Title

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Alteration of the Groundwater Table Due to Construction of a Floodplain Bypass at Upper Pine Creek, Concord, California

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Abstract

The Upper Pine Creek Flood Control Project in Concord, California, includes the construction of a floodplain bypass to the southwest of the natural stream path between stations 140+06 and 168+10 (station numbers increase in an upstream direction). This project increases the capacity of Pine Creek from around 1000 to 3250 cubic feet per second (cfs) in the project reach. Construction of the floodplain bypass required excavation to an elevation below that of the pre-project groundwater table. Such excavation creates a local depression in the water table and threatens to drop the local water table below the bed of the existing creek, effectively killing the natural channel.

Analysis of contour maps of the pre- and post-project groundwater table reveals that the water table has dropped by up to 7 feet in the area between the natural channel and the floodplain bypass. Additionally, the slope of the water table has been altered to a direction that seems to favor flow along the path of the floodplain bypass. A diversion pipe directs flows of up to 100 cfs into the natural channel. This, in conjunction with natural bounding of the aquifer by the Concord Fault to the southwest and by topographically driven flow from the slope of Lime Ridge from the east, effectively mitigate expected groundwater table elevation problems and maintain the natural creek as an active and dynamic channel system.

Introduction

The nearly hundred-fold population growth of the city of Concord, California, during the last 60 years has been accompanied by urbanization throughout the Clayton and Ygnacio Valleys, about fifteen miles east of San Francisco Bay. (City of Concord, CA, 2003, Figure 1) Urbanization has constrained the local creeks to narrow strips surrounded by impervious surfaces that direct storm water into the storm drain systems and creeks instead of into aquifers. Natural creeks through this area of California are not prepared to handle these flows, and the result has been flooding. With the city of Concord expanding onto the floodplains of its creeks, even moderate floods posed a danger to property and infrastructure adjacent to the creeks.

Walnut Creek drains a watershed that comprises the Ygnacio and San Ramon Valleys, and a portion of the Clayton Valley. Its major tributaries are Grayson, Las Trampas, San Ramon, and Pine Creeks, with lesser contributions from Pacheco Creek and Galindo Creek (Pine Creek's principal tributary). Beginning in 1964 , the United States Army Corps of Engineers implemented a plan to alleviate flooding along the main channel of Walnut and San Ramon Creeks. In 1970, the Army Corps of Engineers expanded the plan to include channel improvements to Lower Pine and Galindo Creeks in response to serious floods in the late 1950s and early 1960s. Upper Pine Creek became part of the master plan in 1973. (U.S. Army Corps of Engineers, 1977)

The flood control projects on Pine Creek called for construction of concrete lined channels in the lower reach and earth lined channels with concrete box culverts and drop structures in the upper reach. Between the BART bridge and San Miguel Road on the upper reach, a floodplain bypass was constructed parallel to the natural creek channel (Figure 2). While base flows are diverted to the natural channel, construction of the flood channel below the pre-project water table poses a threat to the groundwater recharge of the natural stream due to water table depression. This report assesses the significance of this threat based on a comparison of the pre- and post-project water table level.

Pine Creek Flood Control Project Description

Lower Pine Creek Project

The initial plan approved by the Contra Costa Flood Control and Water Conservation District and the Army Corps of Engineers for Lower Pine and Galindo Creeks would have placed the creeks underground for a majority of their paths within the project boundaries. (U.S. Army Corps of Engineers, 1979) In February of 1984, the improvements to Lower Pine and Galindo Creeks were completed based on a revised plan that eliminated the covered channel design. The channel improvements constructed are as follows:

- Trapezoidal rock-lined earth channel from the confluence with Walnut Creek to the preexisting rectangular concrete channel at State Highway 242
- Rectangular concrete channel passing under Highway 242, built in conjunction with construction of the freeway
- Rectangular concrete channel from preexisting structure to approximately 600 feet beyond BART bridge at project boundary
- Narrow rectangular concrete channel along Galindo Creek from its confluence with Pine Creek to San Miguel Road at project boundary

(U.S. Army Corps of Engineers, 1985)

Upper Pine Creek Project

Increasing urban runoff augmented natural flows in Upper Pine Creek such that they exceeded the natural channel's ability to drain the watershed, causing extensive flooding throughout the late 1950s, 1960s, 1970s and early 1980s. While a majority of the flooding consisted of nuisance floods, larger events like the 100-year flood of 1958, and the Pine Creek Flood of 1962, made the project a necessity to protect local property and infrastructure.

Pine Creek drains an area of 29 square miles. (U.S. Army Corps of Engineers, 1990) Its watershed is located on the western slope of Mount Diablo and trends northwest through Central Contra Costa County bounded by Shell Ridge to the southwest and Lime Ridge to the east (Figure 3). At the downstream boundary of the Upper Pine Creek Channel project—the BART bridge, the natural channel capacity was 1020 cubic feet per second (cfs) before construction of channel improvements. (U.S. Army Corps of Engineers, 1985) Flashy urban runoff contributed to flows exceeding this capacity. The United States Geological Survey stopped monitoring the sole gauging station on Pine Creek in late 1960, but the largest recorded flow on the creek exceeded this capacity by 140 cfs in 1958. (U.S. Army Corps of Engineers, 1985) The floods of 1958 and 1962 combined to cause nearly $2 million in damage. (U.S. Army Corps of Engineers, 1977, and Todd, 1963) Baseflows were modeled at 5 cfs for the purposes of construction, but actual flows, especially during the summer months, are less. (U.S. Army Corps of Engineers, 1985) The creek is dry in many areas during the summer and early autumn.

Designers of the Upper Pine Creek Channel project sought to control the 100-year floodwaters by increasing channel capacity to 3250 cfs at the interface between the upper and lower channel projects: the BART tracks at station 134+91[1]. This was accomplished in two ways: excavation of a trapezoidal earth channel in place of the existing creek channel, with concrete channel or box culverts under roadways and other infrastructure components; and construction of a floodplain bypass to contain high flows while low flows are diverted to the natural creek. Both regimes include concrete and rip-rap drop structures to dissipate the energy of high flows. The rectangular concrete

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[1] Station 0+00 is located at the confluence of Pine Creek with Walnut Creek. The first number indicates hundreds of feet, and the second number indicates single feet. The BART bridge is located 13,491 feet from the confluence of Walnut and Pine Creeks along the path of the creek.

channel was extended to station 138+55. Excavation took place from station 138+55 to station 140+06, and from station 168+10 to station 223+00. Upstream of station 223+00, the creek flows naturally, with improvements constructed only near roads to protect infrastructure. A detention basin located at station 344+15, constructed per the recommendation of the U.S. Soil Conservation Service in 1981, provides protection against the 50-year flood in the downstream areas. (U.S. Army Corps of Engineers, 1985)

Floodplain Bypass

Between stations 140+06 and 168+10, construction of a floodplain bypass eliminates the need for the natural channel to carry high flows. During the summer and early autumn, both the natural creek and the floodplain bypass are mostly dry with ponded water in some locations, but no surface flow. At the San Miguel Road box culvert, the upstream end of the bypass, a 42-inch cast-in-place reinforced concrete pipe diverts base flows into the remaining natural creek to maintain riparian vegetation (Figure 4). This pipe allows a maximum flow rate of 100 cfs, which provides seasonal flushing for the natural creek. (U.S. Army Corps of Engineers, 1985)

Alteration of the groundwater table resulting from the construction of the floodplain bypass presents a more fundamental concern for the health of the creek system. Exploratory borings and trenches made in December 1983 show that the elevation of the pre-project groundwater table in the area of the floodplain bypass was higher than the bottom of the proposed channel by as much as ten feet. (U.S. Army Corps of Engineers, 1985)

Methods

This report assesses the extent to which excavation of the floodplain bypass affects the groundwater table. A comparison of the water table surface before and after construction provides a straightforward approach. Figure 5 contains a contour map of the groundwater table in the floodplain bypass area before the project. Data points used to create this map come from exploratory boreholes and trenches dug in December of 1983 as part of the pre-project site investigation. I extracted additional data points from Army Corps of Engineers design cross-sections of the project reach, which include an inferred profile of the pre-project groundwater table. I referenced each point to the plan view design drawings, also included in the U.S. Army Corps of Engineers construction plan, for map locations.

Figure 6 contains a contour map of the groundwater table in October of 2003. Data points for this map come from two sources. I mapped the intersection of the groundwater table with the surface in both the natural creek and the floodplain bypass throughout the project reach, yielding a plethora of points from which to contour the groundwater level. Additionally, I installed four makeshift piezometers to collect subsurface groundwater elevations where surface water was absent. Again, I referenced the series of points to Army Corps of Engineers design drawings to obtain map locations and elevations.

In addition to collecting data on the intersection of the water table with the topographic surface, each visit to the site included documentation of general observations of the creek to determine timing, size and frequency of flows. This type of observation provides a valuable insight into the seasonal flow regime of the creek and the floodplain bypass.

Piezometers

I installed four piezometers, constructed using 72-inch sections of one-inch diameter schedule 40 polyvinyl chloride pipe, open on both ends with 32 holes 5/16 inch in diameter drilled in the lower eight inches, and nylon stockings as filter mesh held in place with duct tape. Using a two-man gasoline-powered hand auger, a field assistant and I drilled four borings not exceeding three-and-a-half feet in depth (the maximum depth achievable with the equipment) into the silty sandy clay that characterizes the soil over the entire project reach. We placed piezometer #1 in the natural channel, piezometers #3 and #4 in the floodplain bypass, and piezometer #2 on the levee in between. In some areas, a mechanical jack was required to remove the auger from the ground. The process was completed by pushing the makeshift piezometers through the soft caving material to the bottom of the boring. Backfill and compaction were done manually.

After allowing four days for the water levels to equilibrate, I dropped red food coloring and an absorbent twine with a steel nut tied to the end into each piezometer to measure water level. Only the piezometer in the natural channel showed groundwater within 3.5 feet of the surface.

Data Processing

I translated point data for groundwater elevations from the map to a series of coordinates representing easting, northing and elevation in feet, and I tabulated the data in tables 1 and 2. These data come from four sources: (1) exploratory borings and trenches; (2) piezometers; (3) the inferred pre-project water table level from design plans; and (4) from a variety of points at the standing surface water level.

Surfer 7, by Golden Software, Inc., generated contour plots using these data tables. The output is the georeferenced AutoCAD *.dxf file, which I loaded into ArcView and overlaid on a USGS 7.5 minute quadrangle to produce the contour maps in figures 5 and 6.

Sources of Error

Three sources of error exist for the contour plots of groundwater table elevation. (1) Any error in the data from borings and trenches carries over into this data set, and the same is true for the inferred water table level in U.S. Army Corps of Engineers, 1985. In this study, I ignore this error because there is no way to quantify it since the areas were excavated nearly twenty years ago.

(2) The large-scale design plans do not extend to the natural channel because no improvements were made there, so I could only map the location of piezometer #2 on the 1:24,000 scale USGS 7.5' quadrangle.

(3)Most significantly, the pre-project groundwater table data was collected by the Army Corps of Engineers in December of 1983, when the ground was saturated. I collected the post-project data in October of 2003, before significant seasonal rainfall, when the ground was extremely dry. Thus, quantitative comparisons between the two data sets cannot be made.

Results and Discussion

Observations collected in visits to the site show that during the driest part of the year, surface flow is absent within the project reach in the floodplain bypass and the natural channel. Ponded water, recharged by the local aquifer, creates a riparian wetland in the upstream half of the floodplain bypass, while the downstream half is mostly dry. Surface water ponds in the first 200 feet from the diversion outlet in the natural channel (Figure 7), but downstream, it is also dry (Figure 8). The occurrence of ponded water marks the interface of the groundwater table with the topographic surface.

Riparian vegetation flourishes on the banks of the natural creek, but the creek bed remains relatively clean. Annual grasses grow there, but their presence does not indicate a lack of winter surface flows as they regenerate each year. These grasses on the creek bed were green during an October site visit, indicating the close proximity of the groundwater table to the surface. In this region, this type of grass is usually dead and brown before October because water is not available. The lack of riparian vegetation on the creek bed itself verifies that flushing and scouring flows occur with sufficient frequency to prevent the channel from filling with sediment. A visit to the site in mid-November showed that the natural channel is indeed subject to intermittent flows with enough power to transport logs and rocks. Piezometer #1 in the natural channel had collected a log, a pile of sediment, and scattered vegetation, and it sat at a 30-degree angle with the creek bed. The 42-inch diversion pipe mitigates the effect on surface flows due to the bypass by preferentially placing up to 100 cfs flows in the natural creek. The addition of water here also preferentially recharges the aquifer at the head of the natural channel. This could mitigate the water table decline resulting from excavation of the floodplain bypass below the pre-project water table. Based on the presence of water in the piezometer in the natural channel, it is apparent that the water table is shallow throughout the natural channel, and this could be a result of preferred recharge to the aquifer in this location. Short of sealing the diversion pipe, the best way to determine the effect on the ground water table by the diversion is to model the water table level as a function of flow through the two channels here. This is outside the scope of this investigation, however with sufficient funding and a larger set of piezometers, it is feasible.

In comparing the contour maps of the groundwater table before and after the project (Figures 5 and 6), a decline in the water table as a result of the excavated floodplain bypass is apparent. This was expected since construction of the channel required excavation to an elevation below that of the pre-project water table. Between the two maps, the measured difference in water table elevation is up to 7 feet in some locations. This is not necessarily a true measure of the water table decline because the pre-project data was collected during the wet season while the post-project data was collected at the end of the dry season when the ground is driest. Additionally, the water table elevation varies from year to year with rainfall. 1981 and 1982 were extraordinarily wet years in the area, with rainfall 75% above normal. (Monteverdi and Null, 1997 and Null, 2003, Figure 9) Rainfall in 1983 was normal, but it is likely that the water table remained higher than normal that year due the heavy precipitation of the two previous years. Rainfall during 2001 and 2002 was near normal, contributing to a water table level lower than that in 1983. (Null, 2003)

Aside from the elevation change in the water table, a comparison of the two contour maps shows a major change in the dip of the water table surface. The pre-project water table has a more complex morphology, dipping north-northeast in the northern section of the project reach and southeast in the southern part (Figure 5). A change in the dip is apparent in the middle section of the map. The post-project map shows a much simpler morphology with the water table surface dipping toward the floodplain bypass through the entire project reach, indicating the predicted water table depression here (Figure 6). This demonstrates the strong influence of the floodplain bypass on the shape of the groundwater table surface, which is stronger than that of the natural creek. Monitoring of the two channels over an entire year would likely show the natural channel to be a losing channel, and it would most likely dry up before the flood channel in the summer. During the wet season, both channels likely gain water due to groundwater recharge from Lime Ridge.

Concord Fault

The trace of Concord Fault runs parallel to the creek through the project reach on the southwest side of the floodplain bypass (Refer to figure 2). The exact trace of the fault is uncertain due to rare and weak seismicity, but its inferred map location has been bounded within the creek area by exposures to the north and south. This fault provides a groundwater barrier to the southwest of the creek, bounding the aquifer within the project reach. Water table depth southwest of the fault is greater than 20 feet. (U.S. Army Corps of Engineers, 1985) Topographically driven groundwater flow from the slope of Lime Ridge east of the creek provides a recharging boundary on the east side. The unconfined aquifer surrounding Pine Creek is thus bounded on both sides approximately parallel to the overall flow direction.

Conclusions

Excavation of a floodplain bypass between stations 140+06 and 168+10 on Pine Creek alters the local groundwater table in an area where both a natural and an artificial stream flow parallel to each other and drain the same watershed. Without any mitigation measures, one could expect the stream to be completely diverted to the deeper artificial channel, removing all surface flow into the natural channel. In the summer months when baseflows are less than 5 cfs, the aquifer would receive no recharge from within the natural stream. In higher flows of the winter months, all surface flow would travel through the flood channel, and water would enter the natural stream only by precipitation, local runoff, and minor topographically driven groundwater flow. Only during extreme floods (greater than the 100-year event) would the natural channel receive significant flows. These flows would supply the channel with rare sediment and eventually (on a geologic time scale) fill it in. (Summerfield, 1991)

The Army Corps of Engineers plan for construction of the Upper Pine Creek Flood Control Project incorporated a 42-inch diversion pipe that directs low flows into the natural channel to mitigate the adverse effects described above. This diversion provides surface flows for the natural channel to flush excess sediment and scour the creek bed during the wet season. In addition, the aquifer is preferentially recharged here during summer baseflows flows, which often reach zero on the surface.

Excavation of the floodplain bypass below the elevation of the pre-project water table places a depression in the water table level. Groundwater is present in the natural channel. A combination of two factors likely keeps the groundwater level high enough in the natural channel to sustain the creek. The lateral extent of the water table depression may not reach the natural channel. The diversion pipe in conjunction with local runoff and topographically driven groundwater flow from the adjacent slopes of Lime Ridge recharge the aquifer at the natural channel. This topographically driven flow bounds the aquifer to the east, while the Concord Fault provides a flow boundary to the southwest. The combination of these boundaries stabilizes the water table level through the project reach such that variations are controlled by weather alone. Effective mitigation of adverse effects on the natural creek from construction of the floodplain bypass through diversion of low flows combined with natural stabilization of the water table has prevented the natural channel of Pine Creek from being destroyed by decline of the groundwater table.

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Figure and Table Captions

Figure 1: Map of California with the location of the Walnut Creek Basin, home of Pine Creek, emphasized.

Figure 2: Map of the project reach on Upper Pine Creek between stations 140+06 and 168+10 showing locations of the natural channel, floodplain bypass, diversion pipe, approximate trace of the Concord Fault, and subsurface measurements.

Figure 3: The Pine Creek Watershed, located on the northeastern slope of Mount Diablo within the Walnut Creek Basin. The watershed is bounded by Lime Ridge to the east and Shell Ridge to the southwest (modified from U.S. Army Corps of Engineers, 1977).

Figure 4: Flows less than 100 cfs are diverted to the natural channel by way of a 42-inch diameter cast-in-place reinforced concrete pipe.

Figure 5: Contour map of the pre-project groundwater table elevation. Contour interval is 1 foot.

Figure 6: Contour map of the post-project groundwater table elevation. Contour interval is 1 foot.

Figure 7: Standing water at the head of the natural channel.

Figure 8: Dry creek bed near the downstream end of the natural channel shows that creek flow is entirely subsurface here.

Figure 9: Rainfall measurements for the San Francisco area from 1961 through 2002 (modified from Null, 2003).

Table 1: Raw data that was loaded into Surfer 7 to create the pre-project contour map.

Table 2: Raw data that was loaded into Surfer 7 to create the post-project contour map.

Figures

Figure 1

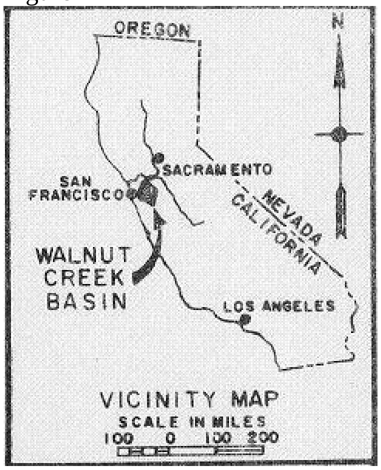


Figure 2

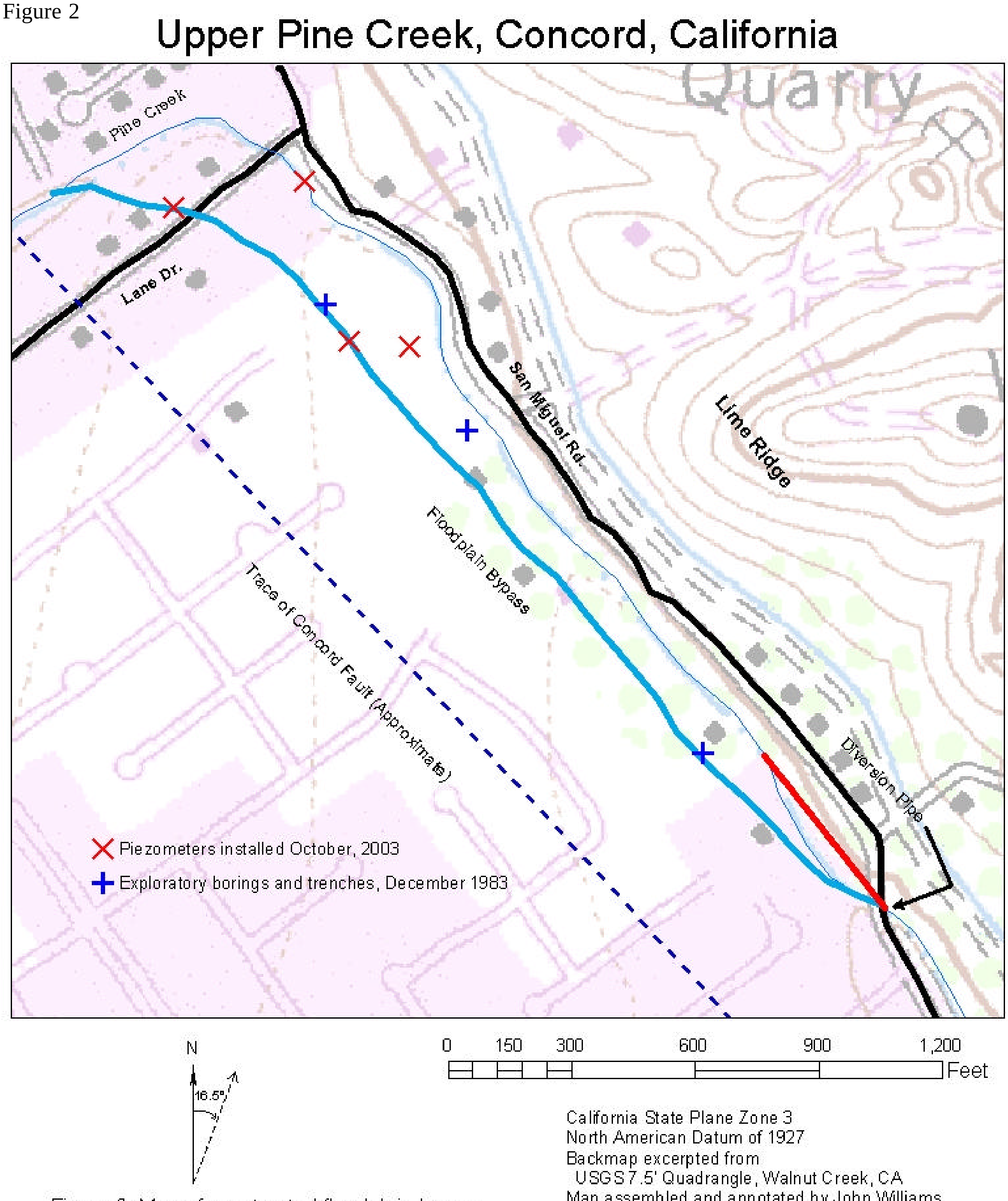


Figure 2: Map of constructed floodplain bypass on Upper Pine Creek between stations 140+06 and 168+10

Figure 3

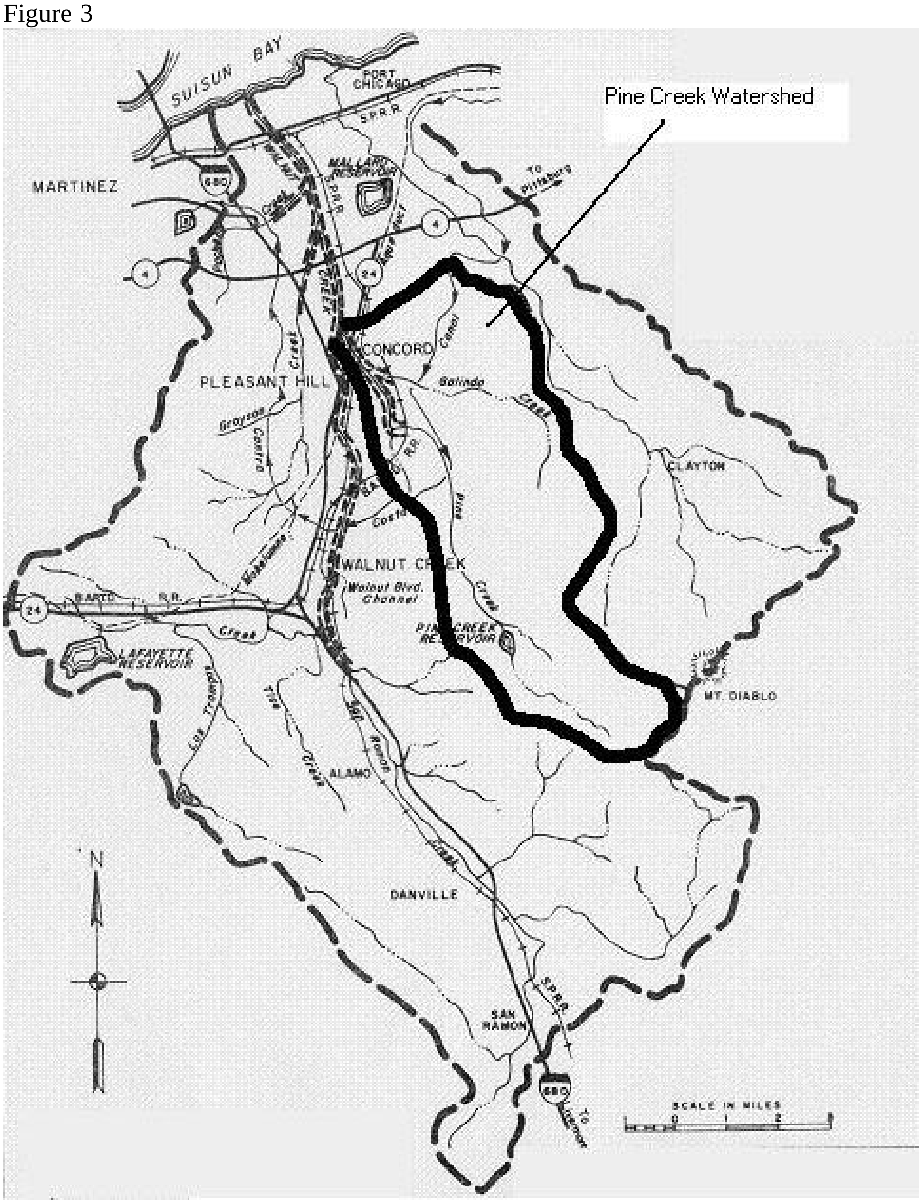

Pine Creek Watershed
SUISUN BAY
PORT CHICAGO
MARTINEZ
CONCORD
PLEASANT HILL
CLAYTON
WALNUT CREEK
PINE CREEK RESERVOIR
MT. DIABLO
LAFAYETTE RESERVOIR
ALAMO
DANVILLE
SAN RAMON
N
SCALE IN MILES

Figure 4


Figure 5

Upper Pine Creek, Concord, California

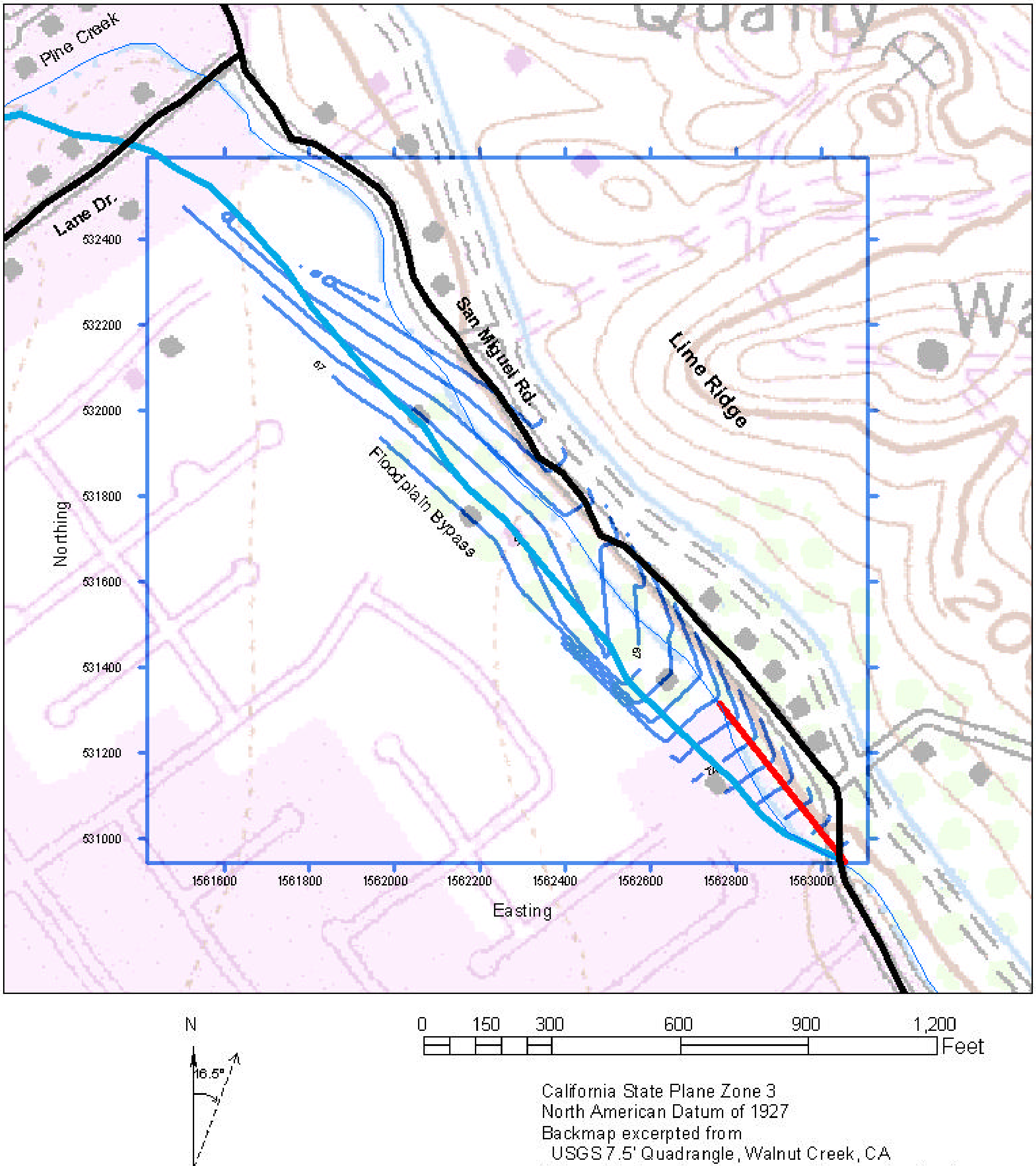


Figure 5: Contour map of the pre-project groundwater table at Upper Pine Creek. Contour interval is 1 foot.

California State Plane Zone 3
North American Datum of 1927
Backmap excerpted from
USGS 7.5' Quadrangle, Walnut Creek, CA
Data points from design cross-sections and exploratory borings and trenches made December, 1983.
(U.S. Army Corps of Engineers, 1985)
Map assembled and annotated by John Williams, December, 2003.

Figure 6

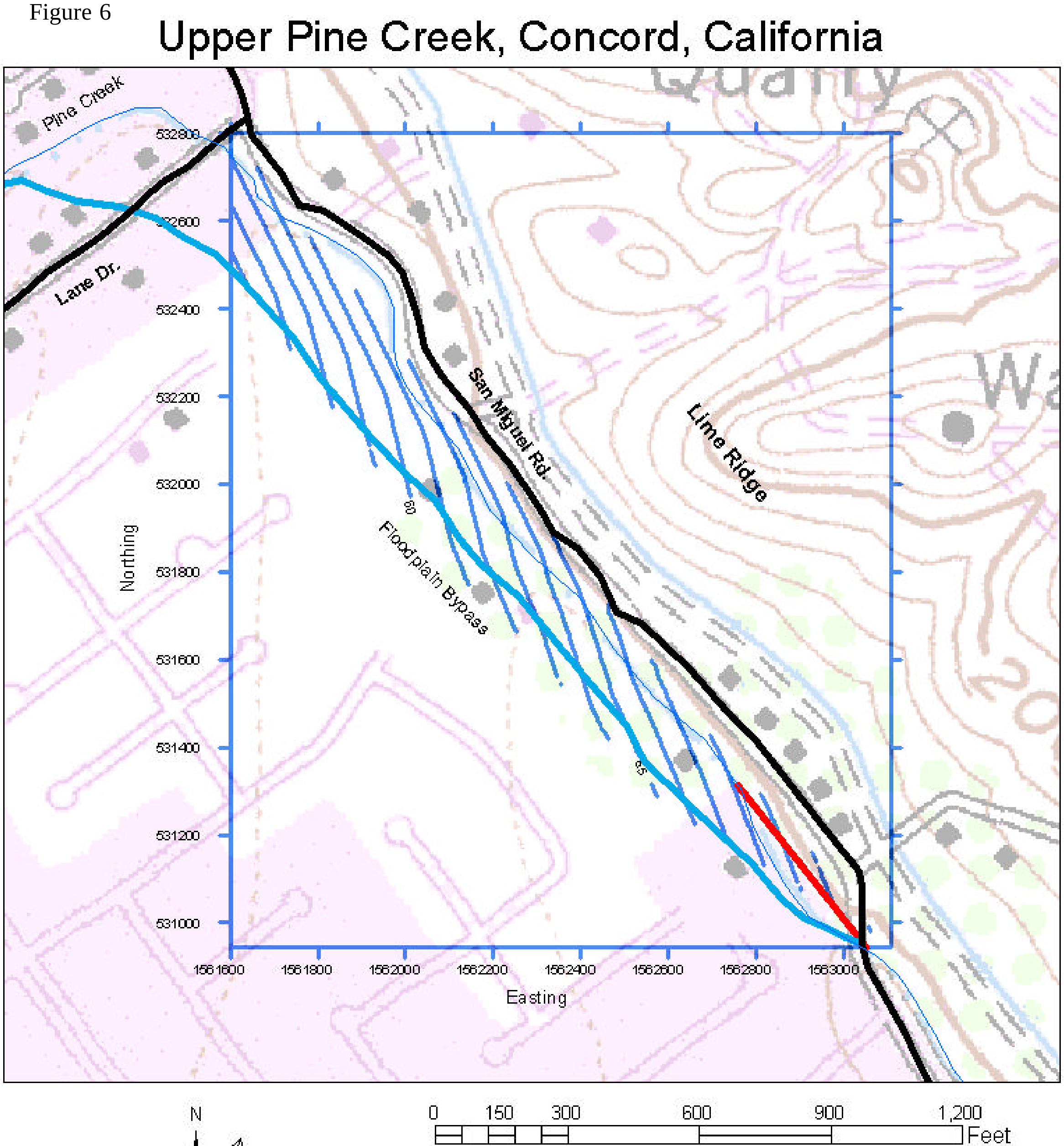


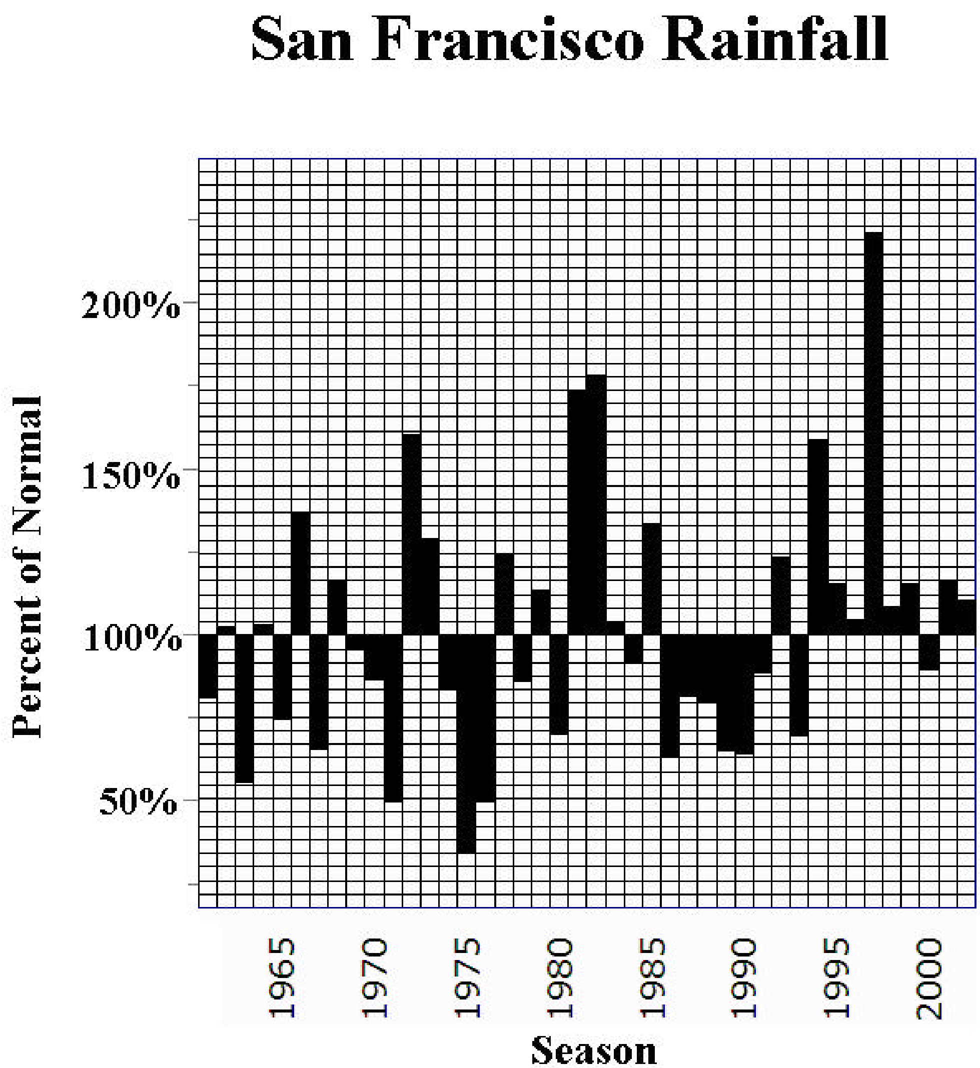
Figure 6: Contour map of the post-project groundwater table at Upper Pine Creek. Contour interval is 1 foot.

California State Plane Zone 3
North American Datum of 1927
Backmap excerpted from
USGS 7.5' Quadrangle, Walnut Creek, CA
Data points from field mapping of surface water and from piezometers installed October, 2003.
Map assembled and annotated by John Williams, December, 2003.

Figure 7

Figure 8

Figure 9


San Francisco Rainfall
200%
150%
100%
50%
Percent of Normal
1965
1970
1975
1980
1985
1990
1995
2000
Season

Tables

Table 1
Pre-Project Groundwater Table Raw Data

Easting	Northing	Elevation	Location
1561422	532591	65	Floodplain Bypass Channel
1561491	532489	65	Floodplain Bypass Channel
1561750	532355	63	Exploratory Boring
1561937	531962	68	Floodplain Bypass Channel
1562184	531673	69	Floodplain Bypass Channel
1562285	532065	62	Exploratory Trench
1562505	531400	66	Exploratory Boring
1562560	531600	67	Natural Creek
1562695	531130	72	Floodplain Bypass Channel
1563107	530943	78	Floodplain Bypass Channel
1562400	531750	65	Natural Creek
1562720	531380	69	Natural Creek

Table 2
Post-Project Groundwater Table Raw Data

Easting	Northing	Elevation	Location
1561600	532800	58.5	Piezometer in Natural Channel
1561600	532480	55.5	Floodplain Bypass Channel
1561773	532396	58	Floodplain Bypass Channel
1562030	531895	60	Floodplain Bypass Channel
1562260	531645	62	Floodplain Bypass Channel
1562560	531600	67	Natural Creek
1562429	531478	64	Floodplain Bypass Channel
1562580	531270	65	Floodplain Bypass Channel
1563107	530943	71.5	Natural Creek
1562400	531750	65	Natural Creek
1562720	531380	68	Natural Creek