelly A. Dunnahoo, B.S.
Laboratory Director

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY

Tel: 831 724-5422
FAX: 831 724-3188

188342-1-4205

Balance Hydrologics Inc.
841 Folger Avenue
Berkeley CA 94710-2800

22 NOV 04

Mark Woyshner

MATERIAL: Water sample received 08 November 2004
IDENTIFICATION: Project #204119, BH9B, 041107.1600.01
REPORT: Quantitative chemical analysis is as follows expressed as milligrams per liter (parts per million):

		PUBLIC HEALTH DRINKING WATER LIMITS[1]
pH value (units)	7.9	10.6
Conductivity (micromhos/cm)	250	1600
Carbonate Alk. (as $CaCO_3$)	0	120
Bicarbonate Alk. (as $CaCO_3$)	65	-
Total Alkalinity (as $CaCO_3$)	65	-
Total Hardness (as $CaCO_3$)	75	-
Total Dissolved Solids	160	1000
Nitrate (as NO_3)	1.4	45
Chloride (Cl)	32	250
Sulfate (SO_4)	9.1	250
Fluoride (F)	0.61	1.0
Calcium (Ca)	25	-
Magnesium (Mg)	3.0	-
Potassium (K)	0.62	-
Sodium (Na)	22	-
Total Iron(Fe)	< 0.05	0.3
Manganese (Mn)	< 0.02	0.05

[1]California Administrative Code; Title 22

ANALYTICAL CHEMISTS
and
BACTERIOLOGISTS
Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY

Tel: 831 724-5422
FAX: 831 724-3188

188342-1-4205

Balance Hydrologics Inc.
841 Folger Avenue
Berkeley CA 94710-2800

22 NOV 04

MATERIAL: Water sample received 08 November 2004
IDENTIFICATION: Project #204119, BH9B, 041107.1600.01
REPORT: Quantitative chemical analysis is as follows expressed as milligrams per liter:

		PUBLIC HEALTH DRINKING WATER LIMITS[1]
Arsenic (As)	0.0085	0.05
Barium (Ba)	< 0.10	1.0
Boron (B)	< 0.1	-
Cadmium (Cd)	< 0.001	0.005
Chromium (Cr)	< 0.001	0.05
Copper (Cu)	< 0.05	1.0
Cyanide (CN)	< 0.05	0.2
Lead (Pb)	< 0.005	0.05
Mercury (Hg)	< 0.0002	0.002
Selenium (Se)	< 0.005	0.05
Silver (Ag)	< 0.010	0.1
Zinc (Zn)	< 0.05	5.0
MBAS (Surfactants)	< 0.025	0.5
Aluminum (Al)	< 0.05	1.0
Antimony (Sb)	< 0.006	0.006
Beryllium (Be)	< 0.001	0.004
Nickel (Ni)	< 0.01	0.1
Thallium (Tl)	< 0.001	0.002
Nitrite (as NO_2)	< 0.5	-

[1] California Administrative Code; Title 22

APPENDIX D

Montara Water and Sanitary District water rights for Montara Creek, San Mateo County, California

TABLE 2-A

Citizens Utilities Company of California
Montara Water District

SUMMARY OF FORMAL PROCEEDINGS
REGARDING RATES AND PROPERTIES*

Appl. or Case Number	Description	Decision Number	Date Decided	Reference
	Moss Beach Realty Company			
A-2029	Established rates	3125	Feb.25,1916	9 CRC 25
C-1205	Complaint of refusal to serve dismissed.	5457	Jun. 4,1918	15 CRC 81
	Granite Rock Water Company			
A-5620	Denied request to revise water rates in Moss Beach area.	8457	Dec.20,1920	-
A-7007	Authorized to buy the water system of Moss Beach Realty Company.	9694	Nov. 4,1921	-
A-7008	Authorized to increase water rates for Moss Beach.	9724	Nov. 8,1921	20 CRC 80
	Montara Water Company (Arthur Wagner)			
A-5124	Authorized to purchase the water system of Montara from Montara Realty Development Co.	7072	Feb. 5,1920	17 CRC 73
A-5127	Authorized to purchase Farallone District of Montara.			
A-5894	Authorized increase in rates and consolidation of water systems purchased earlier. (Dec.7072)	8546	Jan.17,1921	19 CRC 30
	Citizens Utilities Company of California#			
A-15464	Authorized to buy Granite Rock Water Company and to issue securities.	20963	Apr.16,1929	32 CRC 83
A-15466	Authorized to buy Montara Water Company and to issue securities.			
A-28618	Authorized rate increases in Half Moon Bay, El Granada, Moss Beach, Montara, and vicinity.	41617 ~~4252~~ 42252	May 18,1948 Nov.23,1948	48 CPUC 12 48 CPUC 317

* Includes proceedings involving predecessor companies.

\# Name adopted November 14, 1949. Formerly Public Utilities California Corporation.

JGS 521114

THE LOVELAND ENGINEERS, INC.

SAN FRANCISCO ∴ LOS ANGELES

REPORT AND ANALYSIS

IN RE

APPRAISAL OF PROPERTIES

OF

MONTARA WATER COMPANY

AS OF

JULY 31, 1928

The purpose of this report is to determine the value of the properties, rights and interests of the Montara Water Company, located at Montara, San Mateo County, California.

Careful investigations have been made of all properties, rights and interests belonging to this Company to properly determine their value as of July 31, 1928.

TERRITORY SERVED

The Montara Water Company serves the real estate subdivisions known as Montara and Farallone which lie north of and adjacent to the Moss Beach subdivision now served by the Granite Rock Water Company. The service area is situated on the sea coast approximately thirty-eight miles south of San Francisco in San Mateo County, California and has an estimated population of two hundred fifty, as of the present date.

The principal industries in this section are truck farming, dairying and horticulture. This territory was originally served by the Ocean Shore Railroad, but since its abandonment in 1920, transportation has been furnished by auto stage and truck.

HISTORY

* The area served by this company was subdivided about 1907, shortly after the Ocean Shore Railroad was built into it, by the Montara Realty Development Company and the California Suburban Home Company. Both companies constructed water systems to serve their subdivisions in order to facilitate real estate sales. The first company owned the water system serving Montara and the second owned the water system serving the Farrallone subdivision.

This section developed quite rapidly for a time, but has advanced very slowly for the past ten years.

The two water systems were purchased in 1920 by Mr. A. L. Wagner, who has operated them as one unit to the present time.

DESCRIPTION OF PROPERTIES

* The properties of the Montara Water Company consist of two pumping plants, a diversion line from the north

fork of Montara Creek, a concrete storage reservoir and the distribution system.

The pumping plants and the storage reservoir are located on small parcels of ground owned by the Company and the pipe lines are laid in the public streets or else on private property where rights-of-way have been secured.

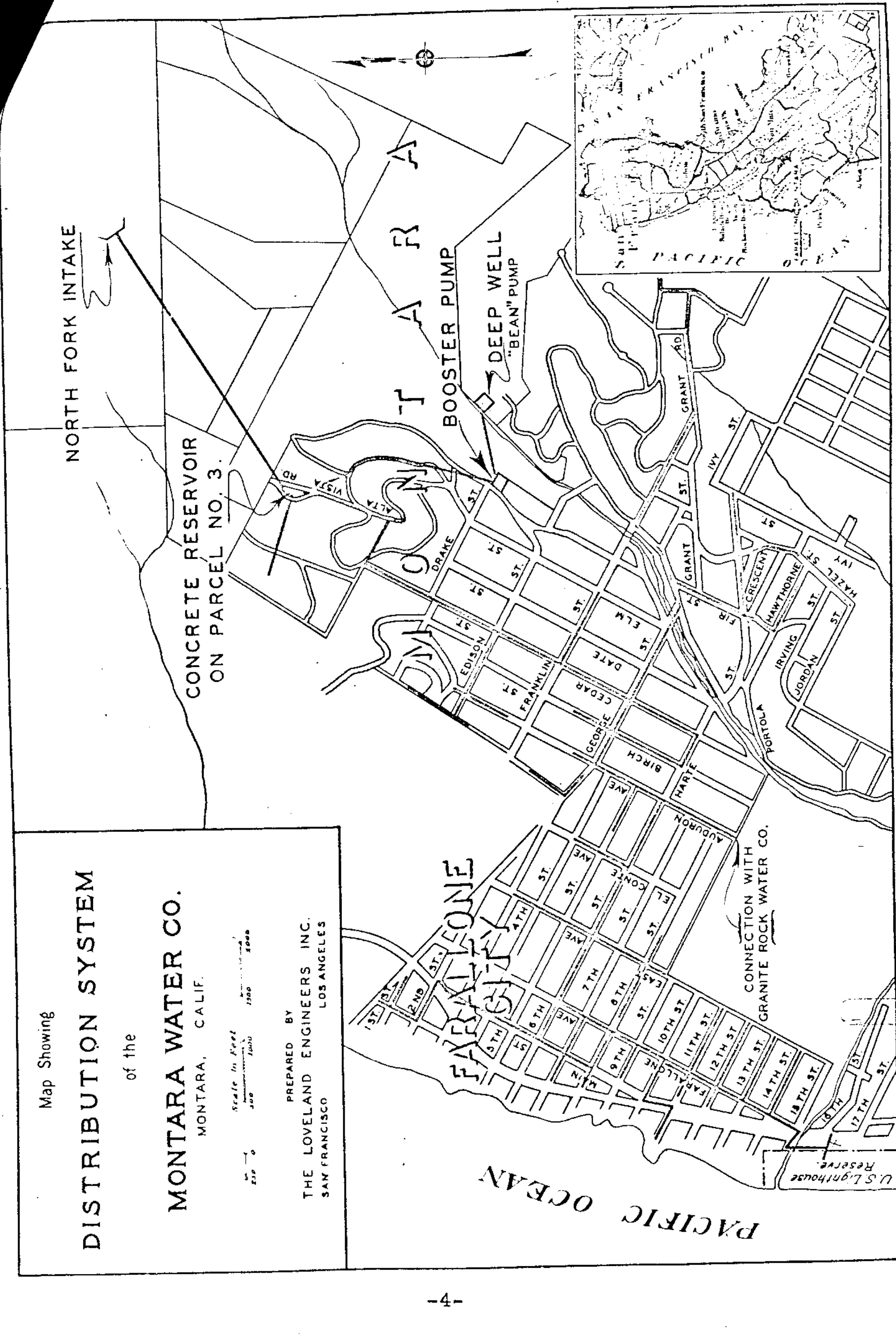
At each pumping plant is located a small frame pump house and a 12 inch well about 100 feet deep. The main pumping plant is equipped with a 7 inch Bean deep well turbine pump belt driven by a 7½ H.P., motor. Water from this plant is pumped to a sump at the other pumping plant which is used primarily as a booster station. The booster pump is a Rumsey 5 inch by 9 inch double geared triplex, operated by a 10 H.P., motor.

A Stover deep well pump and the well at this plant are held for standby service.

Water from the pumping plants together with that diverted from the north fork of Montara Creek, is stored in a concrete reservoir of 50,000 gallons capacity.

The distribution system is supplied directly from the storage reservoir and consists of approximately 41,000 feet of pipe ranging in size from one-half inch to four inches in diameter. There are 83 services of which 67 are active, and 43 metered.

The map on the following page outlines the territory served, its location in respect to San Francisco and shows the location of the facilities owned by the Company.


Map Showing
DISTRIBUTION SYSTEM
of the
MONTARA WATER CO.
MONTARA, CALIF.
PREPARED BY
THE LOVELAND ENGINEERS INC.
SAN FRANCISCO LOS ANGELES
NORTH FORK INTAKE
CONCRETE RESERVOIR
ON PARCEL NO. 3.
BOOSTER PUMP
DEEP WELL
"BEAN" PUMP
MONTARA
FARALLONE CITY
CONNECTION WITH
GRANITE ROCK WATER CO.
U.S. Lighthouse Reserve.
PACIFIC OCEAN
ALTA VISTA RD
DRAKE ST.
EDISON ST
FRANKLIN ST.
GEORGE
HARTE
AUDUBON
ELM ST.
DATE
CEDAR
BIRCH
AVE
GRANT RD
GRANT ST.
IVY ST.
HAZEL ST.
FIR ST
CRESCENT
HAWTHORNE
IRVING ST.
JORDAN ST.
PORTOLA
1ST
2ND
3RD ST.
4TH
5TH
6TH
7TH
8TH
9TH
10TH ST.
11TH ST.
12TH ST
13TH ST.
14TH ST.
15TH ST.
16TH
17TH
MAIN
FARALLONE
EAST
EL CONTE
PACIFIC OCEAN
SAN FRANCISCO BAY

COST OF ACQUISITION OF FRANCHISE

No county or other franchise is held by this company but a constitutional franchise is claimed on account of its being in operation prior to 1911. If this property were to be reproduced a county franchise would be necessary and the cost of acquisition of such a franchise has been placed at $250. As no expense has actually been incurred for the acquisition of franchise no allowance for this item has been made in the Estimated Original Cost appraisal.

WATER RIGHTS

The Montara Realty Development Company filed claim to water flowing in the north branch of Montara Creek in 1908 and later transferred the water rights to the present owner.

This is the main source of supply for the system and provides a sufficient quantity of water for the requirements during the greater part of the year. The supply is augmented by water pumped from a well during dry periods.

It is considered that the sum of $2,000 is a reasonable allowance for this item and is included in the appraisal.

box #1 MT 0023 #1

SCHEDULE OF PROPERTIES AND RIGHTS

OF

MONTARA WATER COMPANY

AS OF

JULY 31, 1928

WATER RIGHTS

Right to divert water from the north and south forks of Montara Creek as follows:

NOTE 2 In Book 1 of Water Rights at page 35 is a Notice of Appropriation, dated December 1, 1908 and recorded December 4, 1908 given by Montara Realty Development Company by C. P. Haag, Secretary giving notice of appropriation of 100 inches of water under a 4 inch head for domestic use and irrigation from the North fork of Montara Creek. In Book 1 of Water Rights at page 37 is a Notice of Appropriation identical in all respects to foregoing except that appropriation is to be from the South fork of Montara Creek.

FRANCHISES

No county or other franchise is held by this Company. A constitutional franchise is claimed on account of its being in operation prior to 1911.

RIGHTS OF WAY

Rights of way for pipe lines on the acerage of the Montara Realty Development Company transferred to Mr. Wagner by deed dated February 7, 1920.

PARCEL 1

BEGINNING at the most Northerly corner of Block "D" as shown on that certain map entitled "Amended and Supplemental Map of Montara San Mateo County, California", filed in the office of the County Recorder of San Mateo County October 16, 1907 in Book 5 of Maps at page 35; thence Southwesterly along the Northwesterly line of said Block, 40 feet; thence S. 62° 31' E. 60 feet; thence N. 29° 20' E. 40 feet to the Southwesterly line of Drake Street as shown on said map; thence along said last named line N. 62° 31' W. 60 feet to the point of beginning. BEING a portion of Lots 16 and 17 in said Block "B".

Old PARCEL 2

BEGINNING at the most Northerly corner of Block "B" as shown on the map hereinabove referred to; thence along the Northeasterly line of said Block same being the Southwesterly line of Drake Street S. 62° 30' E. 60 feet; thence N. 29° 20' E. 34 feet; thence N. 62° 30' W. 60 feet; thence S. 29° 20' W. 34 feet to the point of beginning. Being a portion of Drake Street as shown on said map.

Map Doc #5

PARCEL 3

All that parcel of land marked "Reservoir", and being bounded on the Easterly side by Alta Vista Road and on the Southwesterly and Northwesterly sides by Reservoir Road as said parcel of land and roads are shown and delineated on that certain map entitled "Second Addition to Montara, San Mateo County, California", filed in the office of the County Recorder of San Mateo County August 4, 1908 in Book 6 of Maps at page 28 thereof.

BUILDINGS AND STRUCTURES

An "L" shaped wood frame pump house located on parcels of land numbers one or two.

RESERVOIRS

A concrete reservoir 15'6" x 18'6" located on parcels of land numbers one or two.

A concrete reservoir 40' x 40' with a shingled pyramid roof located on parcel of land number three.

DAMS Intake

A small rubble masonry dam to divert the flow of water from south fork of Montara Creek, located on property of A. L. Wagner.

A small rubble masonry dam to divert the flow of water from the north fork of Montara Creek, located on property of McNee Estate.

WELLS

A well 96 feet deep cased with 8 inch casing located on parcels of land numbers one or two. Sump Pump House

PUMPS

A Rumsey 5" x 9" double geared triplex displacement pump, located at pump house on parcels of land numbers one or two.

A Stover No. 6½ deep well type plunger pump, located at pump house on parcels of land numbers one or two. This pump is completely disassembled.

MOTORS

A 10 H.P. General Electric motor, No. 521841 with starting compensator, and knifeswitch on pipe frame brackets. This equipment operates the Rumsey pump.

A 5 H.P. General Electric motor rebuilt by Enterprise Motor Works, with magnet starter and knifeswitch. This equipment is maintained for the operation of the Stover Pump, but is at present being used by Mr. Wagner for the operation of a pump which is not a part of the utility property.

This would have to be some other motor as this one burned up.

TRANSMISSION AND DISTRIBUTION MAINS

44,110 feet of transmission and distribution mains ranging in size from one-half inch to four inches in diameter, located in streets and on private property within the boundaries of the area served by the Montara Water Company.

SERVICES

A total of 88 service connections ranging in size from 1/2" to 1½" in diameter.

METERS

A total of 43 Trident meters, ranging in size from 5/8" x 3/4" to 2 inches.

METER BOXES

43 Art Concrete meter boxes in place at the location of the above meters.

MATERIAL AND SUPPLIES

1 - 1/2" Worthington Meter
7 - 1/2" Trident "
2 - 3/4" " "
1 - 1" to 2" Stock & Dye
1 - 2½" to 3" Stock & Dye
1 - Pipe Vise
1 - 36" Chain Tongs
1 - 48" " "
1 - 36" Stillson Wrench
6 - Art Concrete meter Boxes
Miscellaneous small tools and pipe fittings

I, ARTHUR R. WAGNER, owner of Montara Water Company, HEREBY CERTIFY that the foregoing is a full, true and correct schedule of all of the assets of said MONTARA WATER COMPANY.

DATED: Dec 3, 1928.

A R Wagner