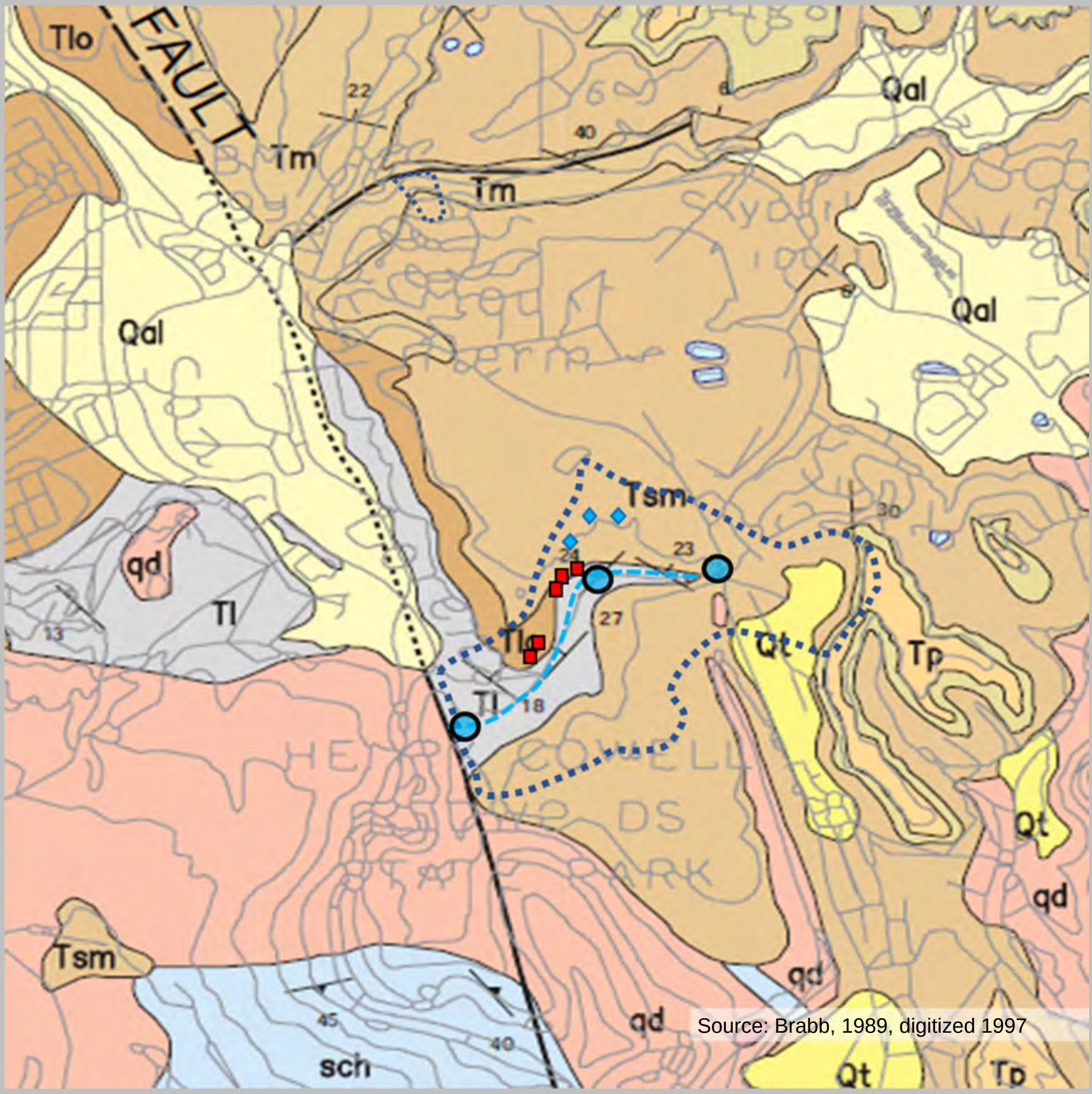
EAGLE CREEK PRELIMINARY HYDROGEOLOGICAL RECONNAISSANCE, SANTA CRUZ COUNTY, CALIFORNIA: SUMMER OF WATER YEARS 2018 – 2020



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Balance Hydrologics

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February 2021

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Eagle Creek Preliminary Hydrogeological Reconnaissance, Santa Cruz County, California: Summers of Water Years 2018 - 2020

 Project Assignment: 218109b

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1. INTRODUCTION

Eagle Creek is in a relatively unexplored portion of the Santa Margarita aquifer area where hydrological properties have remained obscure. During WY 2018, 2019, and 2020, the County of Santa Cruz Health Department asked that Balance Hydrologics explore the basic characteristics and boundary conditions of the portion of the aquifer beneath Eagle Creek, and to assess the directions of subsurface drainage and get some notion of its basic hydrogeologic characteristics. This report documents the questions which we asked and the results of the work. This assignment was originally proposed by hydrologist/geologist Jason Parke.

The predominantly sandy soils of Eagle Creek watershed and the northern end of Graham Hill Road area allow most rainfall to infiltrate into the underlying sandy aquifers, principally the Santa Margarita sandstone. Some of the subsurface drains northwestward toward Bean Creek, some drains northeastward toward Lockwood Lane and the Camp Evers valley (the easternmost segment of Mt. Hermon Road), and some likely drains southward parallel to Graham Hill Road toward Powder Mill Creek. Much of the subsurface drainage is directed down the upper slopes toward Eagle Creek, emanating in springs in the middle and lower course of this watershed and in the San Lorenzo River gorge near its mouth. Additionally, some of the Santa Margarita aquifer beneath Eagle Creek likely drains directly downward into the sandy Lompico aquifer, because the Monterey formation aquiclude has been eroded, enabling minimally-impeded groundwater exchange between the two sandstones. This report lays the framework to begin to assess those topics and to establish a useful hydrologic baseline from which future hydrogeological trends may be assessed.

Since very little information on water movement in this watershed was originally found to be available, investigations of Eagle Creek were initially conceived as a three-year effort beginning with a rough reconnaissance, a second year with continuous gaging and more comprehensive observation, and finally, a broader effort linking surface and groundwater flow during a third season. This final report has been prepared at the conclusion of the study, superseding the prior draft reports

This is the third draft report prepared by Balance as part of the Eagle Creek investigation. The initial draft (February 2020) was superseded by an August 2020 draft, revised to include findings from the rediscovered Ellis (1984) report (see next chapter) and the 2001 to 2005 data on spring flows found in an appendix to the Kennedy Jenks study (2015). This report includes flow measurements from summer 2020 which were part of the study as originally envisioned, and which include important quantification of baseflows during drier seasons (i.e., **Figure 9** and **Figure 10**). This report is part of County's contribution to planning for the Santa Margarita Ground Agency planning, including its Groundwater Sustainability Plan of 2021, and the County's accretion investigations. This version of the draft report will become final once reviewed by the County (our client) and we have made appropriate adjustments and responses.

This work was conducted under permit issued by the main watershed owner, California State Beaches and Parks, Santa Cruz Mountains Region, written by park ecologist Tim Hyland. A copy of this report will be sent to Mr. Hyland at the Felton office once the final report is accepted by the County.

2. HYDROLOGIC SETTING OF THE EAGLE CREEK WATERSHED

Eagle Creek is a small drainage originating on the long linear crest of Graham Hill. The topographic drainage area is about 0.7 square miles (or roughly 450 acres), with a mean annual rainfall of about 42.1[1] inches. The groundwatershed may be substantially different than the topographic watershed over much of its periphery, as discussed below. The upstream-most portions of the watershed are underlain by granitic basement rocks, by Purisima sediments and a thin band of the older lithified mudstones and fine-grained sandstones of the Locatelli formation. Santa Margarita sandstone directly underlies the rest of the watershed. Because most of the outcrop is relatively flat-lying and continuous, it is possible that much can be learned about the hydrogeology of the Santa Margarita formation from observing where surface flows enter and leave the aquifer, and from the water quality emanating from the sandstone (**Figure 1** and **Figure 4**).[2]

Prior hydrogeologic interpretations of the Eagle Creek watershed and vicinity originally appeared to be very limited. During the 2020 field season, we became aware of field work conducted by pioneering local hydrogeologist Bill Ellis in 1984, when much of the Eagle Creek watershed was being assessed for a proposed spray disposal field for treated effluent from an envisioned wastewater treatment plant in Felton. The treatment plant never built. His report was unearthed from personal archives by John Ricker, recently-retired County Water Resources Coordinator, who also worked on that project early during his career. Ellis was able to construct seven (7) piezometers to base of the Santa Margarita in the central and southern part of the watershed, and to collect representative samples of groundwater for major ions analysis.

Using a classic approach to aquifer analysis, Ellis was able to identify the basic structure and functions of the Santa Margarita formation in this area. He used the seven boreholes to define the formation geometry (including its base on older bedrock at an elevation of roughly 500 feet), the approximate horizontal permeabilities of about 500 feet per day, sample water quality from the mid-basin spring system. His work is so

[1] https://streamstats.usgs.gov/ss/

[2] Presence or absence of a thin outcrop of Santa Cruz mudstone, locally a minimally permeable formation or aquiclude which caps the Santa Margarita sandstone, is not mapped in the published literature. Float rocks (eroded material found in the bed of Eagle Creek upstream of Graham Hill Road) which we believe to be Santa Cruz mudstone suggest that it is present beneath the Purisima sediments in the easternmost portions of the watershed. If present, these horizons could potentially direct shallow groundwater in the direction of its dip to the northeast either toward the Camp Evers and an unnamed tributary just to the southeast.

central to understanding the Eagle Creek watershed that we have attached his report both because of the elegance of work and to celebrate its rediscovery and make it more broadly available (as **Appendix A** to the present report). Ellis' report does not consider recharge, flow beyond the boundaries of this spray disposal site, or set the site within a broader geologic and hydrogeologic context of the Santa Margarita, some of which are discussed below.

Also, during spring 2020, we came to be aware of one of the appendices to a 2015 study by Kennedy Jenks Consultants which cites measured spring yields in the cluster of diffuse springs at the southward bend of Eagle Creek midway along its course (**Table 2**).[3],[4]

Table 2 Measurements of Eagle Creek near mouth cited in Kennedy/Jenks (2015)

Spring Discharges - Scotts Valley, CA

Eagle Creek		
DATE	Discharge (cfs)	Discharge (gpm)
3/28/2001	1.81	812.38
10/16/2001	0.33	148.11
3/21/2002	0.84	377.02
9/25/2002	0.33	148.11
4/7/2003	0.66	296.23
10/16/2003	0.33	148.11
3/24/2004	0.66	296.23
11/15/2004	0.42	188.51
4/20/2005	0.66	296.23
10/25/2005	0.35	157.99

These flows are shown along with measurements from the 2019 and 2020 to the current water year (**Figure 8**) for context with the most recent data. Methods used in measuring these 2001 to 2005 flows are not stated.

Both for the 2001-5 and 2018-2020, measurements in March or April are much larger than those late in fall and vary with the prior year's rainfall. The more it rained, both in 2001-2005 and in 2018-2020, the greater were the later wet-season (or early dry-season) flows. Conversely, flows at the end of summer had receded to baseflows which – while

[3] It is not immediately clear who made and reviewed these measurements, which seem to have been first published 10 to 15 years later.

[4] Regional annual runoff for water years 2001 through 2005 is also shown on **Figure 8**.

still large relative to less sandy areas – were very similar from year to year irrespective of the prior winter's precipitation. The semi-annual flow measurements suggest a copious source of groundwater relative to late-winter yield, with late fall measurements not varying much from one winter to the next, or even following consecutive near-consecutive wet winters, 2017 and 2019. The volume of water draining through Eagle Creek during the end-of-summer measurements is large relative to most other streams in the Santa Cruz Mountains, particularly those with moderate mean annual rainfall. The 0.7-square-mile watershed has late-summer flows of 0.33 cubic feet per second (cfs) or so, during most years, including ones as dry as 2020. This is equivalent to unit runoffs of about 0.50 cfs/sq. mi. By contrast, other upland streams of similar size and with similar geology, drainage size and 35 to 40 inch rainfall may yield 0.03 to 0.05 cfs/sq. mi (Wilder Creek, Peasley Gulch, or upper Arana Gulch), or even Peavine and Hare Creeks, in the much wetter Boulder Creek area (0.05 to 0.10 cfs/sq. mi.). Eagle Creek can routinely support a much wetter late-summer baseflow and mesic riparian vegetation over the downstream-most course, between the springs and the San Lorenzo River. The hydrologic importance of this riparian vegetation is further discussed in **Figure 10** (**Section 3.6**).

2.1 Geologic Boundaries of the Eagle Creek Hydrogeologic System

Three aspects of the geological structure are pertinent to the overall understanding of the Santa Margarita Groundwater Basin (SMGB). First, much of the western half of the groundwatershed is deformed by drag folding along an uplift on the western side of the Ben Lomond fault (**Figure 6**). As Ben Lomond Mountain was tectonically raised, the Santa Margarita and underlying formations were folded such that individual beds would tend to drain eastward and northward. Dips exceeding 30 degrees to the northeast are mapped on ribs of Locatelli formation along the San Lorenzo River at the western edge of the Eagle Creek sub-basin, diminishing to dips of similar direction, but only a few degrees magnitude, beneath the center of the sub-basin. It is possible that the Santa Margarita or underlying formations were fractured by this folding, and now pull groundwater southward or westward out of this sub-basin.[5] Secondly, the northern border of groundwatershed is probably a zone where the shales of the Monterey formation were eroded away during the late Miocene, unroofing the sandy Lompico

[5] County-wide, we have not been able to find any mapped units of the typically semi-indurated Santa Margarita formation which have survived folding in excess of 10 or 12 degrees. It is possible that at tighter folding, the formation is not sufficiently coherent to withstand disaggregation and erosion, likely along fractures which develop along the axis of the fold. Sapping associated with accelerated groundwater drainage through such fractures would be a logical process by which such erosion occurs.

aquifer. allowing direct movement of groundwater from the Santa Margarita into the Lompico, from which it is withdrawn through numerous wells just to the north (c.f., Phillips, 1981; Ellis,1984; Kennedy Jenks Consultants, 2015). Most of the Eagle Creek watershed itself is underlain by near-impervious crystalline rocks or highly cemented members of the Locatelli formation; it is the areas at and north of the watershed divide which are underlain directly by the Lompico aquifer.

The water in Eagle Creek and associated springs seems to have some of the lowest content of dissolved solids of any groundwater-fed landscape within the Santa Cruz Mountains. Such low mineral content is typical of springs and seeps within portions of the Santa Margarita formation. Concentrations in the springs tend to increase over the course of the rainy season in the Eagle Creek watershed, suggesting that as contributing areas to the springs extend deeper and further to the north, slightly saltier portions of the Santa Margarita become engaged (see **Figure 8**). Understanding why the salinities (measured as specific conductance) are so low may help in inferring the location of the points of greatest recharge and directions of groundwater movement within the SMGB.

Finally, the similarity of 2019 and 2020 baseflow measurements to Ellis' observations in 1984 (see **Appendix A**) and the records of flow reported by Kennedy Jenks Consultants (2001 to 2005) is noteworthy. One implication is that there has been little or no change in groundwater conditions within the Eagle Creek watershed over the past 35 years, despite major declines in annual mean groundwater levels in the Lompico and Santa Margarita formations immediately to the north, in actively-pumped portions of the SMGB. Another implication is that groundwater conditions within the Eagle Creek watershed may provide suitable baseline conditions against which to measure effects of past and future groundwater development or climate change in these two aquifers.

2.2 Soils and Vegetation

Soils and vegetation of most of the Eagle watershed are very dry (xeric), typical of the sandy substrate or sand-hill hydrology which is a distinctive hydrological attribute of most of the landscape within the SMGB, particularly those areas underlain by the namesake formation. Soils are mapped primarily as being within Zayante (USDA Soil Conservation Service, 1980) or Arnold (Storie and others, 1947) series, units with vertical permeabilities typically exceeding 6 inches per hour, more than double the highest rainfall intensities to be expected (Rantz, 1971). Much or most rainfall in such areas recharge the local and regional aquifer system. Soils along and east of Graham Hill

Road are also characteristically sandy, but less so, particularly with contemporary land uses and engineered drainages. Vegetation is also distinctively dry over most of the upland portions of the watershed, with typically sandy scrub and woodland vegetation communities supported by the sandy soils. Ponderosa and knobcone pine, cypresses, and chaparral forbs and bushes typical of the drylands occupy much of the Eagle Creek watershed, with more typical conifer and mixed hardwood communities developed on the steeper slopes near the watershed's western edge (see **Appendix B**).

Most of the watershed is devoted to open-space uses, primarily state park and largely-wooded public portions of Mount Hermon Association and other semi-public ownerships. Impervious areas are found on the roadways, primarily Graham Hill Road and residential streets occupying the eastern fringe of the watershed. Parking areas for the County Probation Center and for State Park trailheads are located near the topographic ridge followed by Graham Hill Road, all draining to Eagle Creek. Impervious or compacted surfaces probably account for less than three percent of the watershed area, but do appear to be the sources of small drainageways incised 3 to 8 feet below the general land surface which converge in the middle portion of the drainage.

3. EAGLE CREEK FLOW RECONNAISSANCE: RESULTS AND FINDINGS

Our initial literature review showed almost no hard data on hydrologic conditions in this watershed. As a result, our responding work scope included identifying seeps, springs, and wetlands, how these were related to Eagle Creek and the underlying aquifer, plus making basic measurements of baseflows and how these all the different water bodies interrelate. End-of-season flow measurements were made at an apparently-favorable gaging location near the mouth of the creek. We temporarily installed a stream gage as a trial for further work during the subsequent two seasons. The gage was removed at the onset of winter storms. We also made observations confirming that the watershed hydrology was fundamentally sandy, with very high infiltration rates and identified seeps and springs.

3.1 Flow-Measurement Activities

We re-established the pioneer gage during the last week in March 2019. A watershed-wide reconnaissance was conducted on April 29, 2019 by walking all trails within the watershed and exploring the private lands east of Graham Hill Road. Several points of inflow from the south were noted while walking the Eagle Creek trail. It was also noticed that flow dramatically increased downstream from the culvert upstream of Graham Hill Road to the gaged location about 150 feet upstream of the San Lorenzo River. During late-summer 2019, it became apparent that continuous sand transport (even at flows of less than 0.5 cfs) created unstable bed conditions at the gage, generally in concert with twigs and small branches which accumulated against the cobbles on the channel bed. Water levels in the channel grew higher throughout August as flows gradually diminished, and then again in September after the gage was physically cleared. We chose to let the instrumentation remain in place through winter 2020. After clearing several inches of sediment from the gage pool, measurement continued through the end of the contract period at the start of July 2020 to the end of the summer runoff season following the first runoff-producing storm in October 2020 after which the program was discontinued and the gaging hardware was removed.

Figure 8 shows the overall flow pattern during the three years of observation, and the comparison with flow in the San Lorenzo River at Bigtrees. Runoff at Bigtrees for the three years as 36 percent, 164 percent, and 35 percent, respectively, of the 83-year USGS gaging record at that site (see **Figure 2**, **Figure 3**, and **Figure 4**).

3.2 Surface-Groundwater Connection

Given the persistent base flow, we infer that it is likely that much of the groundwater to the west of Graham Hill Road flows toward Eagle Creek. Groundwater beneath the headwater valley to the east of the road can be seen in small springs to be tributary to Eagle Creek, but some deeper groundwater likely flows northeastward toward the Camp Evers and Carbonera watersheds, as shown in the Kennedy/Jenks (2015) report which are largely based on 2012 data (**Figure 6**). This inferred groundwater gradient flow direction is also suggested by Nick Johnson's 2005 work shown on **Figure 7**. Westward from Lockwood Lane, the flow divide likely moves beneath the topographic watershed, with some flow toward Ferndell Spring, Redwood Spring and a diffuse line of seepages visible on the south bank of Bean Creek, perhaps associated with the Bean Creek fault. These conclusions were reaffirmed once the data described in Ellis' 1984 report came to our attention, as described in Chapter 2,

3.3 Findings from the 2020 Reconnaissance

Goals of the 2020 reconnaissance were to locate previously mapped seeps and springs, note changes in vegetation and measure flow and specific conductance at various positions in the watershed (upper, middle, lower). Prior to these field activities we examined previous work including geologic maps and previous observations of stream/seep flow in the Eagle Creek watershed, supplemented by the information later obtained (Ellis 1984), as noted below. On April 24, 2020, Balance staff walked the Eagle Creek trail in Henry Cowell State Park after measuring flow upstream of Graham Hill Road and attempting to locate mapped springs east of Graham Hill Road. Flow increased sharply from Graham Hill Road from 0.04 cfs (19 gpm) to 0.37 cfs at the Eagle Creek trail crossing 0.37 cfs (164 gpm) to 0.92 cfs at the gage which is 150 ft upstream of the San Lorenzo River. Rainfall during water year 2020 was about 60 percent of mean annual, of which nearly all had fallen by the date of the initial field work on April 24.

While specific springs previously mapped in the Kennedy Jenks (2015) report near the crossing of Eagle Creek trail with Eagle Creek were not found at the indicated GPS locations, several springs slightly downstream of this location were observed. The single spring with greatest volume found was estimated to have 30+ gpm had incised through the hillside approximately 6 feet deep and 2 feet wide. Other springs observed downstream of the Eagle Creek trail crossing added another at least 10 gpm flowing into Eagle Creek. There were no springs or seeps noticed entering the Eagle Creek channel from the southern side of the canyon. Accretion from the south is likely minimal.

These springs roughly coincide with the geologic contacts between the Santa Margarita, Lompico and Locatelli formations (**Figure 2**); however, the measured specific conductance (informally, also known as 'conductivity') of these springs (64 µS normalized to 25ºC) was approximately half of the measured specific conductance in Eagle Creek (128 µS at 25ºC). The low conductivity found in the springs is likely due to the influence of the Santa Margarita formation. Both formations are composed primarily of arkosic sand; however, the Lompico has a finer-grained matrix imparting higher specific conductance to waters emanating from the Lompico than from the Santa Margarita aquifer. It is likely that the least conductive of these waters are recharged into the Santa Margarita, and then discharged without traveling far. Specific conductance values of approximately 100 µS at 25ºC have been noted in other Santa Margarita-derived waters such as Ferndell Creek/Spring and the spring just upstream of the weir at the Zayante Creek at Woodwardia stream gage. For context, conductivity values below 100 µS at 25ºC (and generally below 40 to 50 µS at 25ºC) are typically observed in coastal rainfall prior to interacting with the ground.

3.4 Summary of Watershed Outflow

Our flow measurements near the mouth of the watershed were similar to prior flow measurements from water years 2001 to 2006 cited in 2015 by Kennedy/Jenks (**Figure 7**) As noted above, late-season baseflow appears to consistently be within roughly the same range of approximately 0.3 to 0.4 cubic feet per second (cfs) regardless of the type of water year (wet/normal/dry), equivalent to 135 to 180 gallons per minute (gpm)

Water quality emanating from mid-watershed spring area seems to remain unchanged from the values measured in 1984 by Ellis and the specific conductance values which our staff has been measuring. Recent mid-summer values from individual springs in this cluster have ranged from 65 to 72 umhos/cm, adjusted to 25degC; Ellis reported a value of 70 (at 25 degrees) recorded by the (unknown) analytical laboratory. Major cations were 4, 0.8, and 8.5 for Ca, Mg, and Na, respectively; we would expect similar numbers from a contemporary analysis. The 1984 test reported nitrate-nitrogen to be 0.2 mg/L. All values are remarkably low in comparison to the chemistry of other natural waters in Santa Cruz County. These values are deemed likely to prove representative of current conditions, in part because the specific conductance values match. We recommend that the springs be resampled by Balance for analysis by the County laboratory for comparison with the analysis obtained by Ellis in 1984. It could prove valuable to assess whether or not groundwater major-ion chemistry in this portion of the aquifer has changed over the past 35 years as a way of assessing the geochemical baseline of the Santa Margarita Groundwater Basin's pending Groundwater Sustainability Plan.

3.5 Attempts to Develop a Continuous Flow Record for Eagle Creek

Results of our attempts to develop a continuous record of flow at the Eagle Creek gage site are shown in **Figure 8** and **Figure 9**. Earlier drafts of this series of reports include similar records covering briefer periods.

We were not able to develop a rating curve that would sufficiently represent flow relative to changes in stage, despite extending the gaging record through October 29, 2020, after the first runoff-producing rain of the season. A reliable stage-discharge rating curve could not be established given the constant change in bed conditions as sand was continually transported even at flows of 0.3 to 0.4 cfs. Concurrently, twigs, branches and leaves would accumulate. As an example, stage rose progressively each day during August and October 2019 despite observed decreases in flows; the same pattern was recorded during January and February 2020. Branches and twigs transported during and following each storm would also intermittently obstruct flow at the gage, distorting the stage record. Review of other possible gaging sites near the mouth of the creek did not identify a pool with more favorable conditions or more-articulated control. We concluded that a daily flow record could not be responsibly developed from these data; rather the most useful flow record consisted of our direct flow measurements, concurrent observations, and the records of daily water-level fluctuations, In the future, if a gage is reinstalled, it may be desirable install a self-cleaning weir (such as a Cipoletti configuration) which would likely be helpful to obtain a usable record of flow. Both alternatives require digging into the bed and/or banks of the channel, which may not be a suitable activity at this site in the state park without great care.

The end of the dry season in October/November for WY18, WY19 and WY20 yielded observations consistent with the end of season measurements made by Kennedy-Jenks from WY02 to WY06 with flow in the 0.3 to 0.4 cfs range. The general slope of the hydrograph during WY20 was similar to the slope of the decrease in flow between March and September of WY02, the year with the best prior record.

From these data, it is possible to very generally bracket the amount of recharge which leaves the watershed as baseflow in Eagle Creek as being about 0.6 to 0.8 acre feet per day during the 6-month dry season, and about 1.2 to about 2.0 acre feet at between-storm winter baseflow, for an average of about 1.8 to about 2.8 acre feet per day under a typical range of dry- and wet-year conditions. If substantiated by future work, summer-plus-winter baseflows leaving the watershed would be equivalent to about 14.4 to 20.4 inches of rainfall, respectively, during dry and wet years over the 450-acre watershed, which (as noted above) has a mean annual rainfall of about 41 to 42 inches. We do not have sufficient data to estimate surface flows during storms, which would need to be added to complete an approximation of typical ranges for surface runoff. In this very sandy watershed, direct measurements or storm runoff would be needed.

3.6 Daily Water-Level Fluctuations and Effects of Summer 2020 Wildfires

The CZU Fire burned in the Santa Cruz Mountains from August 16 to September 22, 2020. This fire did not burn acreage in the watershed, but – as we show later in this section -- did affect flows in the Eagle Creek watershed, although the burn periphery was about one mile to the west beyond Highway 9.

On September 9, smoke from this and other fires as far north as Oregon and Washington obscured sunlight throughout the Bay and Monterey Bay areas in an event sharply noted to nearly all observers (see **Figure 11**). Drivers used headlights throughout the day, and lights were on continuously in nearly all residences. Effects gradually attenuated over the following week. The smoke blocked sunlight lowering the air temperature as well as evapotranspiration rates. The gage instrumentation showed (a) an increase in flow and (b) a decrease in the daily fluctuation range. The daily flow minima were suppressed on September 9 and for several subsequent days. Smoke appears to have raised flows intermittently by suppressing evapotranspiration (ET) for two- or three-weeks following September 9, and (more locally) for several days between August 18 and Sept. 8. A full range of daily flow fluctuations effectively re-established by the heat spell on October 1 through 3. Flows increased seasonally during the first two weeks in October with reduced ET as temperatures diminished and as leaf-drop proceeded, followed by the first runoff event of the season.

With several dozen homes within the watershed east of Graham Hill Road, the fire may also have affected local hydrographs by lowering return flows from domestic water usage while residents were evacuated[6]. There were no noticeable responses to these

[6] Beyond the Eagle Creek watershed, the fire caused substantial damage to the SLVWD's distribution system and led to large-scale releases from water tanks which appear as brief

events at the Eagle Creek gage; however, the slope of the stage hydrograph did flatten out, altering the decline characteristic of the summer months.

increases in the San Lorenzo River at Bigtrees gaging record (see **Figure 8**, **Figure 9**, and **Figure 10**), as well as post-fire reductions in evapotranspiration, especially within the burn periphery..

4. DISCUSSION

Given that there is very little runoff from this watershed, recharge is likely abundant during nearly all years. There is a legitimate question of where does this recharge go?

It is likely that there is a recharge connection with waters sourced in Eagle Creek topographic watershed flowing to the north/northwest toward other local springs within the Mt. Hermon community such as Ferndell, Manzanita, and (likely) Redwood Springs if so, it is probable that some this recharge emanates into the Mt. Hermon Quarry, and its network of quarry floor ponds. But the extent of the area contributing to northward flow is constrained by the location of visibly south-flowing springs not far from the northern limit of the topographic watershed. Similarly, Ellis' observations of monthly water levels (**Appendix A**) suggest that most of the topographic watershed does flow toward the southwest, consonant with the slope of the bedrock platform at the base of the Santa Margarita sandstone.

We noted no seeps or springs flowing into the Eagle Creek drainage from the southern side of the canyon which may indicate at least some groundwater movement to the south, toward the Powder Mill drainage. It is also probable that water is draining southwestward directly toward the San Lorenzo River. The eastward-steepening dips associated with the drag fold along the Ben Lomond fault would tend to direct flow toward lowermost Eagle Creek.[7] A reassessment of likely groundwater flow directions at the southern edge of the Eagle Creek catchment might be justified, particularly if a few more data points were available. The individual well borings in the Eagle Creek watershed could be reexamined with the more broad-brush regional conclusions (**Figure 6**). Such reassessment might commence with careful review of remote sensing photography, followed by on-site assessment of the slopes south of the Eagle Creek mouth. Best results might be obtained in May or June of a wetter-than-average year.

Further questions might include examining if recharge from the northeast Eagle Creek topographic watershed moves toward Bean Creek or toward the Lockwood Lane /Camp Evers or Carbonera Creek. Concurrently, does water in the southeast portion of

[7] Ellis (1984) calculated that more than half of the flow in Eagle Creek near its mouth was sourced in the southern half of the watershed. His estimate appears based in part on the visual estimate of 450 gallons per minute leaving the watershed at the River, and a total yield of 150 gpm in the spring area at the southward bend. While a more realistic estimate would be something less than half from the southern part of the basin, the absence of any visible springs or seeps is surprising and suggests that further searches are warranted.

the Eagle Creek basin move toward the lower Eagle Creek drainage or does it move southerly toward Powder Mill Creek?

Specific conductance during the drier 2018 and 2020 dry seasons are lower than those measured during the higher recharge year of 2019. One possibility is that with more recharge during a wet year that there may be more mixing of water on the flat near and south of Bear Mountain and the juvenile detention center. The sources of low conductivity water are likely overwhelmed by the influence of the larger aquifer which likely includes recharge into slightly saltier portions of Santa Margarita or through parts of the unroofed Lompico aquifer. Another not-dissimilar possibility is that a zone yielding less salts is found within the upper Santa Margarita in the north-central portion of the Eagle topographic watershed; such a zone might either be the results of post-depositional leaching, or perhaps may be attributable to ‘cleaner’ primary deposition of the Santa Margarita possibly associated with less matrix or fine-grained content. Such zones may be among the first areas filled with percolating rainwater during the winter season and may be a larger fraction of the drainage from the springs following drier winters. Additional measurements might address the nature and direction of aquifer recharge between the Santa Margarita and Lompico aquifers.

5. CONCLUSIONS

1. Subsurface drainage from the Eagle Creek watershed appears to flow in every direction[8] – mainly to Eagle Creek and Bean Creek (to which it is directed by geologic structure), and toward the Camp Evers and unnamed west-side tributaries of Carbonera Creek, as well as possibly toward Powder Mill Creek, and directly into the San Lorenzo River. The extent to which groundwater flows toward other streams likely varies from year to year, and is likely proportionately greatest following wet winters.

2. Seasonally, flows and specific conductance reflect the year's rainfall for the first two or three months following the winter rains, with flows being very similar from year to year in the later part of the summer.

3. Flows in late summer are an order of magnitude larger relative to baseflows measured in less-sandy areas of the County with similar rainfall, averaging in the low 40s inches per year. They appear to be somewhat greater even than from granitic springs and seeps draining Ben Lomond Mountain, where greater rainfall is typically measured.

4. As in other areas with the Santa Margarita Groundwater Basin (SMGB) assessed in this and earlier reports, no particular evidence was found for finer zones within the Santa Margarita which may perch recharge in the seepage zones above the regional groundwater table.

5. Specific conductance values of the mid-basin springs are presently identical to those we recorded from the same springs in 2020, suggesting minimal or no changes over the past 35 years. We recommend that the major-ion chemistry of the mid-basin spring cluster be analyzed to further ascertain the long-term stability of mineral chemistry in those portions of the Santa Margarita aquifer not appreciably disturbed by changes in pumping or land use. As such, measurements of low-flow hydrology of Eagle Creek can help document 'control' for changes elsewhere in the SMGB.

6. The location of the southern edge of the Santa Margarita Groundwater Basin relative to the Powder Mill Creek and Carbonera watersheds is poorly known, and merits further inquiry.

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[8] The technical term for flows in all directions from a dome-like feature is "quaquaversal drainage; it is unusual.

7. Further refinement of the search for springs and establishing flow directions should occur during a year of average or wetter conditions. It should proceed through (a) exploration for springs, seeps or hydrophilic vegetation along the contacts that we have identified, (b) using remote sensing (perhaps false-color infrared aerial photography) to identify areas of intense or seasonally-prolonged water-using vegetation, (c) using various age-dating technologies now commonly applied in coastal California to identify whether the entire Santa Margarita and Lompico aquifer unit in and just north of the Eagle Creek watershed discharges as an unmixed unit or has areas of multi-year storage, and possibly (d) inferring different sources from major-ion or trace-element distributions in wells and springs. These non-intrusive approaches seem appropriate since the majority of the watershed is owned by California State Parks.

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TABLES

Table 1. Station Observer Log, Eagle Creek,
County of Santa Cruz, California, water year 2018 - 2020 (partial)

Site Conditions				*Streamflow*				*Water Quality Observations*				*High-Water Marks*		*Remarks*
Date/Time	Observer(s)	Stage (staff plate)	Hydrograph	Measured Flow	Estimated Flow	Instrument Used	Estimated Accuracy	Water Temperature	Specific Conductance at field temp.	Specific Conductance at 25C	Additional sampling?	Estimated stage at staff plate	Inferred dates?	
(mm/dd/yr)		*(feet)*	*(R/F/S/B)*	*(cfs)*	*(cfs)*	*(AA/PY)*	*(e/g/f/p)*	*(oC)*	*(µmhos/cm)*	*(at 25 oC)*	*(Qbed, etc.)*	*(feet)*	*(mm/dd/yr)*	
Eagle Creek at Graham Hill Road														
4/30/19 10:30	jp	-	B	0.12	-	PY	g	12.6	99	130	-	-	-	Water from road runoff comes in at this location. High water-mark may be due to road runoff.
7/10/19 8:16	jp	-	B	0.04	-	visual est.	f	13.4	105	134	-	-	-	No notes.
9/24/19 10:00	jp	-	B	-	0.01	visual est.	f	13.8	139	177	-	-	-	Visual estimate of flow 3 to 4 gpm. Flow is leaking under the culvert and not flowing through the pipe.
4/22/20 13:44	jp	-	B	0.04	-	PY	g	12.6	106	132	-	approx. 0.5 ft above water level	-	High-water mark may be largely due to road runoff. Noticed 3-4 cm mudstone clasts in the channel.
5/28/20 12:27	jp, bh		B	0.03	-	PY	f	14.8	109	135	-	-	-	Inventory Tsm springs in Scotts Valley, Felton today. Headwaters of Eagle Cr about (~1,000 ft US) is flowing about 0.5 gpm (0.001 cfs).
10/30/20 12:15	jp		B		0.001 (0.4 gpm)	visual est.	f	9.8	122	171	-	-	-	Very low flow 0.25 to 0.5 gpm.
Eagle Cr at Eagle Creek Trail Crossing														
4/23/20 14:00	jp	-	B	0.37	-	PY	g	14.1	82	103	-	approx. 0.5 above water level	-	Measured flow approximately 100 feet upstream of the Eagle Creek trail crossing walking from the upper watershed to the lower.
Accumulation of flow from seeps on right bank observed while walking down to the confluence														
4/29/19 14:00	jp	-	B	-	-	-	-	-	-	-	-	-	-	Approximately 30+ gpm were noticed while walking from the upper watershed
4/23/20 14:30	jp	-	B	0.09 (41.25 gpm)	-	bkt	-	13.9	50	64	-	-	-	Median SCT is reported. SCT at 25C values are between 68 uS and 59.1 uS.
Eagle Creek gage 150 feet upstream of the San Lorenzo River														
10/1/18 15:30	jp	-	B	0.43	-	PY	g	14.8	59	74	-	-	-	Lighter colored fine sand substrate with larger granitic and schist clasts.
11/20/18 14:10	jp	-	B	0.33	-	PY	g	10.2	58	81	-	-	-	Flow appears to be about same as previous visit. Rain forecast soon.
4/29/19 14:00	jp	-	B	1.28	-	PY	g	12.7	93	120	-	0.55 ft. above water level	WY18	Walked down from Graham Hill Rd - multiple points of in-flow (10 gpm) to the creek observed.
6/14/19 14:15	jp	6.45	B	0.83	-	PY	g/e	-	-	-	-	-	-	**Installed gage** downstream of foot bridge. SCT meter not working.
6/19/19 7:59	jp	6.45	B	-	-	-	-	13.8	90	115	Nitrate	-	-	Sampled nitrate at 7:59.
9/24/19 11:04	jp	6.45	B	0.40	-	PY	g/e	13.7	67	85	-	-	-	Measured SCT at gage and on San Lorenzo River upstream of Eagle Creek. Stage dropped from 6.53 to 6.45 after clearing debris from gaged pool.
4/23/20 15:05	jp	6.46	B	0.92	-	PY	g	13.7	101	128	-	0.56 ft. above water level	WY19	Measured high-water cross section at the gage and measurement section. Unable to download sensor. Stage dropped from 6.62 to 6.46 after clearing debris from gaged pool.
7/14/20 8:55	jp	6.37	B	-	0.30	vis. Est	f	13.6	63	93	Nitrate	-	-	Sampled nitrate at (WY19-2, sample number). Light turbidity, no debris downstream of gage causing back-water.
10/30/20 13:00	jp	6.37	B	0.40	-	PY	g	10.7	57	80	-	-	-	**Removed gage** after measuring flow and allowing water levels to stabilized after clearing debris. Eagle Cr at Graham Hill Road had very low flow 0.5 to 0.25 gpm

Stage: Water level observed at outside staff plate
Observers: (jp) Jason Parke, (bh) Barry Hecht
Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), baseflow (B), or uncertain (U).
Instrument: If measured, typically made using a standard (AA) or pygmy (PY) bucket-wheel ("Price-type") current meter. Extremely low flows are measured with a bucket+stop watch (B) If estimated, from rating curve (R) or visual (V).
Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy given
High-water mark (HWM): Measured or estimated at location of the staff plate
Specific conductance: Measured in micromhos/cm in field; then adjusted to 25degC by equation (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance
Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, Nutr = nutrients; other symbols as appropriate

Spring Discharges - Scotts Valley, CA

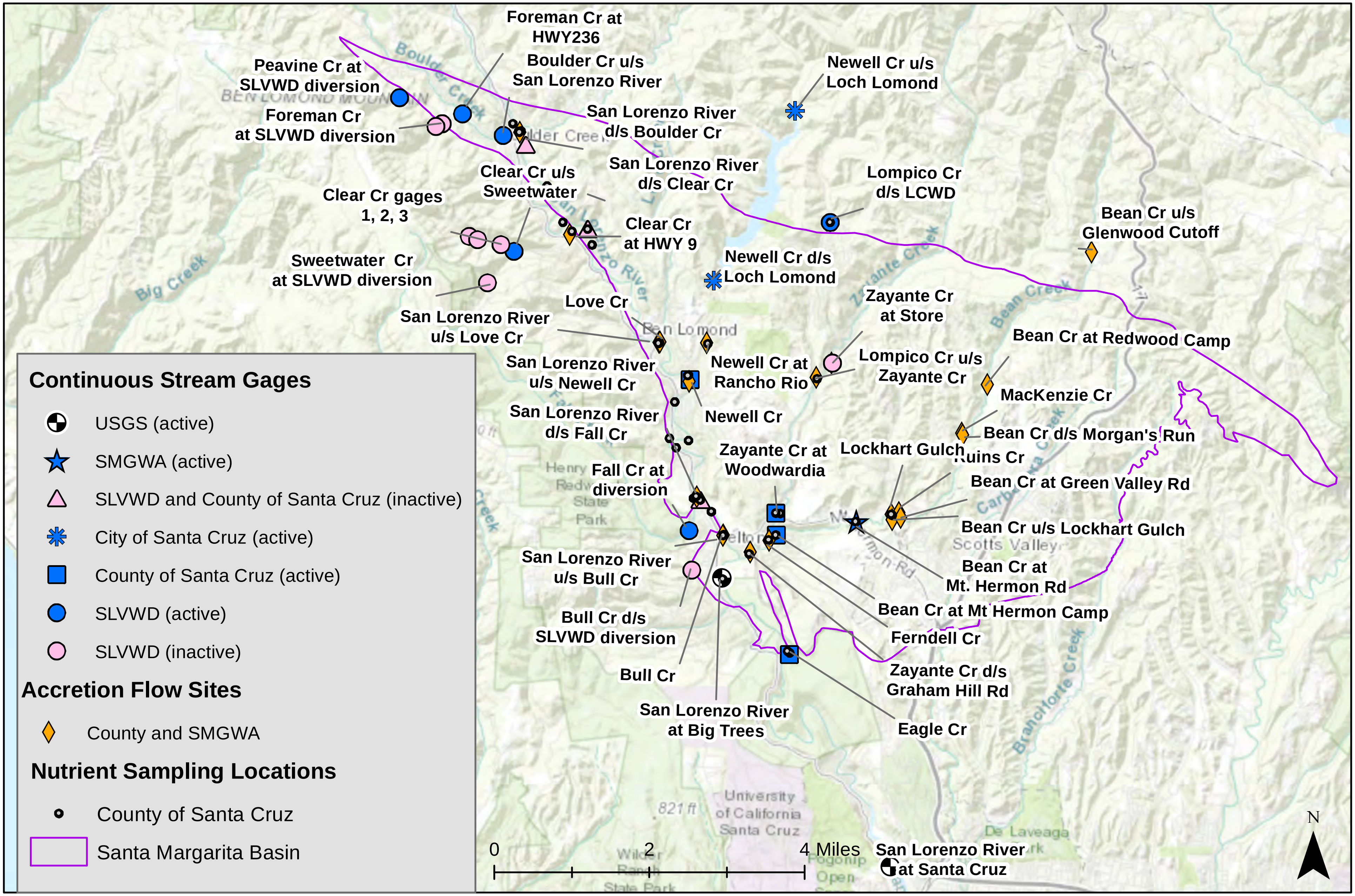
Eagle Creek		
DATE	**Discharge (cfs)**	**Discharge (gpm)**
3/28/2001	1.81	812.38
10/16/2001	0.33	148.11
3/21/2002	0.84	377.02
9/25/2002	0.33	148.11
4/7/2003	0.66	296.23
10/16/2003	0.33	148.11
3/24/2004	0.66	296.23
11/15/2004	0.42	188.51
4/20/2005	0.66	296.23
10/25/2005	0.35	157.99

Balance Hydrologics

Table 2. **Measurements of Eagle Creek near mouth cited in Kennedy/Jenks (2015)**

Source: Kennedy/Jenks, June 24, 2015

FIGURES



Balance Hydrologics

Figure 1. Sites with summer flow and specific conductance measurements 2019, San Lorenzo Valley, Santa Cruz County, California
See location table for greater detail.

Source: Balance Hydrologics

U:\gis\Projects\218237 Santa Margarita gaging locations.mxd

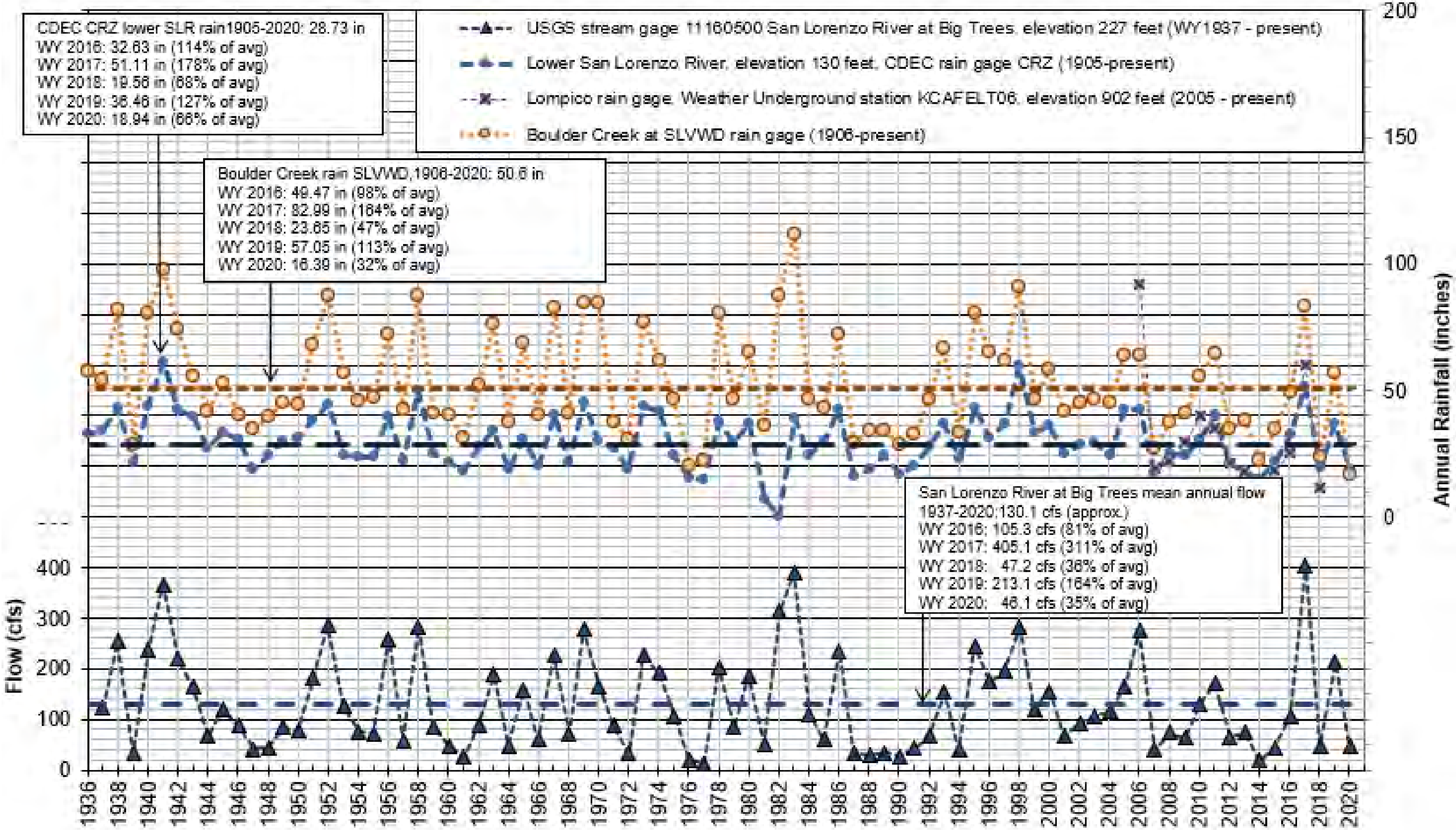


Figure 2. **Comparison of historic annual rainfall in San Lorenzo Basin to annual streamflow at USGS Gage 11160500, San Lorenzo River at Big Trees, Santa Cruz County, CA**

Source: 219018 Rainfall and USGS at Big Trees and other WY19

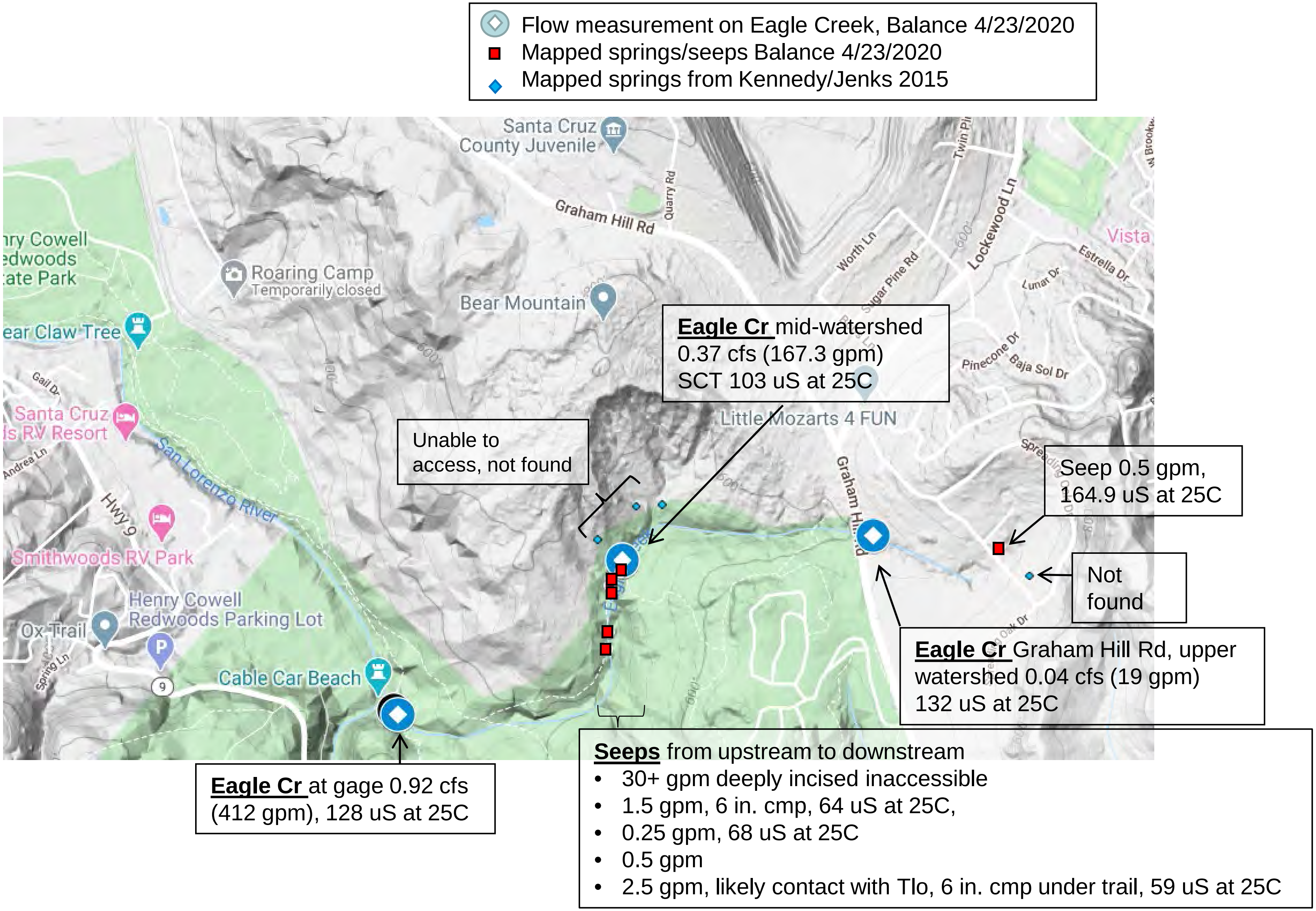
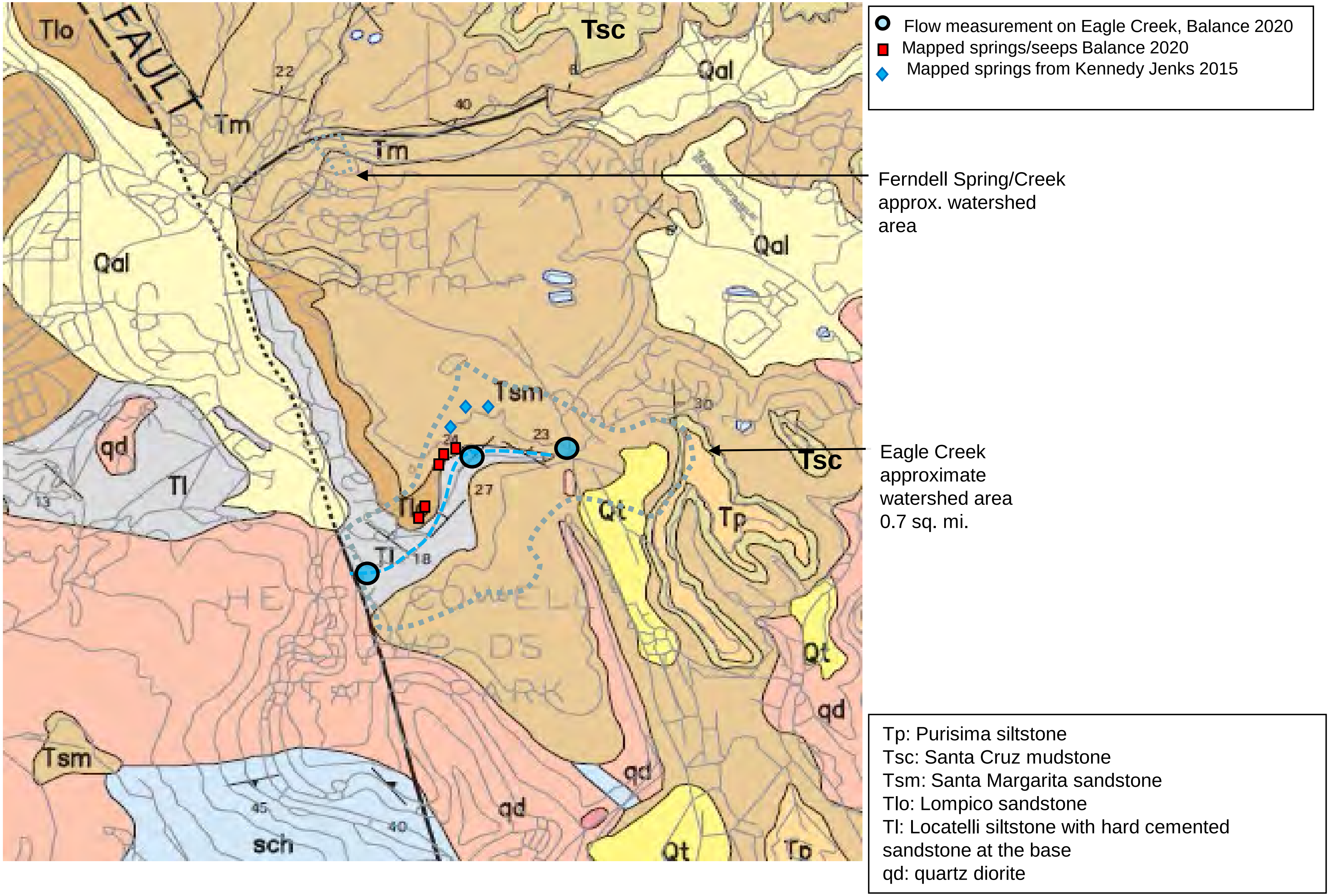


Figure 3. Eagle Creek synoptic flow measurements and seep inventory 4/23/2020, San Lorenzo Valley Santa Cruz County, CA.

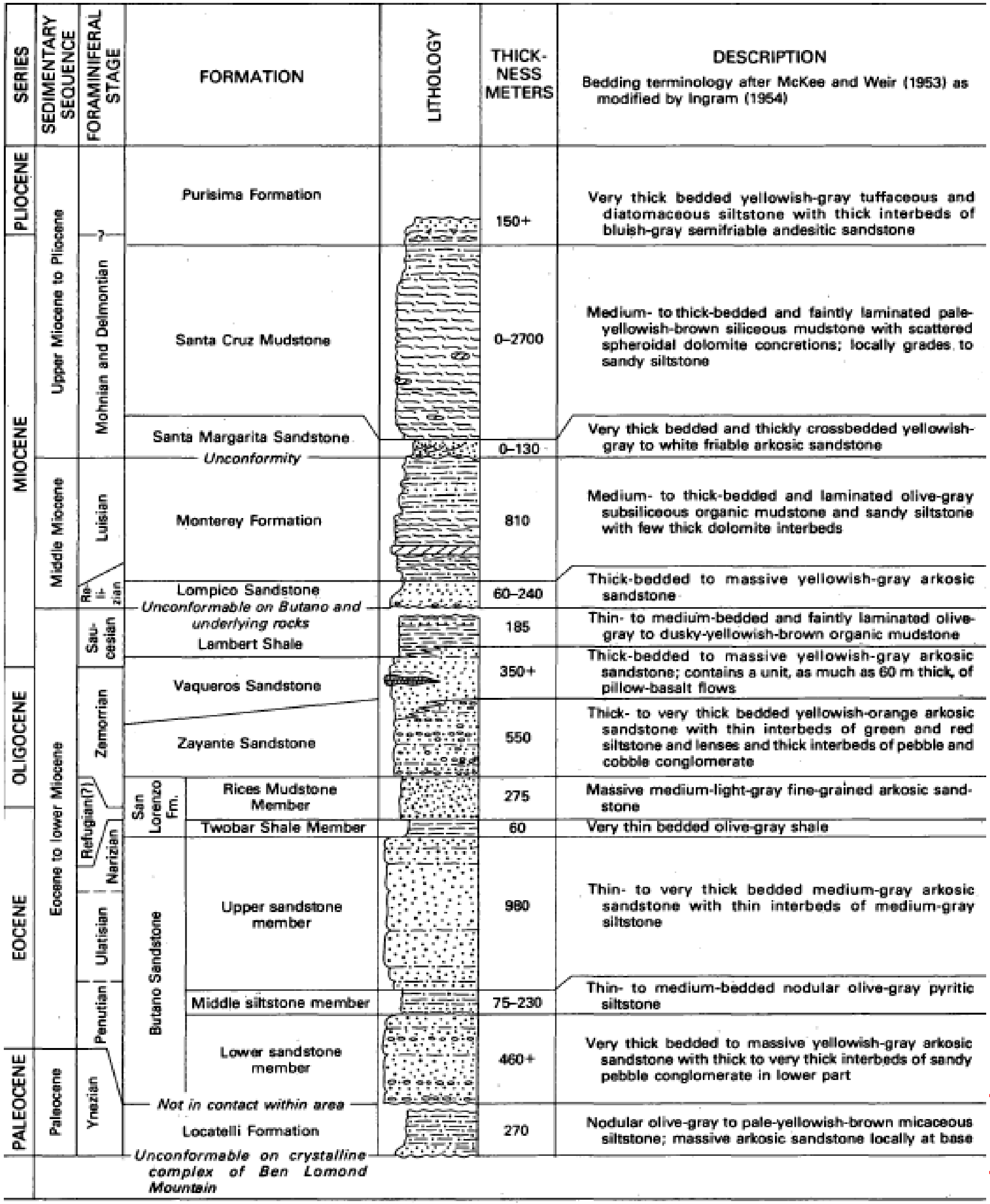
Source: Basemap: Google Maps



Balance Hydrologics

Figure 4. **Eagle Creek geology, springs/seeps and flow measurement locations, San Lorenzo Valley Santa Cruz County, CA.**

Source: Brabb, 1989, digitized 1997



Santa Margarita sandstone (Tsm)

In the Eagle Creek watershed the Monterey mudstone (Tm) formation has been eroded away which allows the Santa Margarita (Tsm) sandstone and the Lompico (Tlo) sandstone to be in contact with each other.

Lompico sandstone (Tlo)

Locatelli (Tl) siltstone underlies Lompico sandstone in the Eagle Cr watershed

Balance Hydrologics

Figure 5. **Composite stratigraphic section of Tertiary rocks of the central Santa Cruz Mountains northeast of San Gregorio fault.**

Source: Clark J.C. and Reitman O., 1981 Stratigraphy, Paleontology, and Geology Central Santa Cruz Mountains California Coast Ranges, Geological Survey professional paper; 1168. Page 8, Figure 2; Composite stratigraphic section of Tertiary rocks of the central Santa Cruz Mountains northeast of San Gregorio fault.

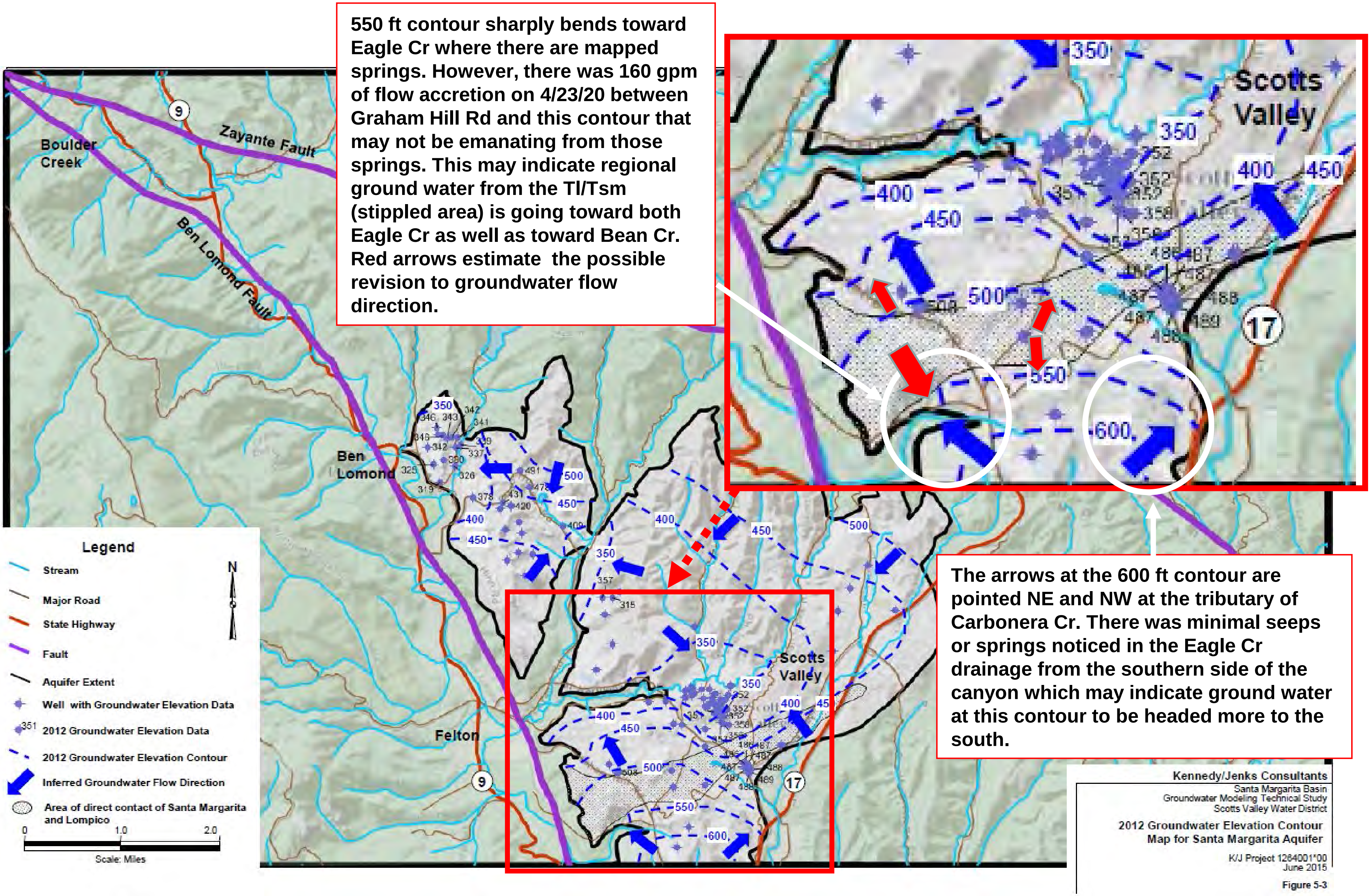


Figure 6. 2012 Groundwater elevation contour map for Santa Margarita aquifer

Source: Kennedy/Jenks, June 24 2015.

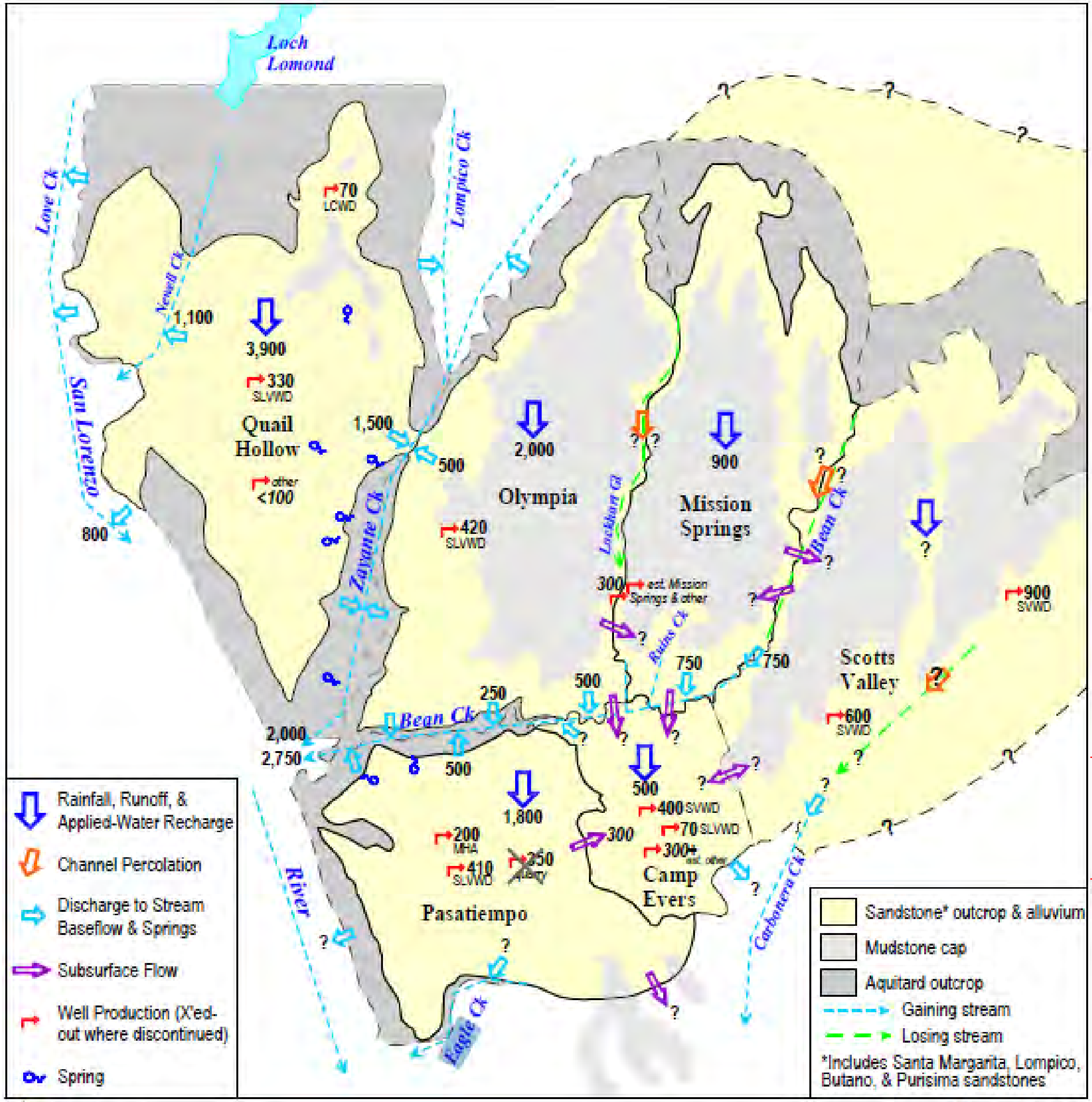


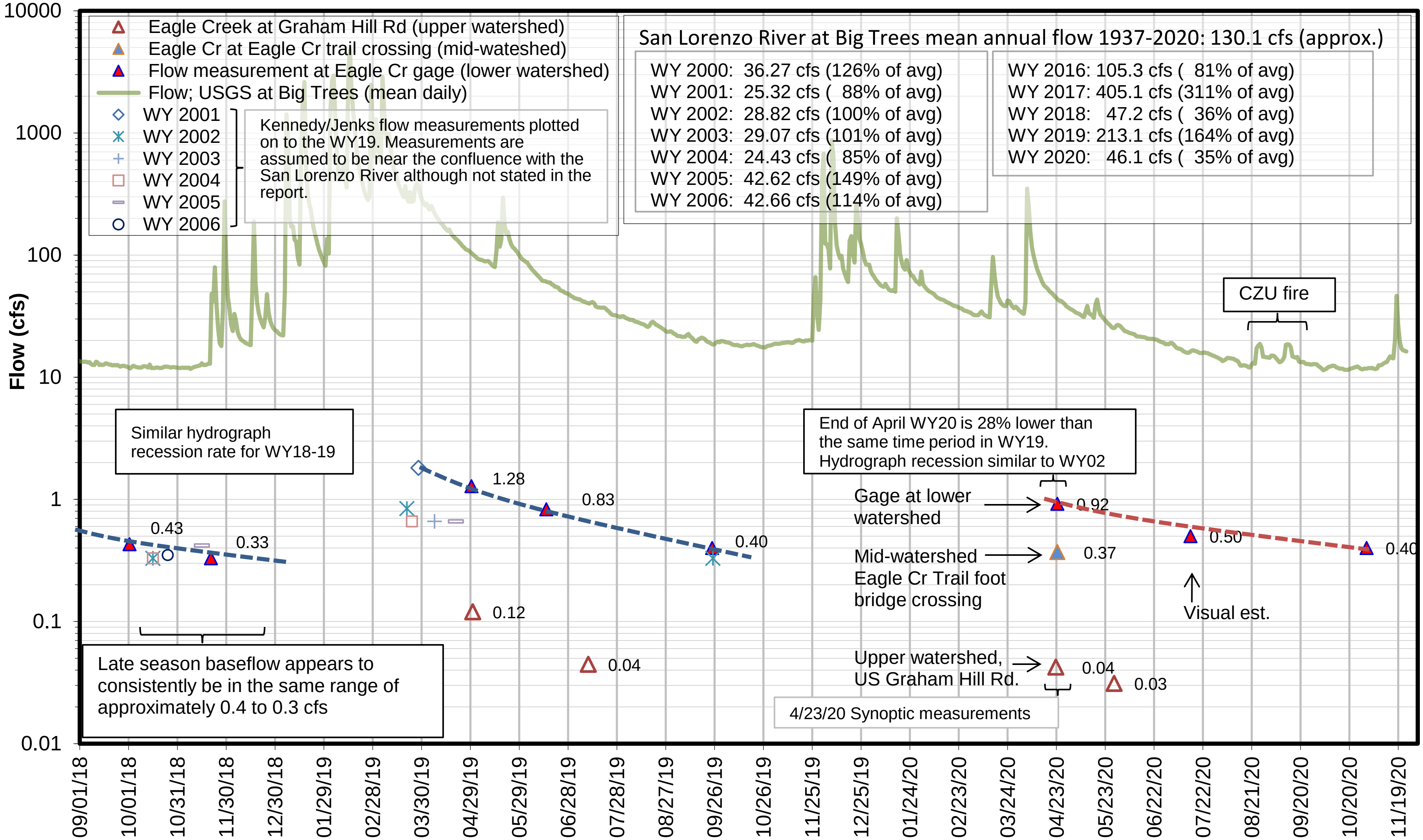
Figure 5-35
Estimated Subarea Groundwater Budgets
Representative of Recent Average Conditions
(AF/yr)

All values are highly approximate except metered pumping by SLVWD, SVWD, and MHA.

2005 N.M. Johnson report shows subsurface flow and recharge headed toward Eagle Cr. The arrow east of Eagle Creek shows inferred outflow from the ridge east of the headwaters of Eagle Creek toward the unnamed tributary of Carbonera Cr

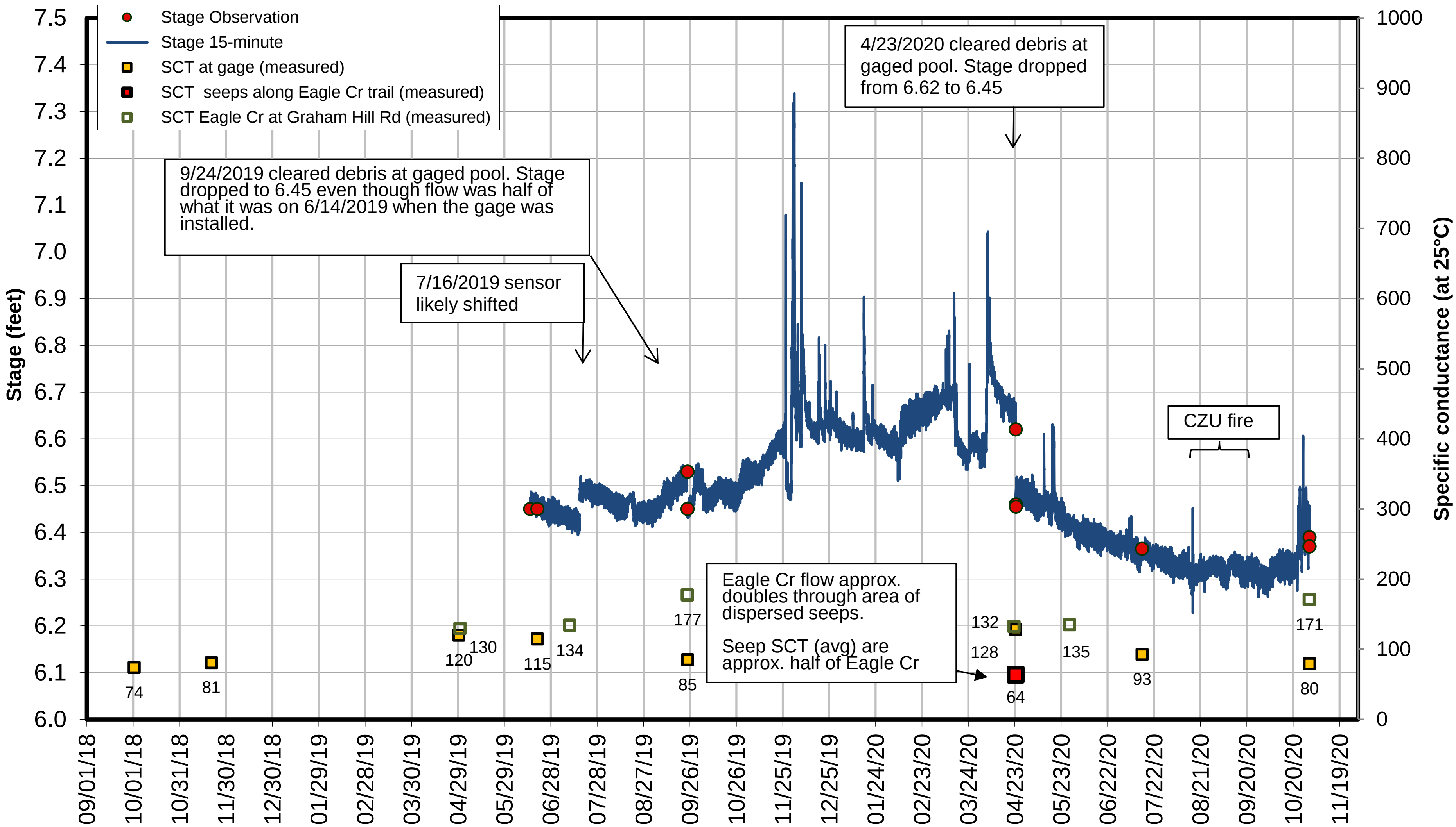
Balance Hydrologics

Figure 7. Estimated subarea groundwater budgets, Johnson N.M., 2005



Balance Hydrologics

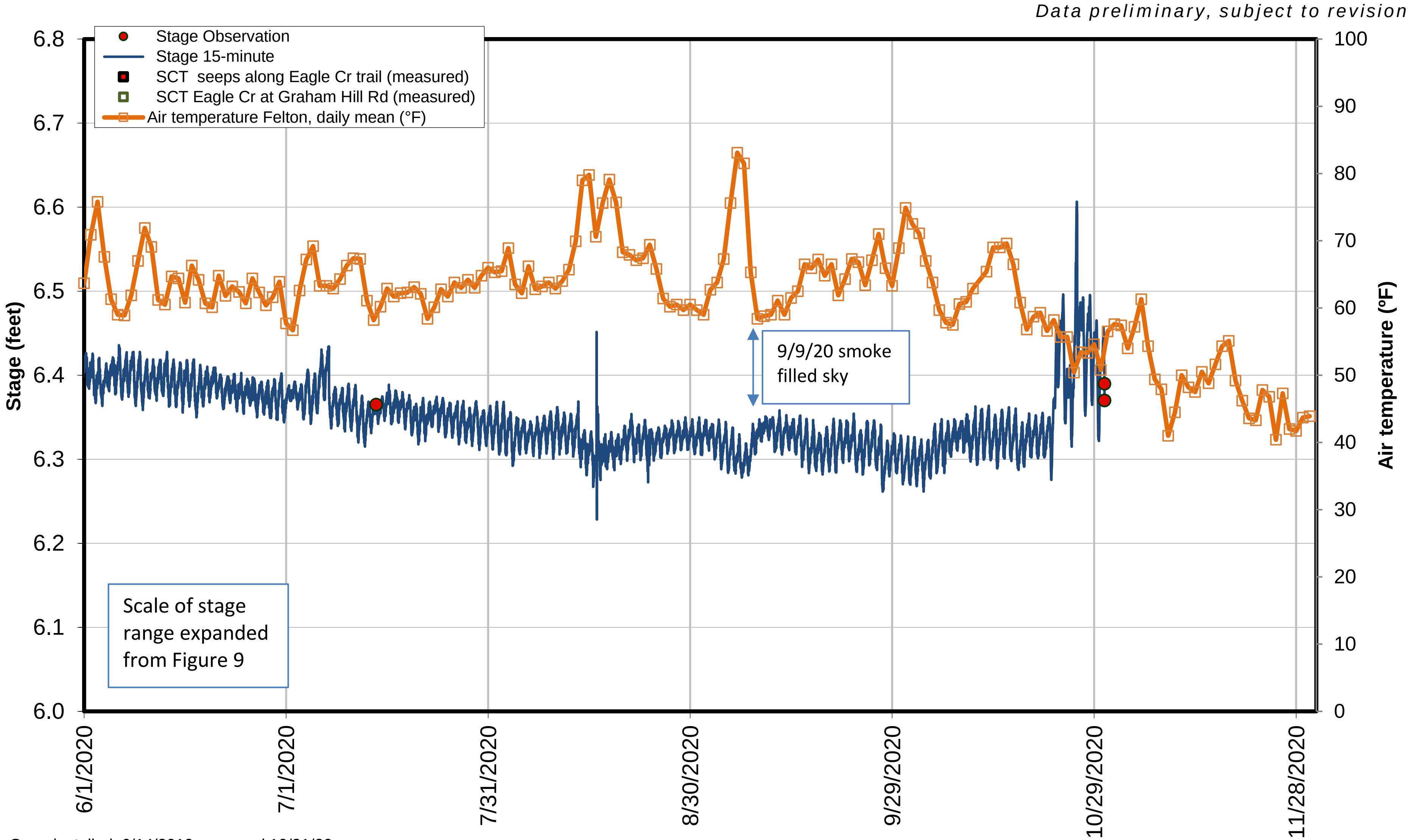
Figure 8: **Flow: Eagle Creek flow measurements, Santa Cruz County, California, water years 2018-2020 (partial).**
15-min flow record is not available as of the publication of this data due to frequent debris jams and constant sand transport in the gaged reach.



Gage installed 6/14/2019, removed 10/30/20

Balance Hydrologics

Figure 9: Stage and specific conductance: Eagle Creek, Santa Cruz County, California, water years 2018 to 2020 (partial).



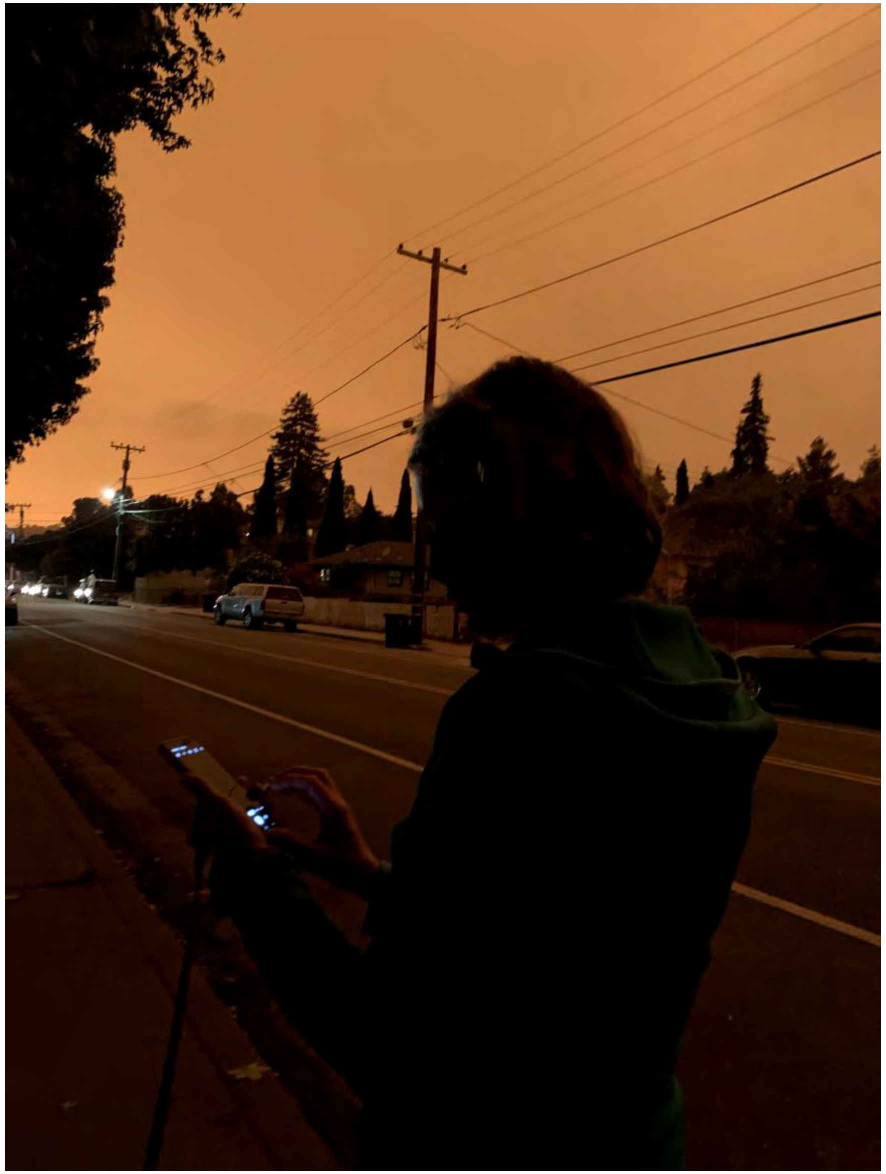
Gage installed 6/14/2019, removed 10/31/20

Balance Hydrologics

Figure 10: **Stage and mean daily air temperature: Eagle Creek, Santa Cruz County, California, summer 2020**

Air temperature: wunderground.com, station: KCAFELTO10

Cars are using headlights and streetlights are on at 4:30 pm. Sunset is at 7:30 pm.



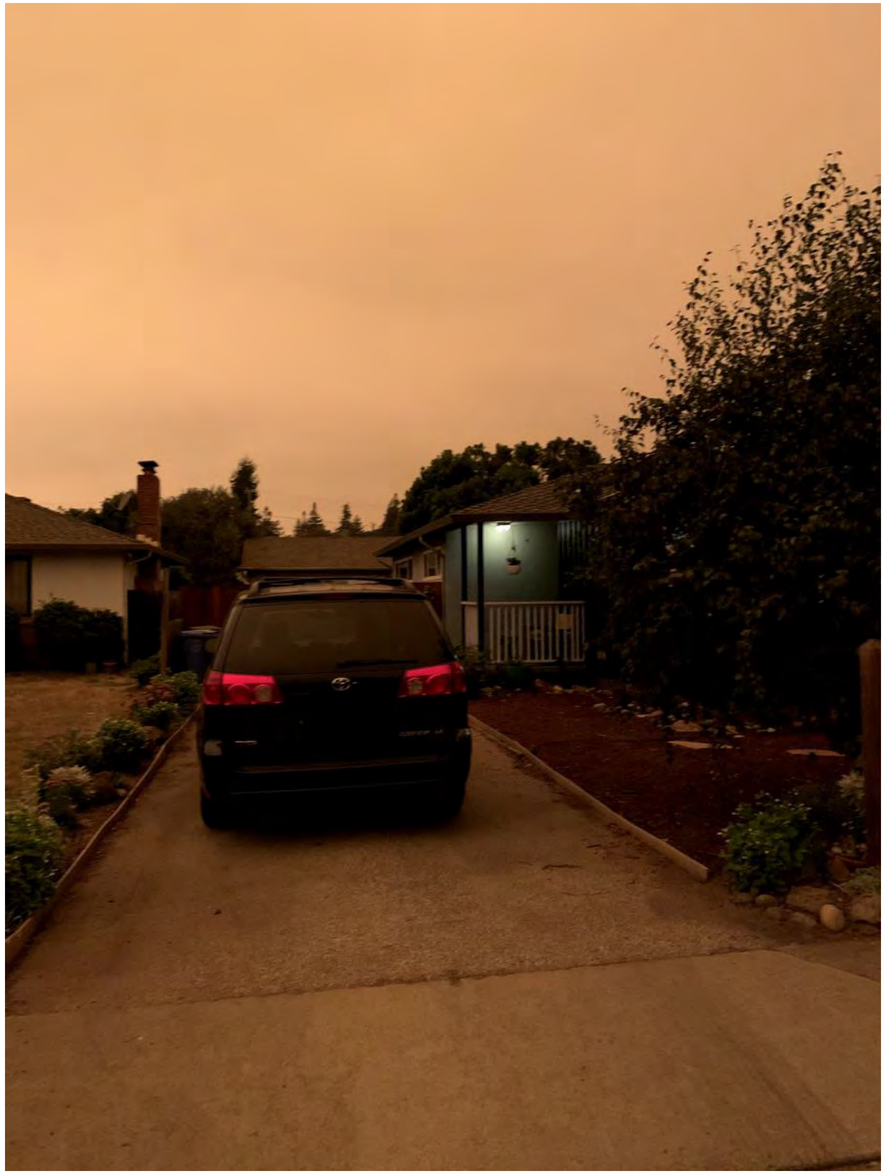


Figure 11:
September 9, 2020 Smoke obscured skies due to multiple fires in Northern California. Photo in Santa Cruz near Emeline Ave. approximately 3 miles SE of Eagle Cr.

Balance Hydrologics, Inc.

Photo by Jason Parke

APPENDICES

APPENDIX A

Ellis, 1984?

Groundwater resources of the Felton Effluent Disposal Site investigations: Valleywide waster project EIR. Scanned manuscript as received from John Ricker, who retrieved this document from personal archives.

DRAFT

Subject to Revision

VALLEYWIDE WASTEWATER PROJECT E.I.R.

Felton Effluent Disposal Site Investigations

GROUNDWATER RESOURCES

CONTENTS

TABLES

FIGURES

VALLEYWIDE WASTEWATER PROJECT E.I.R.
Felton Effluent Disposal Site Investigations

GROUNDWATER RESOURCES

INTRODUCTION

A hydrogeologic investigation was carried out to determine groundwater occurrence and behavior related to the Felton disposal site, and the probable groundwater response to prospective disposal operations. Included in this assessment were aquifer location and dimensions, and groundwater occurrence, movement, recharge and discharge, quality, and other related factors. Data findings were interpreted and evaluated to determine these parameters for the pertinent groundwater resources underlying the disposal site and also in contiguous areas.

As discussed in detail elsewhere in this report, the project plan involves the spraying of treated effluent on the ground surface at rates much less than the absorptive capacity of the surface soils. The geologic formation underlying the site must be capable of transmitting the effluent downward and dispersing it in ways which will not adversely affect area water resources.

The Felton site under consideration for disposal is underlain by the Santa Margarita Sandstone Formation, except in the western and southwestern fringes, where erosion has removed it and underlying formations are exposed. Elsewhere, these older formations lie beneath the Santa Margarita Sandstone at depths up to about 300 feet, or so. The surface geology of the site area is described in the foregoing report section, "Geology of the Felton Disposal Site".

The Santa Margarita Formation is the principal aquifer in the area to the northeast of the site, including Scotts Valley. It is this geologic unit which would receive and transmit the treated effluent from the proposed disposal project. In order to define the limits and character of this formation aquifer and the groundwater contained within it, a subsurface exploration program was implemented consisting of drilling a series of test-hole/piezometers, as described below.

EXPLORATION PROGRAM

Subsurface conditions were probed by the drilling of 7 bores at sites selected to provide the maximum data obtainable. Test hole locations are shown on the hydrogeologic maps, Figures ___, ___, and ___. Drilling was by the rotary-mud method; bore size was approximately 8 inches in diameter. Each hole completely penetrated the Santa Margarita Sandstone and encountered the underlying formations which were penetrated 5 to 10 feet. Two-inch diameter PVC casing was installed in the holes, slot-perforated in the lower 80 feet of the Santa Margarita Formation. A coarse sand mix was placed as a pack in the annular space between the bore wall and the casing up to a depth of 50 feet from the surface, and a cement slurry seal was placed in the uppermost 50 feet of the annular space. Drill cutting samples were taken at 10-foot intervals in each test hole and identified. Because of the massive nature and uniformity of the Santa Margarita Formation, such samples were closely similar, consisting of well-sorted medium-to-fine sand, with occasional coarser streaks. Therefore, geologic logs of the holes are redundant for this material.

The depths to the bottom of the Santa Margarita Sandstone (equivalent to its thickness) and the top of the underlying bedrock are given for the test holes in Table ___, with corresponding elevations.

An attempt was made to flush the holes with compressed air to clean out drilling mud and cuttings from bore walls and the sand pack. Due to the water table depths, this operation was only partially successful since air-line submergence was not adequate to obtain a proper air lift. Nevertheless, it was found that aquifer groundwater entered the casings freely, and stabilization of water levels in the pipes was virtually immediate.

TABLE

Felton Disposal Site
TEST HOLE EXPLORATION

BOTTOM OF SANTA MARGARITA SANDSTONE
(Top of underlying older formations

Test Hole	Ground Elevation [1]	Bottom of Santa Margarita Depth	Bottom of Santa Margarita Elev. [1]	Bedrock
1	726.0	93	633.0	Blue shale
2	821.5	290	531.5	"
3	706.0	207	499.0	Tan clayey siltstone
4	735.0	175	560.0	Blue shale
5	779.0	292	487.0	"
6	658.5	194	464.5	"
7	688.5	168	520.5	"

[1] Rounded to nearest 0.5 foot.

GROUNDWATER CONDITIONS

The older formations underlying the Felton disposal site crop out at the ground surface around the edge of the Santa Margarita Sandstone immediately north of the site, in the western portion of the site property, and south of the site along Eagle Creek. These exposures are indicated on the geologic map in the geology section of this report, and also on the hydrogeologic maps, Figures __, __ and __. These older formations consist of the Locatelli Siltstone, the Lompico Sandstone, and the Monterey Shale. Some of these contain variable groundwater, and supply wells from more permeable beds stratified within them, however, relatively impervious strata predominate and prevent appreciable vertical groundwater movement within these formations. Shale and siltstone were encountered in the test holes drilled for this project investigation, indicating that the buried bedrock surface underneath the site does not transmit any significant water downward from the overlying Santa Margarita Sandstone aquifer. Outcroppings of bedrock in the vicinity confirm this conclusion. Therefore, groundwater moves within the Santa Margarita on the bedrock to points of surface discharge, or to contiguous aquifer areas.

The buried surface of the older formations, or bedrock, is shown by elevation contours on Figure ___, as interpreted from test hole and outcrop data. The essential configuration is a low or valley in the central area which slopes southerly, a feature of the pre-Santa Margarita surface drainage pattern. This closely coincides with the water table trough existing in the Santa Margarita Formation discussed later, and appears to control groundwater movement accordingly. A difference in bedrock elevation of about 240 feet exists in the relatively short distance between the San Lorenzo Valley Water District's wells at the County Probation Center just northeast of the site. In the absence of more detail on the bedrock surface, this interval is shown as a uniform steep slope on the contour map.

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This difference could be caused by a fault, probably of the thrust type, however, there is no other evidence of faulting known in the area and none has been found in previous geologic studies. If faulting runs through the Felton site, it is not evident in any of the data available and is assumed compatible with the hydrologic analyses of this investigation.

The Santa Margarita Sandstone, henceforth referred to as the "aquifer", is discussed in the following sections as to hydrogeologic conditions and dynamics.

Occurrence

The Santa Margarita Sandstone aquifer ranges in thickness here from somewhat over 300 feet in more central areas to a feather edge around the north, west and southern fringes where it wedges out over the underlying older formations. Hydrogeologic Cross-sections A-A' and B-B' (Figures __ and __) illustrate aquifer thickness variations over the area.

As also illustrated by the referenced cross-sections, groundwater saturates the lower depths of the aquifer over much of its extent here, however, the saturated interval is commonly thin and, in the northern part of the site, a large area contains no significant saturation (water table). Depth to the water table varied from about 94 to 277 feet below the ground surface in the test hole/piezometers drilled elsewhere on the site. Two measurements made two weeks apart showed no significant change in level. Table ___ gives water table depths and elevations gaged.

Saturated aquifer thickness is shown by contours on the isopach map, Figure ___. It is seen that maximum saturation occurs in the east-central part of the site, but amounts to only slightly over 60 feet. The localized thickening in the vicinity of test hole 4 seems to be a recharge anomaly, as discussed below.

Felton Disposal Site

WATER TABLE MEASUREMENTS (feet) in Santa Margarita Sandstone

Test Hole	Measuring Point[1] Height above surface[2]	Measuring Point[1] Elev.	Water Table Below M.P.	Water Table Below surface	Water Table Elev.	Change
1 [4]	3.0	728.8	— [3]	—	—	
[5]	1.0	726.8	— [3]	—	—	
2	3.0	824.3	276.5	273.5	547.8	
	0.5	821.8	275.1	274.6	546.7	-1.1
3	1.5	707.5	156.0	154.5	551.5	
	0.5	706.5	156.2	155.7	550.3	-1.2
4	3.5	738.6	127.2	123.7	611.4	
	0.5	735.6	124.7	124.2	610.9	-0.5
5	3.5	782.3	247.7	244.2	534.6	
	1.0	779.8	245.5	244.5	534.3	-0.3
6	2.0	659.2	96.4	94.4	562.8	
	1.0	658.2	95.0	94.0	563.2	+0.4
7	3.0	691.6	148.0	145.0	543.6	
	0.5	689.1	144.3	143.8	544.8	+1.2

[1] Top of casing
[2] Rounded to nearest 0.5 foot; casing cut off between measurements
[3] No significant saturation in this area.
[4] Measurement March 8, 1984 — all holes.
[5] Measurement March 22, 1984 - all holes.

The configuration of the water table (or potentiometric surface) beneath the site is depicted on Figure ___ by elevation contours. The principal feature is the central trough which slopes southward bounded by roughly parallel groundwater ridges. The slopes on the water table, or gradients, control the directions of groundwater flow. The water table in the vicinity of test hole 4 indicates that a local source of concentrated recharge exists along the topographic valley or draw in this area, which builds the water table up anomalously high in relation to adjacent areas. This is not thought to be an important aspect of the groundwater regimen here.

The configuration of the water table is illustrated on Cross-Sections A-A' and B-B'.

Hydrogeologic factors controlling the aquifer's capacity to transmit and store water were estimated based on determinations made from a number of well pumping tests for the Santa Margarita Sandstone in nearby areas. Such factors relate to the groundwater regimen and are necessary to the groundwater flow model analysis of groundwater behavior under project conditions. Based on a consensus of previous test results judged most applicable to the Felton disposal site, permeability (or hydraulic conductivity) is estimated to be between 50 and 100 gallons per day per foot. Specific yield, the measure of aquifer capacity to store drainable water, is estimated at 20 percent.

Groundwater Movement

The water table contours shown on Figure ___ indicate both the directions of groundwater movement and flow gradients. Directions of flow, shown by map arrows, converge into two basic patterns; a) into the large trough and thence southward toward Eagle Creek, and b) northward across Graham Hill Road. The primary movement is into and along the trough southward.

Recharge and Discharge

Recharge of groundwater in the aquifer beneath the site is derived solely from downward percolation of rainfall absorbed essentially where it falls on the ground surface. As discussed in another report section, local average rainfall is estimated at about 42 inches per year. The maximum which might occur an average of once in 100 years is estimated at 80 inches, although more than that fell during the exceedingly wet winter of 1982-83. The highly absorptive nature of the Santa Margarita Formation surface, confirmed by special project infiltration tests, precludes significant runoff of rainfall. It is considered that, even in unusually wet years, the intensity of rainfall is within the absorptive capacity of the ground surface, except in the few roadways and bare erosion channels where the surface conveys runoff, at least for a limited distance, before being absorbed. Overall, it can be assumed that essentially all rain seeps into the soil zone, a portion is consumed by root zone evapo-transpiration, and the remainder percolates to groundwater.

Discharge of groundwater from the site area occurs through subsurface flow, chiefly southward to Eagle Creek, and to a lesser extent northward across Graham Hill Road. Discharge to Eagle Creek is through several large springs and assorted seepages; to the north, subflow moves within the aquifer to contiguous areas north and northeastward of the site. Along the north side of Eagle Creek, at least three substantial springs plus various seeps, some seasonal, issue within a stretch of 1000 feet or more (see Figure___). Groundwater thus discharges from the lower part of the aquifer at and above the bedrock contact. The noted springs are presently flowing at individual estimated rates of 20 to 50 gallons per minute. All aquifer discharge along this front may be on the order of 150 gpm.

Groundwater Quality

Existing groundwater quality is relatively good and acceptable for domestic use. In order to obtain a representative composite sampling of site groundwater, a sample was collected from the principal spring outflow point just above Eagle Creek. Chemical properties determined by laboratory analysis are listed in Table ___.

Area Groundwater Users

There are no water wells on the project site property and there have been no previous drillings. The most proximate wells to the site are those of the San Lorenzo Valley Water District at the County Probation Center across Graham Hill Road (see locations on Figure ___). The so-called "Old Probation" well, just northwest of the Center, produces exclusively from bedrock aquifers with only some 30 feet of the Santa Margarita Formation shown at the surface in the well log. The "New Probation" well, just southeast of the Center, penetrates 280 feet of Santa Margarita, then older formations to a depth of 395 feet where the well encountered granitic rock. Only the lowermost 15 feet of the Santa Margarita Sandstone is open to the well by casing perforations, from 265 to 280 feet, due to the deep static water level encountered and the deeper pumping water level when the well is in operation. The pumping level is currently running in the 250-foot range, although in the past it has been recorded as deep as 281 feet. Therefore, it is obvious that most of the yield from this well is from deeper aquifer sources and to only a minor extent from the Santa Margarita Sandstone aquifer.

To the northeast, within some 400 feet of the site, there are two residential water wells serving several houses from the Santa Margarita aquifer (see locations on Figure ___). They produce at the rate of only a few gallons per minute and annually yield no more than an acre-foot or so (350,000 gallons). Other residences in the vicinity are served by the San Lorenzo District.

TABLE ____

CHEMICAL ANALYSIS
of
SPRING DISCHARGE FROM PROJECT SITE AREA
TO EAGLE CREEK

(Collected March 27, 1984)

Analysis	Results (mg/L)
pH (no unit)	7.24
Specific Conductance (uhmo/cm)	70
Total Dissolved Solids	45
Total Hardness as $CaCO_3$	12
Calcium	4.0
Magnesium	0.46
Iron	0.03
Sodium	9.5
Potassium	0.91
Phosphate	0.10
Sulfide	0.05
Bicarbonate as $CaCO_3$	21
Carbonate as $CaCO_3$	0
Chloride	8.5
Nitrate as NO_3	0.18
Nitrate as N	0.04
Ammonia Nitrogen	0.08
Organic Nitrogen	0.14
Sulfate	0.8

It should be noted that all homes in this area use septic tank sewage disposal systems and, due to the clustered development there, at least a dozen such systems probably exist within the close proximity of these wells.

Farther to the northeast, about one-forth mile from the Felton site, about 13 small domestic wells serve a group of approximately 20 residences. These wells also pump small yields from the Santa Margarita aquifer and are in close proximity to numerous septic tank systems.

The so-called "Champion" well of the San Lorenzo Valley Water District is located a short distance northeastward from the wells noted above; the District's "Estrella" well is situated less than a thousand feet east of Champion. Each of these wells taps the Santa Margarita aquifer and had been pumped for District supply purposes. However, in recent years each displayed a high nitrate content in the water produced and was taken off-line. These installations are in areas containing numerous septic tanks, which are the suspected source of the nitrate pollution.

Northwest of the Felton site some two-thirds of a mile, and near the intersection of the Southern Pacific Railroad and Graham Hill Road, the Roaring Camp property has a supply well which produces exclusively from older formations and has no connection with the Santa Margarita aquifer beneath the project site. Roaring Camp also obtains a small spring supply at a point about one-third of a mile northwest of the project site, which similarly is in older formations and unrelated to site groundwater. A test bore was reportedly drilled on this same property along Graham Hill Road within 1000 feet of the project site and found significant groundwater. The bore was totally in older formations and was never developed as a well.

The Mount Hermon Association obtains water supplies to serve resort and household demands in its service area from two springs, Redwood Springs and Ferndell Springs. These are located over one-half mile north of the project site, and are indicated to issue from the Santa Margarita aquifer near its contact with the Monterey Shale along Bean Creek. Because of the drastic thinning and absence of Santa Margarita Sandstone immediately north of the site, as well as prevailing piezometric gradients, there is no hydrologic connection between the site and the Mount Hermon spring area.

As for all area communities, the Mount Hermon community must dispose of sewage through septic tank systems. A third spring, Manzanita Springs, located southwest of Ferndell Springs, was originally utilized by the Association as a source of water supply, but had to be abandoned due to pollution from septic tank systems.

SPRAY DISPOSAL PLAN

The project plan for treated effluent disposal at the Felton site is described in detail elsewhere in this report, thus, the plan is discussed here only in relation to aquifer recharge and impacts.

Approximately 770 acre-feet of effluent is to be annually treated and applied to the ground surface at this site, amounting to an average of about 650,000 gallons per day the year around. Field infiltration tests have shown the ground surface to be highly pervious; the minimum test percolation rate was 2 inches per hour. Using only a minute percentage of that capacity, it is planned to apply treated effluent to a restricted area selected to minimize impacts on effluent-groundwater flow patterns and on native plant life. A disposal area of 18 acres is considered which would involve application of 520 inches a year of effluent. Also considered is a larger area of 26.5 acres, with an annual application rate of 350 inches, as an expansion of the other. These areas are shown on Figure ___.

The principal objective in selecting the optimum location for effluent disposal within the site area was to provide, to the extent possible, control of subsurface effluent-groundwater movement under project operation similar to the present groundwater flow pattern, with most subsurface discharge to Eagle Creek.

It was also considered important to locate disposal applications away from the steep cliff topography in the south-central part of the site (near test hole 5) to reduce the prospects of inducing cliff erosion (see Soils Engineering section discussion).

The theoretical net contribution to groundwater from effluent disposal and rainfall was derived for each prospective disposal area for an average year. These factors are given by months in Table ___. Site lands outside the effluent disposal area would continue to receive deep percolation from rainfall as at present. At least half of the average rainfall may percolate to groundwater in those areas after satisfying consumptive use demands of native vegetation.

In order to assess the possible aquifer impacts of these disposal plan operations, a computer flow model was set up and operated to show the probable water table buildup, directions and rates of effluent-groundwater flow, and flow times to points of discharge and use offsite under project operation. Details of this model analysis and results derived are described later in this report.

TABLE

SLVWD FELTON SPRAY DISPOSAL SITE

Loading Factors for Effluent Disposal

MONTH	Aver. Precip.	Potential ET_0 2/	SPRAY DISPOSAL AREAS 1/ 26.5 ac. Area: Effluent Disposal	26.5 ac. Area: Total Water	26.5 ac. Area: Net Perc. 3/	18.0 ac. Area: Effluent Disposal	18.0 ac. Area: Total Water	18.0 ac. Area: Net Perc. 3/
Jan	9.8"	1.3"	29.2"	39.0"	37.7"	43.3"	53.1"	51.8"
Feb	9.0	1.9	↓	38.2	36.3	↓	52.3	50.4
Mar	5.0	2.8	↓	34.2	31.4	↓	48.3	45.5
Apr	1.8	3.9	↓	31.0	27.1	↓	45.1	41.2
May	0.8	4.6	↓	30.0	25.4	↓	44.1	39.5
June	0	4.7	↓	29.2	24.5	↓	43.3	38.6
July	0	5.5	↓	29.2	23.7	↓	43.3	37.8
Aug	0	4.9	↓	29.2	24.3	↓	43.3	38.4
Sept.	0.8	4.4	↓	30.0	25.6	↓	44.1	39.7
Oct.	2.2	3.1	↓	31.4	28.3	↓	45.5	42.4
Nov.	4.2	1.8	↓	33.4	31.6	↓	47.5	45.7
Dec.	8.4	1.1	↓	37.6	36.5	↓	51.7	50.6
Totals	42.0"	40.0"	350"	392"	352"	520"	562"	522"

Note: No runoff assumed from either average or maximum rainfall. Maximum rainfall (100-year) estimated at 82 inches.

1/ Tentative disposal areas shown on Figure____.

2/ Evapo-transpiration - water use from soil zone.

3/ Net deep percolation to groundwater.

WATER QUALITY IMPACTS - CONSIDERATIONS

In advance of any determinations made by the groundwater flow model analysis of the prospective impacts of this project effluent disposal on the aquifer/and Eagle Creek, certain facts and conditions are apparent which have a strong bearing on any considerations of impacts. These are briefly discussed below.

Groundwater Quality

The first consideration in considering the impacts of project disposal on water quality is the quality of the treated effluent to be applied to the ground surface. Effluent collected will be given tertiary treatment, including de-nitrification, with a resultant estimated quality as follows:

Based on this expected treated effluent quality, the effluent sprayed on the ground surface at the Felton site will essentially be of drinking water purity.

The existing aquifer water quality, shown in Table ____, indicates low mineral content in the native state, and is a reliable measure of the quality of natural recharge to the aquifer which will mix with and dilute percolated effluent.

Under natural existing conditions, rainfall can supply only part of the potential evapo-transpiration which is possible with year-around irrigation. The maximum estimated rate of 3.33 feet per year (40 inches) will be applicable on the project disposal area. Using a disposal area of 27 acres , an overall site area of 170 acres contributory to recharge, an assumed evapo-transpiration rate outside the disposal area of 1.5 feet per year supplied by rainfall, and assuming that one-third the evapo-transpiration in the disposal area is supplied by rainfall, then it is seen that total deep percolation on the site under project operation will be on the order of 1050 a.f./yr. as recharge to the aquifer. Of this quantity, something like 350 a.f. will be from rainfall. Therefore, on this basis, rainfall will make up about 33 percent , or one-third, of the total percolation on the site under project operation, a 1:2 ratio. This dilution with the very low mineral content native water will lower mineral content significantly.

Groundwater filtering through a porous medium for any significant distance receives considerable reduction in bacterial and certain mineral content. The more porous the medium, the less beneficiation is realized over a given travel distance. Although the Santa Margarita Sandstone is relatively pervious, a noticeable upgrading of effluent quality should be expected by the time it has traversed the flow distances to discharge points or wells in its path.

With respect to possible impacts on the supply wells at the County Probation Center operated by the San Lorenzo Valley Water District, it can be stated that project effects will be minimal to nil, without further analysis. The Old Probation well pumps no water from the Santa Margarita Sandstone and cannot be affected. The New Probation well, as explained earlier, is perforated in only the lowermost 15 feet of the Santa Margarita and the pumping level is often at the bottom or below this interval. Thus, it is obvious that this well produces only a minor portion of its yield from the Santa Margarita. Overall average contribution from this aquifer is probably not more than 10 percent. It seems reasonable to assume that admixing 10 percent of diluted, filtered project effluent with 90 percent water from older formations will produce no noticeable effect.

Residential wells a short distance northeast of the project site, located on Figure ___, will receive the diluted, filtered effluent-groundwater mix after it has traveled some 1200 feet from the disposal area through the aquifer. In view of these circumstances, it is difficult to visualize any noticeable impact on groundwater quality in this locality. Considering the occurrence of numerous septic tanks in the near proximity of these wells for many years, it is conceivable that the water now pumped from these wells is somewhat degraded and if there is a project impact, it could be positive.

Residential wells located a thousand feet or so farther to the northeast from the above wells are much less likely to have any noticeable effects from the project. And the same septic tank conditions apply there, also.

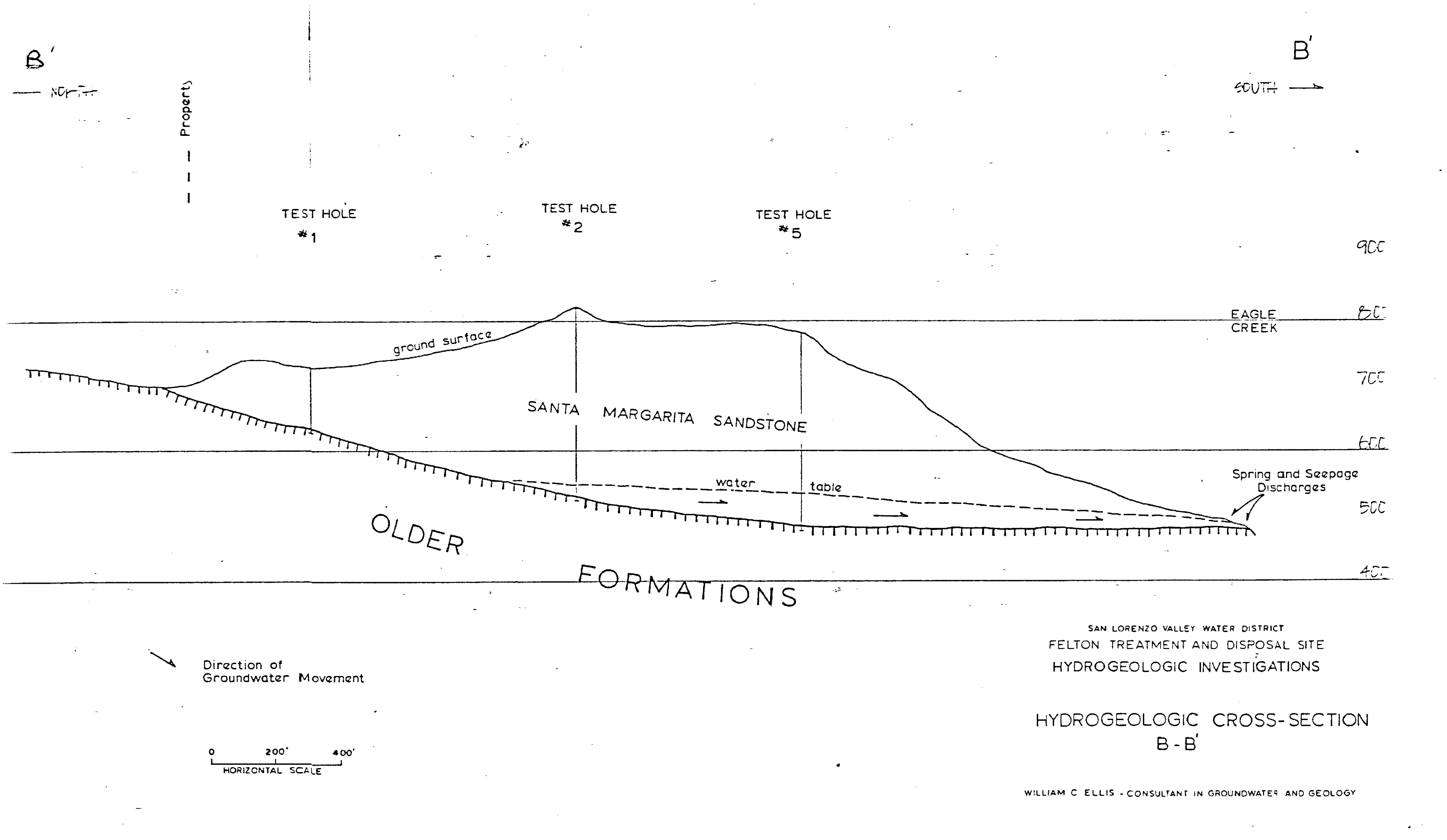
Eagle Creek Quality

As discussed in another report section, flows in Eagle Creek are now polluted, apparently from faulty septic tank systems in Cowell State Park to the south of the Felton site. If it can be assumed that this condition will be corrected in the near future, then Eagle Creek flows contributed from springs and seeps on the south side area should be of very good quality, virtually identical to present spring flow from the site area (see Table ___). The total creek flow at its confluence with the San Lorenzo River is roughly estimated at about 1 cubic foot per second, or 450 gallons per minute. If it is assumed that half of this flow is contributed from the area south of the creek, and that this represents something near an average flow over the year, then some ~~365~~ a.f./yr. flows from the south side area. Under project operation, if 90 percent of site groundwater recharge flows to Eagle Creek, which from earlier discussions would amount to about 950 a.f./yr., total flow in Eagle Creek with the project will total on the order of 1300 a.f./yr., of which 28 percent will be high quality groundwater from the south area. This 1:2.6 mix-dilution in flow will further enhance the diluted aquifer water from the project site, which will have already filtered through at least 1500 feet of aquifer to reach the creek.

Other

As discussed under the hydrogeologic section of this report, no other wells or springs in the general region of the project stand to be affected one way or the other by the Felton disposal operation.

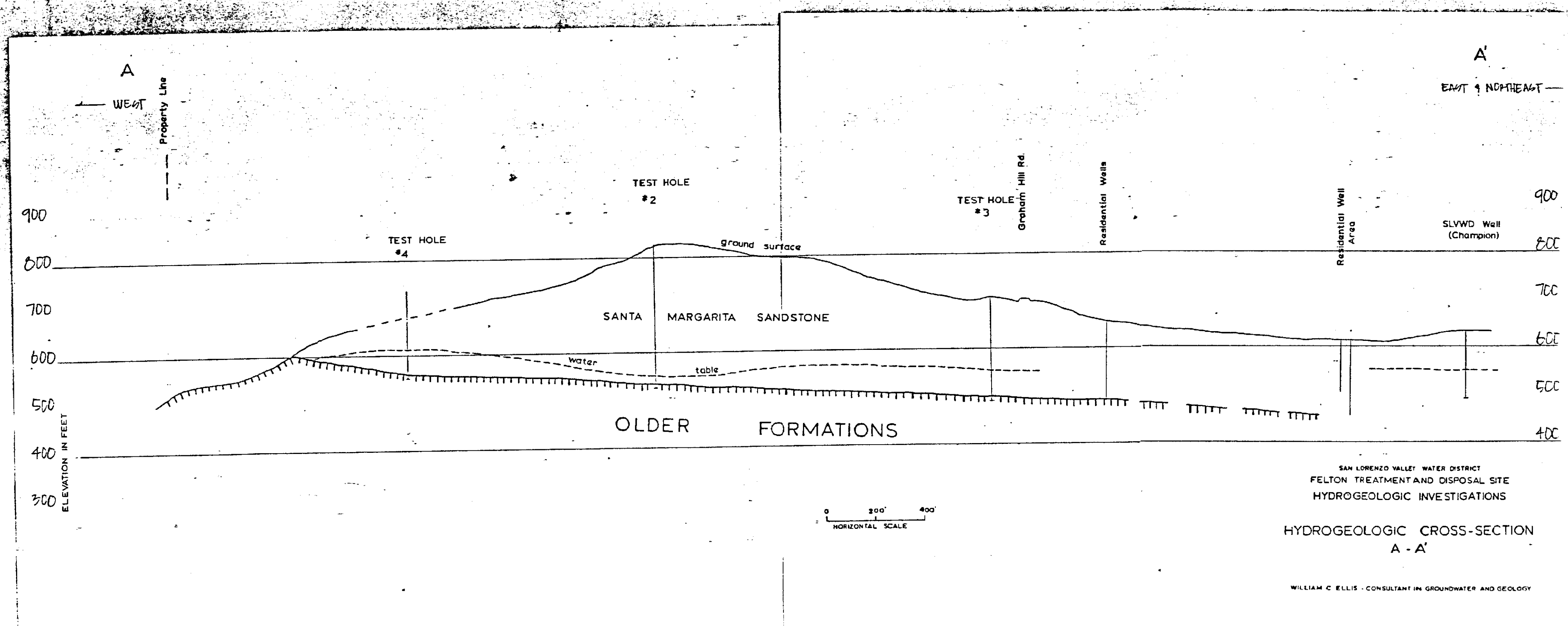
It is possible that project disposal could create some seepage or spring flow along the contact of the Santa Margarita Sandstone aquifer with older formations in the western fringe of the site property. If this should occur, such discharge would merely issue in draws and flow, either to the San Lorenzo River, or be absorbed into more pervious outcropping strata of older formations in the intervening area. Quality of water issuing should be acceptable, considering the dilution and travel distance in the aquifer over a distance of some 700 feet from the disposal area.



SAN LORENZO VALLEY WATER DISTRICT
FELTON TREATMENT AND DISPOSAL SITE
HYDROGEOLOGIC INVESTIGATIONS

HYDROGEOLOGIC CROSS-SECTION
B - B'

WILLIAM C ELLIS - CONSULTANT IN GROUNDWATER AND GEOLOGY



SAN LORENZO VALLEY WATER DISTRICT
FELTON TREATMENT AND DISPOSAL SITE
HYDROGEOLOGIC INVESTIGATIONS

HYDROGEOLOGIC CROSS-SECTION
A - A'

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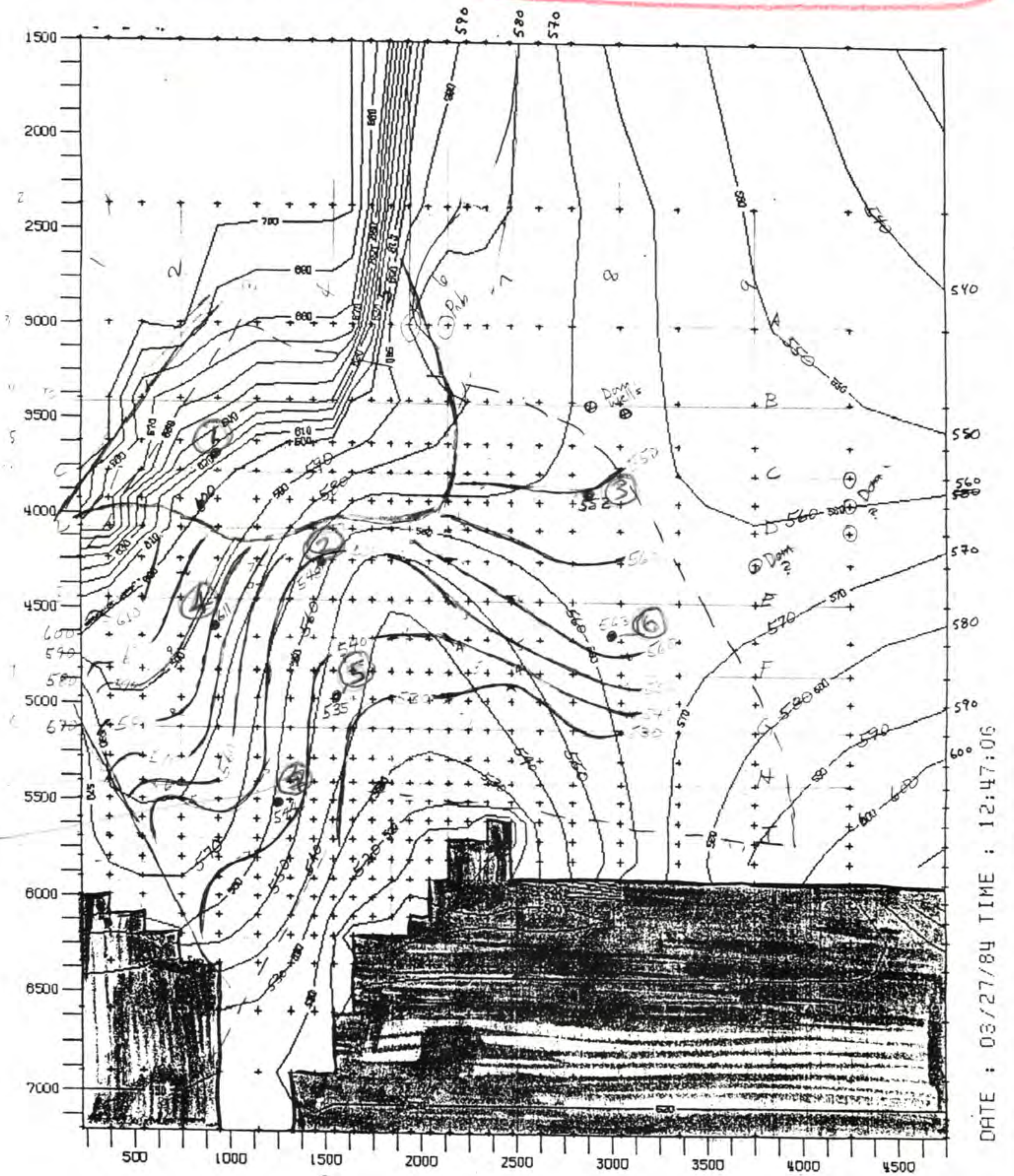
DRAFT COPY
SUBJECT TO REVISION

POTENTIOMETRIC MAP FOR MARCH, 1984

SOURCE: WILLIAM C. ELLIS — modified and extrapolated by WCC



SCALE: 1 INCH = 500 FEET

CONTOUR INTERVAL: 10 FEET

Figure 2.

16169B - 3000

APPENDIX B

Selected Photographs of Eagle Creek

Flow measurement cross section looking upstream. Note how steep it is.

Flow cross section looking downstream

Sand bed at the cross section.

Eagle Cr looking upstream of flow cross section. Granitic boulder & cobbles. Smaller schist gravel 5-15cm

Eagle Cr looking upstream. Granitic boulder & cobbles. Smaller schist gravel 5-15cm


SLR
Alluvial fan from Eagle
10.01.2018 15:51
Eagle Cr


SLR
Eagle Cr
Alluvial fan from Eagle
10.01.2018 15:51


SLR
Eagle Cr
Alluvial fan from Eagle
10.01.2018 15:51

Alluvial fan at the outlet of Eagle Cr into the SLR.
This fan has probably not been scoured by the higher flow of the SLR due to the fallen tree just upstream of the confluence creating a velocity shadow.

Looking downstream toward Eagle Cr confluence behind fallen tree