SANTA PAULA CREEK PERCOLATION: AN UPDATE

United Water Conservation District
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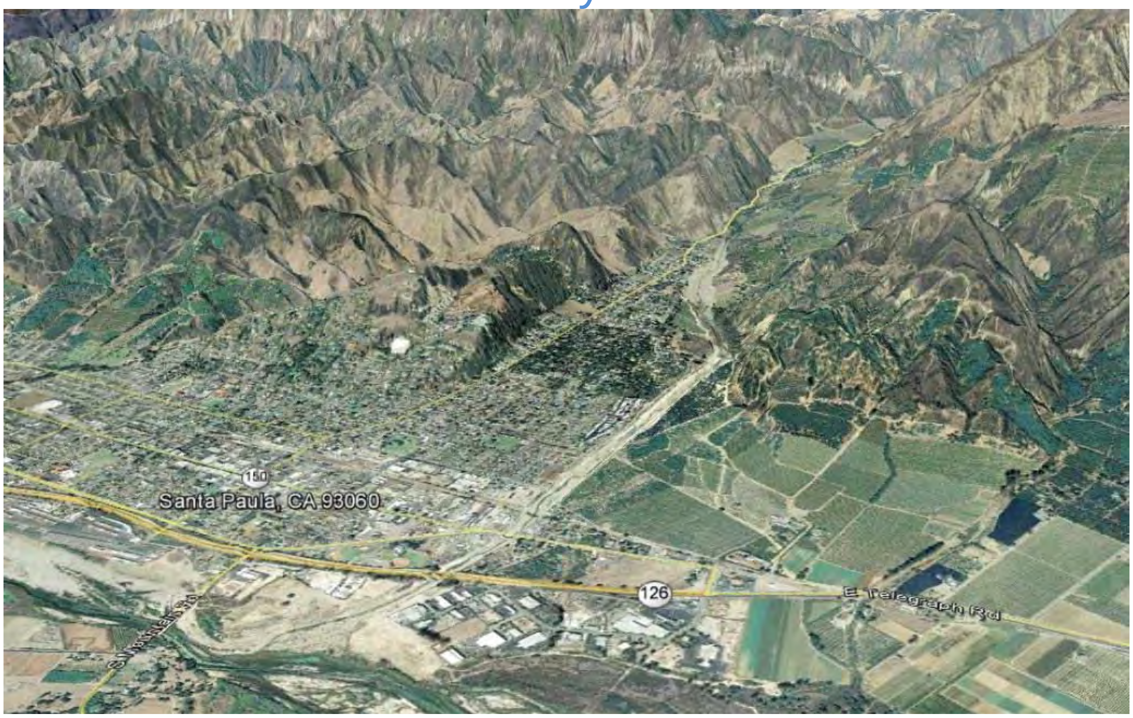

THIS REPORT IS PRELIMINARY AND IS SUBJECT TO MODIFICATION BASED UPON FUTURE ANALYSIS AND EVALUATION

PREPARED BY

GROUNDWATER DEPARTMENT

UNITED WATER CONSERVATION DISTRICT

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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SANTA PAULA CREEK PERCOLATION: AN UPDATE

UWCD OPEN-FILE REPORT 2013-02

EXECUTIVE SUMMARY / ABSTRACT

Santa Paula Creek has historically been thought to be a key source of recharge to the Santa Paula Basin. A 2.5 mile section of Santa Paula Creek's alluvial fan crosses the upper end of the Santa Paula groundwater basin, extending to where the creek joins the Santa Clara River. The percolation rates of this portion of the creek have been studied several times since the early 1930s. United Water Conservation District recently reproduced a study that was performed in the 1930s by the California Division of Water Resources. The DWR study was conducted in 1932 on the receding limb of a storm, and documented percolation as great as 40 cfs at stream flows of about 135 cfs. The current study measured percolation rates on the receding limb of a large storm that peaked on March 20, 2011 and found percolation of 6 cfs at a flow of 199 cfs. A major flood control project completed along lower Santa Paula Creek in 1998 has likely had a negative impact on the ability of this reach of Santa Paula Creek to percolate water to the groundwater basin. A number of recent flow measurements recorded minor gains in flow along the lower creek, likely related to a small area of rising groundwater located just upstream of the mapped northern boundary of the Santa Paula basin where beds of the San Pedro Formation are exposed in the creek bed. Minor inflows were also identified along the channelized lower portion of the creek. Measured groundwater elevations from wells near Santa Paula Creek show the regional water table to be well below the elevation of the creek bed, both historically and in recent times.

1 INTRODUCTION

United Water Conservation District (United Water) is a public agency within Ventura County, California that is charged with conserving the water of the Santa Clara Rivers and tributaries. United Water works to manage the surface water and groundwater resources within eight groundwater basins including the Santa Paula Basin. Recent interpretations (UWCD, 2009; UWCD, 2011) have indicated a long-term, gradual decline in groundwater levels in the Santa Paula basin. These interpretations have spurred a review and re-analysis of available hydrologic and hydrogeologic data that may assist in determining the factors contributing to the water level declines. This study is related to these efforts, and examines groundwater recharge along lower Santa Paula Creek in the area where it overlies the Santa Paula groundwater basin.

The primary objective of this study is to compare past measurements of percolation along lower Santa Paula Creek to recent measurements collected after construction of the U.S. Army Corps of Engineers (COE) flood control project. Visual observations suggest the percolation along the low-flow channel of the creek is minor, likely related to the compaction of shallow sediments along the channel bottom by heavy machinery during channel construction and the periodic removal of accumulated sediment. This document presents recent stream flow measurements from lower Santa Paula Creek and compares recent measurements to available historical records. Information related to groundwater elevations in wells near Santa Paula Creek and the vertical offset between the creek bed and the underlying water table are also presented.

1.1 GEOLOGY/HYDROGEOLOGY OF SANTA PAULA BASIN

The Santa Paula Basin is located within the valley of the Santa Clara River. Figure 1 is a surface geology map of the Santa Paula Basin. The basin is bounded by the Sulphur Mountain foothills on the northwest and South Mountain on the southeast. The basin is elongated in a northeast-southwest orientation. It is approximately 10 miles long and 3.5 miles wide. The surface area of 13,000 acres ranges in elevation from 130 feet above sea level (near Saticoy) to 270 feet above sea level near the City of Santa Paula. The major fresh water-bearing strata commonly utilized for groundwater production are the San Pedro Formation and various overlying deposits including alluvial fan deposits of various ages and recent alluvial deposits of the Santa Clara River and other stream deposits (Mann, 1959). The alluvial fan deposits of Santa Paula Creek occupy the northeast portion of the basin.

The basin sediments have been warped into a syncline that is oriented in a northeast-southwest direction. To the east, the Santa Paula Basin is considered to be in hydraulic connection with the Fillmore Basin. To the south, the Oak Ridge fault forms a partial barrier to groundwater movement. To the north, a portion of the aquifer represented by the San Pedro Formation is exposed in an outcrop along the Sulphur Mountain foothills. The Santa Paula basin borders the Oxnard Forebay and Mound basins on the west. The western boundary of the Santa Paula basin is more complex, with local uplift, artesian conditions, and faults mapped by some investigators. Although there is general agreement that there is some hydraulic connection between Santa Paula basin and the Mound Basin, the degree of connection is uncertain.

Hydrogen and oxygen isotope data, and other recorded data, indicate that the Santa Paula Basin receives recharge from the Santa Clara River (Reichard et al, 1999), by rainfall percolation through the San Pedro Formation outcrops that are exposed along the foothills to the north, and by percolation of streams crossing these sediments. Other sources of recharge are by percolation into the recent alluvium of Santa Paula Creek and other tributaries, and underflow from the Fillmore Basin. In general, inflow from the Fillmore Basin (United Water, 2011), along with infiltration of rainfall, streambed recharge from the Santa Clara River and streambed recharge from Santa Paula Creek appear to be the dominant recharge mechanisms for the basin.

Groundwater levels in the majority of wells throughout the basin show significant seasonal variability. Wells screened in the shallow alluvial aquifer near the Santa Clara River, however, show some of the least variability, and recorded wet-year highs are fairly stable over time in wells along the lower reach of Santa Paula Creek (UWCD, 2012). Groundwater flow in the Santa Paula basin is generally down the axis of the basin, from northeast to southwest.

1.2 CHANNEL MODIFICATIONS IN LOWER SANTA PAULA CREEK

The watershed of Santa Paula Creek drains approximately 45 square miles, and much of the area consists of mountainous terrain in an area dominated by recent geologic uplift. The steep terrain tends to produce significant runoff, and the erodible sedimentary rocks of the region produce high sediment loads during flood events (Stillwater Sciences, 2007 and 2007b). The alluvial fan at the mouth of Santa Paula Creek is completely developed, with agricultural land uses dominant on the east bank and residential development in and adjacent the City of Santa Paula the dominant land use on the west bank. Industrial activities predominate in the areas south of the railroad bridge. The high flows and high sediment loads of Santa Paula Creek resulted in persistent flooding problems in the lower reach of the creek since the time the area was first developed (HDR CDM, 2012).

Early proposals to channelize lower Santa Paula Creek were opposed by United Water, due to concerns that lining and channelization of the lower creek would diminish groundwater recharge to the Santa Paula basin. A major flood control project was approved in 1973, and in 1974 some 1,800 feet of the creek were channelized in the area immediately above the confluence with the Santa Clara River. The second and third phases of this project were never completed, as construction was blocked by a suit in the U.S. District Court, apparently related to the adequacy of National Environmental Policy Act (NEPA) documentation for the project. One of the environmental concerns related to the project was the potential impact to groundwater recharge (USACOE, 1991).

In spring 1996 the U.S. Army Corps of Engineers received authorization to remove the existing channel improvements and construct an extensive new flood control project along the entire lower reach of the creek. Construction began in 1997 and was completed in October 1998. The lower 1.5 miles of the creek were channelized with grouted stone channel side slopes, and an earth channel bottom ranges from approximately 40 to 120 feet in width. At the head of this section a fish ladder was constructed, and the channel bottom in the steeper segment hosting the fish ladder is grouted stone. Figure 2 shows the portions of Santa Paula Creek channelized by both the 1974 and 1998 flood control projects. Design drawings for the 1998 channel improvements are included in the appendix of this report. Sediment is normally deposited in the channel bottom during high-flow events, and this sediment is periodically removed from the channel to restore flow capacity.

Additional channel modifications were constructed upstream of the COE fish ladder near Bridge Road. Construction in this area largely consisted of grading the banks of the stream channel and placement of groins on opposing banks to center flow within the channel. The geomorphology and channel modifications in the 4.5 miles of channel located above the COE fish ladder remains an area of active study (Stillwater Sciences, 2007b).

2 PREVIOUS INVESTIGATIONS OF FLOW

Historical records exist from a number of prior studies that included flow measurements along Santa Paula Creek. Details from a number of these investigations are reported in the section.

The California Department of Public Works, Division of Water Resources published Bulletin No. 46, Ventura County Investigation, in 1933. This investigation was initiated following applications to appropriate water from upper Sespe Creek for use in the Ventura River watershed, and applications to appropriate water from Piru and Sespe Creeks for use in the Moorpark area. It was determined that not enough was known of the water resource of the County to adequately evaluate these proposals. Extensive records were collected between the years 1927 and 1932, allowing evaluation of the potential of a number of dam sites, characterization of geology and the groundwater basins in southern Ventura County, some potential routes for water conveyance pipelines, and opportunities to use groundwater spreading grounds in some locations.

In February and March of 1932, numerous daily stream flow measurements were collected along lower Santa Paula Creek. These measurements allowed assessment of streambed percolation in the approximately 3.5-mile reach between Mud Creek and the confluence with the Santa Clara River. These records are displayed in Table 1, and shown in Figure 3. Measurements collected in February 1932 were the highest flows recorded during the study. On five consecutive days flows at the upstream location ranged from 95 to 135 cfs, and percolation ranging from 25 to 41 cfs was measured. Over the following five days upstream flows fell from 91 to 69 cfs, and about 10% of these flows percolated along Santa Paula Creek between Mud Creek and the confluence with the Santa Clara River. Above-average precipitation was recorded in 1932.

In March of 1932 United's predecessor agency, the Santa Clara Water Conservation District, was operating the Santa Paula Creek Spreading Grounds, diverting as much as 20 cfs from the creek at a location 2.1 miles below Mud Creek. The approximate location of the spreading grounds are shown in the Appendix. While the diversion rates were measured, the reduction of in-channel flow along the lower 1.45 miles of Santa Paula Creek may have served to reduce percolation along the lower reach by reducing the width of the wetted channel. Measured percolation values in March 1932 ranged from about 3 to 12 cfs, with percolation percentages ranging from 10 to 98 percent (after correction for diversions). Santa Paula Creek percolation measurements from the times the spreading grounds were in operation are not further presented or characterized in this report.

In 1946 a study was conducted to assess percolation along lower Santa Paula Creek, motivated by concerns that a concrete-lined channel proposed for flood control purposes on lower Santa Paula Creek would reduce recharge to the Santa Paula basin. This study again measured the receding limb of winter storms during a wet period. Flow measurements from the investigation apparently were not published, but the study concluded that Santa Paula Creek percolates at rates similar to Sespe Creek and Hopper Creek. The study estimated that Santa Paula Creek contributes, on average, 2,000 acre-feet per year to the Santa Paula Basin (technical memorandum dated June 27, 1946, by Richard H. Jamison). The study concluded that this percolation estimate was on the low side, perhaps due to the lower observed percolation values as compared to the 1932 measurements. Also of note is that the spreading grounds along lower Santa Paula Creek were no longer active by this time.

In 1953 United Water Conservation District published the *Hydrologic Investigation of the Water Resources of the District* (UWCD, 1953), the document resulting from a significant effort by the District to quantify surface water runoff and groundwater resources in the Santa Clara River valley and on the Oxnard Plain. Included are monthly estimates of flow volumes for Santa Paula Creek for the years 1923 through 1952. The report included a plot of the estimated percolation capacity of lower Santa Paula Creek, although it is unclear how the percolation estimates were derived. A 1956 supplement to the 1953 Hydrologic Investigation revised many of the percolation curves published in the earlier report, as it was recognized that the original percolation estimates resulted in estimates of basin storage that were unrealistically high (UWCD, 1956). The original and revised percolation curves for Santa Paula Creek are shown in Figure 4. Percolation estimates for Santa Paula Creek flows greater than 1,300 AF/month (average flow of 22 cfs) were revised downward, while percolation estimates for flows less than 22 cfs remained unchanged.

In 1971 United Water, in cooperation with the County of Ventura, conducted yet another study to measure spring runoff and percolation along lower Santa Paula Creek, likely for the same purposes as the 1946 study. The winter of 1971-1972 lacked significant storms, and no measurements over 24 cfs were collected at the upstream location near Bridge Road. The percolation rates identified in this study are modest, generally less than 4 cfs, (Table 1 and Figure 3). While records exist from this joint investigation, a formal publication was apparently not drafted. A 1992 environmental assessment for a channel repair project in the lowermost reaches of Santa Paula Creek does however include the following two sentences as the groundwater characterization for the document: *According to the 1983 Design Memorandum No. 4, Supplemental Design No. 2, groundwater recharge occurs in Santa Paula Creek downstream of the Mupu School, where bedrock dips steeply and is overlain by recent alluvium. The average annual recharge rate was established as 850 acre feet by the Ventura County Flood Control District in 1973* (USACOE, 1992). This estimate of annual recharge may well be based on the gauging conducted in the winter of 1971-72, when rainfall and runoff totals were modest.

In the early 1990s the U.S. Geological Survey conducted an investigation of surface water and groundwater along the Santa Clara River, in cooperation with United Water Conservation District. The main focus of study was evaluation of gaining and losing reaches of the river, but several low-flow measurements were collected along lower Santa Paula Creek. The USGS low-flow measurements from 1993 and 1994 recorded percolation rates of up to 4 cfs in the reach between a location near Bridge Road and the railroad bridge near Harvard Blvd. (Reichard et al, 1999). Records from this investigation are displayed in Table 1 and Figure 3.

3 RECENT MEASUREMENTS OF FLOW

United Water staff recently collected stream flow data during low and somewhat higher discharge conditions, with most measurement collected in April and May of year 2011. Stream flow measurements were collected using Sontek® FlowTracker flow meters, following USGS standard protocols. Transects were established across Santa Paula Creek where channel conditions were suitable for measurements. Flow velocity and water depth were measured at increments across the channel, allowing the calculation of river flow. Details of the individual measurements are included in the Appendix. Upstream measurements were performed first, with downstream measurements performed soon thereafter, allowing measurement of the same unit of water to the degree practical. The timing of measurements in this manner serves to minimize the uncertainty of flow measurements related to potential changes in flow between measurements caused by losses of flow other than by stream percolation. Plots of 5-minute flow data from USGS gauge 11113500 (located 2.1 miles upstream) are shown in the Appendix.

In spring 2011, five sets of paired measurements were made following the last significant storm of the year, which produced peak runoff of approximately 12,000 cfs on March 20 (USGS Gauge 11113500, see location on Figure 2). A flow measurement on April 1, 2011 recorded flow of nearly 200 cfs at a location downstream of Bridge Road and near the Mupu Elementary School. Given the channel characteristics of this portion of Santa Paula Creek, this is about the highest flow that can be safely measured while wading the creek (see photographs in the Appendix). The remaining measurements were collected over the following eight-week period as flow in the creek steadily diminished. The flow measurements were collected near the same locations used in the earlier 1932 and 1972 studies (upstream measurements were made at a location 0.4 miles below Bridge Road, and downstream measurements were made at a point just south of the Harvard Boulevard bridge, as shown in Figure 5). The paired flow measurements allow a calculation of percolation (or gain) along the approximately 2.3 mile reach between the two gauging locations. Additional measurements were collected in September 2011 and February 2012.

Recent measurements of flow in lower Santa Paula Creek are shown in Table 1. The records show that on April 1, 2011 flow near Bridge Road was nearly 199 cfs, and flow below Harvard Blvd. was about 192 cfs. These records indicate percolation of 6.4 cfs, or just 3.2 percent of the flow in the creek. On May 26, 2011, measured flow along the same reach diminished from 17.7 cfs to 16.8 cfs, indicating percolation of less than one cfs. The remaining UWCD measurements from 2011 and 2012 show small gains in flow between the two stations. Gains of nearly five cfs were measured on two dates in April 2011, when upstream flows near Bridge Road were measured at 64 and 42 cfs.

Much of the increased flow likely comes from the area located above the COE fish ladder, near the northern mapped extent of the Santa Paula groundwater basin. In the vicinity of Maple Street, beds of the steeply dipping San Pedro Formation are visible within the stream channel (Figure 4). Immediately upstream of this area alluvial creek deposits overlie the older deposits, and the growth of riparian vegetation along a couple channel lineations here suggest the discharge of shallow water back to the stream channel. Additional flow measurements were not collected in this area, as this feature was recognized after field work for this study had concluded.

Seeps are sometimes observed along the west bank of the creek in the area below the COE fish ladder. Seepage from shallow perched zones along the creek contribute minor inflow to the creek (see shallow groundwater discussion, next section). Flow measurements were not conducted up- and down-stream of the reach where seepage is observed, as observed flow is small and intermittent. Photographs of the seeps are included in the Appendix.

Some degree of error is associated with all of the flow measurements reported in this Open-File Report. The SonTek FlowTracker used by United to measure stream flow provides an estimate of the uncertainty associated with each measurement. The estimate of potential measurement error is based on variability among the velocity, depth and width terms from each stream transect where flow is gauged (SonTek, 2007). Estimated error was generally less than 4% for United's 2011 and 2012 measurements. The estimated error for the high-flow measurement on 4/1/2011 was 3.5% (7 cfs). Similar error is likely associated with both recent and historic measurements of flow in lower Santa Paula Creek, as gauging methods are assumed to be similar.

4 INTERACTION WITH GROUNDWATER

Few active wells exist in close proximity to the channel of the lower reach of Santa Paula Creek. Water levels in 15 historic and active wells located within 2,000 feet of the creek were reviewed in order to evaluate whether changes in groundwater conditions might influence percolation rates along the creek. Groundwater elevations at or near the channel elevation of Santa Paula Creek would likely influence percolation from, or groundwater discharge to, the creek.

4.1 SHALLOW GROUNDWATER

Along the west bank of Santa Paula Creek, in the area below the COE fish ladder, a number of seeps can be observed along the grouted rock that forms the side of the channel. Several seeps are located adjacent a surface water reservoir (pond) located within 50 feet of the embankment of the flood control channel, with seeps extending about 300 feet downstream from the reservoir location (Figure 5). The reservoir is on the Wilson ranch, and believed to receive water delivered from the Harvey Diversion some distance upstream. Increased flow in these seeps is commonly observed following irrigation events at the Wilson ranch (personal communication with landowner Chris Wilson, October 2012). The observed relationship between irrigation adjacent the creek and increased flow in the seeps along the west side of the constructed channel suggest shallow units of low permeability that serve to produce localized perched water table conditions in this vicinity.

A couple additional seeps can be observed along the west bank of the channel near the terminus of Say Road, located approximately 500 feet downstream of the seeps near the Wilson pond.

Irrigated orchards occupy the upland area adjacent the flood control channel at this location as well. Shallow perching layers likely exist in these upper areas of the alluvial fan of Santa Paula Creek, and result in the discharge minor flows of irrigation return water to this portion of Santa Paula Creek. However, a majority of the driller's logs for nearby wells do not note clays at depths shallower than 100 feet.

A drain is located along the grouted side of the creek channel at the extension of Richmond Road. Considerable discharge is periodically observed in this drain, which is the discharge point for a city water supply reservoir located some 4,000 feet to the west on upper 10th Street. South of this location wet seeps or drains are not observed on the west bank of lower Santa Paula Creek.

Along the east bank of lower Santa Paula Creek, irrigated orchards occupy upland areas adjacent the creek channel from the vicinity of the COE fish ladder south to the railroad bridge. No seeps are observed on the east side of the channel, suggesting shallow perching beds are absent along this channel reach, or the orientation of geologic bedding directs percolating water away from the channel.

4.2 GROUNDWATER ELEVATIONS IN WELLS

All known water level records for wells located near Santa Paula Creek are shown in Figure 6. Well records are clustered by location and plotted on a consistent scale. Screened intervals are not reported. Good records exist for wells on both side of the creek since the early 1970s, but records are spotty for earlier periods.

Water level records begin for a number of wells in the late 1920s, following the formation of United Water's predecessor agency, the Santa Clara Water Conservation District. The District operated the Santa Paula Creek spreading grounds for the years 1931 through 1941, which consisted of a series of unlined pools and drop structures along a conveyance channel located near the east bank of Santa Paula Creek. Photographs of the facility are included in the Appendix. Monthly spreading totals are displayed in Table 2, which shows annual spreading averaged approximately 1,800 AF per year over the eleven-year duration of the project. Operation of the facility was abandoned due to persistent high water levels in the vicinity. A cartoon depiction of groundwater elevations near lower Santa Paula Creek in the early 1930s is included in the Appendix. Well control for the diagram is poor, and the transect is drawn at a location well south of the location of the Santa Paula Creek spreading facilities.

Water level records displayed in Figure 6 show that, with few exceptions, water levels were no higher in the early 1930s than they were in the late 1970s. Recorded annual highs are slightly lower in a number of wells in the years following construction of the COE flood control project on lower Santa Paula Creek (completed in 1998). Reduced groundwater recharge related to channel modifications (channel narrowing and concrete sides) and the compaction of sediments along the channel bottom is likely a causal factor in the lower groundwater elevations observed in this area in recent years.

4.3 CHANNEL ELEVATIONS OF SANTA PAULA CREEK

The documentation of historic channel elevations for Santa Paula Creek appears to be somewhat sparse, but at least some measurements of channel elevation are readily available. Topographic maps show channel elevations in the years 1903 and 1951, and LiDAR elevations are available from 2005. Profiles of the channel invert were also drafted in 1977 and prior to the construction of the COE project in the mid-1990s. These data allow a comparison of recorded groundwater elevations in wells near Santa Paula Creek to the elevation of the channel of the creek, which has changed over time.

The USGS Santa Paula Quadrangle (1951) shows a channel elevation of 340 feet above sea level at a location due west of well 03N/21W-11B01S, commonly known as the Newsom well. An earlier edition of this map, dated 1903 and reprinted in 1942, shows a channel elevation of about 335 feet above sea level due west of the Newsom well, with the active channel located some distance east of its current alignment. Figure 7 displays profiles generated from these two topographic maps, and an additional profile based on LiDAR data collected in 2005. The profile shows that the elevation of the channel has changed very little over time in the area downstream of the railroad bridge (~ 3,500' above SCR confluence), but the 2005 channel elevation upstream of this point to the base of the COE fish ladder is about 20 feet lower than represented in the earlier maps. The LiDAR profile shows an channel elevation of approximately 320 feet above sea level at the location due west of the Newsom well (approximately 6,000 feet above the confluence).

The channel elevation west of the Newsom well was surveyed in August 2010. The land elevation at the Newsom well is 334.8 feet above sea level, as determined by a LiDAR survey conducted in 2005. The elevation of the channel of Santa Paula Creek was surveyed from the well site with rod and level in 2010, and the water surface within the creek channel (invert) some 1,000 feet west of the well was measured at 308.2 feet above sea level. The water surface elevation in Santa Paula Creek west of the Newsom well was recently resurveyed, and measured at 313.24 feet. At the time the low-flow channel was incised about three feet in the broader plane of the channel sediments. This measurement is more in line with both the channel elevation documented in the 2005 LiDAR survey and the planning documents for the COE project. Channel elevations remain variable over time due to changing bedforms in the channel, deposition during high flow events, and the periodic excavation of accumulated sediment.

A planning document for the 1998 project includes a channel profile that shows the Santa Paula Creek channel invert from a survey conducted in 1977. Mile 0 appears to be the confluence with the Santa Clara River, with the Harvard Blvd. bridge located at mile 0.7. This would place the western projection from the Newsom well just downstream of mile 1.2. The 1977 creek profile shows an elevation of approximately 340 feet at this location, consistent with the elevation reported on the 1951 topo map. The 1977 channel profile (USACOE) is included in the Appendix.

The planning document for the 1998 flood control project (USACOE, 1995) also shows proposed channel profiles and cross-sections from below the Highway 126 bridge to the COE fish ladder (see Appendix). In these drawings, the downstream extent of the Harvard Blvd. bridge is identified as mile 0.58. The Newsom well is located due east of Station 71+10, at River Mile 1.02. The plans show an existing channel invert of 323 feet, a proposed channel invert of 317 feet, and the toe of the proposed grouted stone sidewall at 312 feet. United Water has been unable to locate “as-built” drawings for the flood control project to confirm the project was constructed as proposed in 1995.

The channel cross-sections included in the planning document show the proposed channel bottom is commonly ten or more feet below the existing channel invert. The sections also show the distance between the toes of the grouted sidewalls ranging from approximately 40 to 120 feet. Several photos of channel conditions in the early 1990s, before the major COE project, are included in the Appendix. The grouted sidewalls of the modern channel severely limit the potential for riverbank recharge during large flow events.

Comparison of historic channel elevations at the location west of the Newsom well (~340 feet) to the proposed channel invert (of approximately 317 feet) shows channel lowering of about 23 feet in this vicinity following construction of the COE flood control project. Channel bed elevations remain variable over time, with the deposition of sediment during flood events and the periodic re-excavation of the channel (some 300,000 cubic yards of sediment deposited in 2005 was removed in late 2009). Channel material has been periodically removed from the lower Santa Paula Creek channel since at least 1978 (Stillwater Sciences, 2007b). Recent channel elevations upstream of the railroad bridge are thought to be consistently lower than they were historically, as the COE project in the 1990s excavated a large quantity of alluvial material to increase to flood flow capacity of the lower reaches of the Santa Paula Creek. The current flood control channel is designed to pass 28,000 cfs, and constructed banks are as high as 40 feet (HDR CDM, 2012).

4.4 COMPARISON OF CHANNEL ELEVATIONS AND GROUNDWATER ELEVATIONS

Water levels in the Newsom well have been measured regularly since fall 1980, and the well was instrumented with a pressure transducer in May 2010. In March 2011, transducer records from this well record a high groundwater elevation of 260 feet, and the 2012 high water level was measured at 254.5 feet on April 15. The historic high groundwater elevation recorded in this well, with records dating to 1980, is 270.54 feet (recorded in February 1997). This high groundwater elevation is nearly 46.5 feet lower than the excavated channel elevation (~317 feet) that resulted from the COE project.

Well 03N21W02P01S was located near the east bank of Santa Paula Creek, a short distance northwest of the Newsom well. Historic records from this well document high groundwater elevations of 279 feet in year 1978, representing the highest recorded groundwater elevation for any well near Santa Paula Creek. This high groundwater elevation was 60 lower than the nearby channel elevation (340 feet, as mapped in 1951).

In the vicinity of Hwy 126, wells near Santa Paula Creek recorded historic (1978) highs of approximately 263 feet above sea level. The 1951 USGS quadrangle maps a channel elevation of approximately 280 feet in this vicinity. Available data suggest that channel elevations have changed little in this vicinity over the period of record (see Figure 7).

Available records for groundwater elevations in wells near Santa Paula Creek in the area where the creek overlies the Santa Paula groundwater basin show separation of at least 17 feet between the creek bottom and recorded historic groundwater levels, with this minimum offset between channel invert elevation and regional groundwater elevations observed near the confluence of Santa Paula Creek and the Santa Clara River. A mile north of the confluence, the minimum-recorded separation between measured channel bed elevations and the underlying water table is about 40 feet. This recorded separation between the channel bottom and the water table suggest that for the period 1928 to present, the regional water table of the Santa Clara River valley has never intercepted the channel of lower Santa Paula Creek. This lack of convergence indicates no direct connection between the creek channel and the underlying regional water table, such as would be required for the creek to gain flow from groundwater. Inflow associated with urban sources and irrigation return flow has however been documented along specific segments of the lower creek, but observed flow associated with these sources are minor and not from the regional water table. Rising groundwater is however thought to periodically exist near the northern basin boundary, where the recent alluvium of Santa Paula Creek deposits thin and dipping beds of the San Pedro Formation are exposed in the creek channel. The potential for groundwater mounding below the channel during periods of sustained high flow in the creek remain undetermined, but the relatively low percolation rates documented along the modern lower channel of Santa Paula Creek suggest the potential for significant groundwater mounding is minor.

5 OBSERVATIONS & FINDINGS

In spring 2011, five pairs of measurements were made along lower Santa Paula Creek following a large storm that peaked at approximately 12,000 cfs. The first measurement was made at a flow of 199 cfs, and the corresponding downstream recorded a loss of 6.4 cfs. This recorded percolation, however, lies within the accepted range of error for the methods employed. Additional measurements were collected at 64, 41, 27, and 18 cfs. Three of these four measurements indicated a slight gain in the river, likely related to rising groundwater in the upper segment of the measured reach, and minor seeps and inflows below the COE fish ladder. Greater confidence is assigned to some of these measurements, as recorded gains in flow exceed the 4% error range that may be associated with the measurements. The area of rising groundwater along Santa Paula

Creek near the groundwater basin boundary was not recognized until after field measurements were concluded.

Gauging locations were selected to correspond with earlier investigation of percolation on lower Santa Paula Creek. Percolation rates measured as part of this study are considerably less than those recorded in 1932, when percolation rates ranged from about 9 to 34 percent of flow the flow near Bridge Road. Percolation percentages generally diminished with time and with diminished flow over the ten days when measurements were collected.

Low-flow measurements from the early 1970s and the early 1990s consistently recorded percolation in lower Santa Paula Creek, with no recorded instances of gaining flows.

In the wet spring of 2011, rising groundwater was likely contributing flow to the creek in the area of the northern basin boundary, where San Pedro Formation deposits are exposed in the creek channel. The magnitude of this inflow was not assessed.

Irrigation return flows from orchards located near the creek appear to contribute minor flow to the stream channel. This is observed most notably as small seeps on the west bank of the flood control channel in the area just south of the COE fish ladder. Shallow perching layers of unknown extent likely exist in this vicinity. Seeps are not observed along the east bank of the creek.

Available records of groundwater elevations in wells located near Santa Paula creek indicate that significant offset exists, both recently and historically, between the elevation of the creek channel and the elevation of the regional groundwater table. Given the observed percolation rates in 2011, the potential for groundwater mounding below lower Santa Paula Creek is believed to be minor.

Recorded groundwater elevations suggest that even though the 1998 COE project deepened the channel elevation of lower Santa Paula Creek, channel elevations remain well above the regional water table. No available records indicate a convergence of the channel elevation and the regional water table, such that the channel of the creek might drain groundwater from the basin.

6 CONCLUSIONS

Based on the results of this study, United Water offers the following conclusions:

- The 1932 DWR study found that percolation was occurring at rates similar to the Sespe Fan in the Fillmore basin, with measured percolation as great as 33 cfs with upstream flow of 95 cfs, and 41 cfs with upstream flow of 135 cfs;

- Recent measurements show little to no percolation in lower Santa Paula Creek, suggesting the COE flood control project completed in 1998 has impaired the ability of the creek channel to provide recharge water to the groundwater basin;

- Measuring upstream flow near Bridge Road does not allow for a quantification of rising water near the Santa Paula basin boundary, which also precludes an accurate assessment of percolation in Santa Paula Creek in the reach below the COE fish ladder;

- The channel elevation of lower Santa Paula Creek does not currently or historically intercept the regional water table, so the changes in channel elevation associated with the COE project did not significantly change groundwater interactions with the creek. Channel elevations have not changed significantly in the lowest portion of the creek, where separation from the regional water table is the less than in upstream areas.

7 RECOMMENDATIONS

While recent measurements suggest that percolation along lower Santa Paula Creek is minor, United Water offers the following recommendations that might serve to improve understanding of recharge volumes and recharge dynamics along lower Santa Paula Creek:

- Continue to periodically measure the percolation rates in Santa Paula Creek to gather data over a larger range of flows, to the extent practical;

- Perform additional gauging to measure rising groundwater along Santa Paula Creek near the northern basin boundary, and to measure recharge in the reach below the COE fish ladder;

- Perform gauging during or soon after the wetting of a dry channel by a significant flow event, allowing determination of recharge under dry antecedent conditions. Consider using gauging equipment that is safe and accurate at higher flows;

- Increase monitoring of wells near Santa Paula Creek in an effort to document recharge from the creek associated with high-flow events (monitor additional wells, some with transducers);

- Seek additional historic records relating to flow and recharge along lower Santa Paula Creek, as the records known to exist and presented here are relatively sparse.

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FIGURES

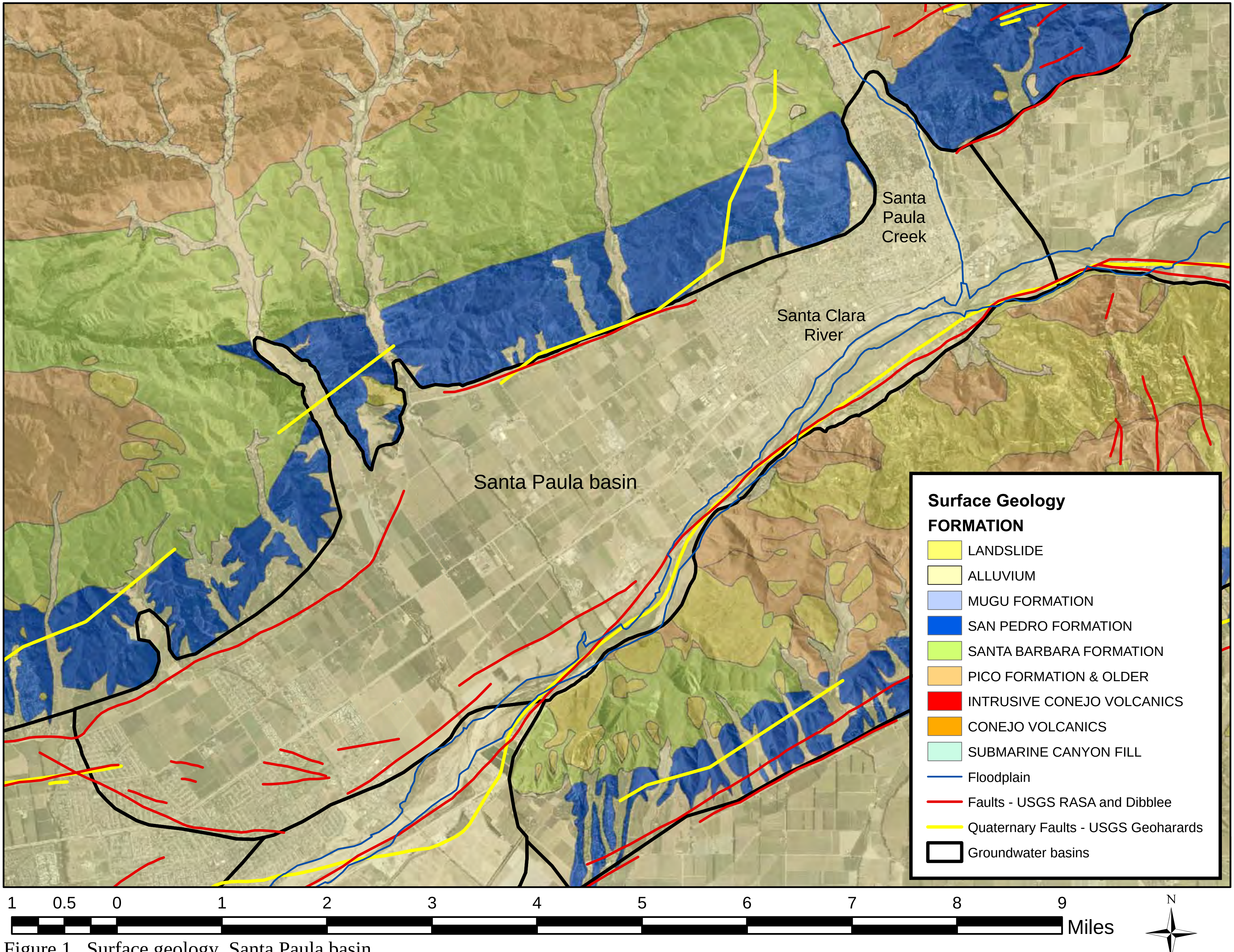


Figure 1. Surface geology, Santa Paula basin

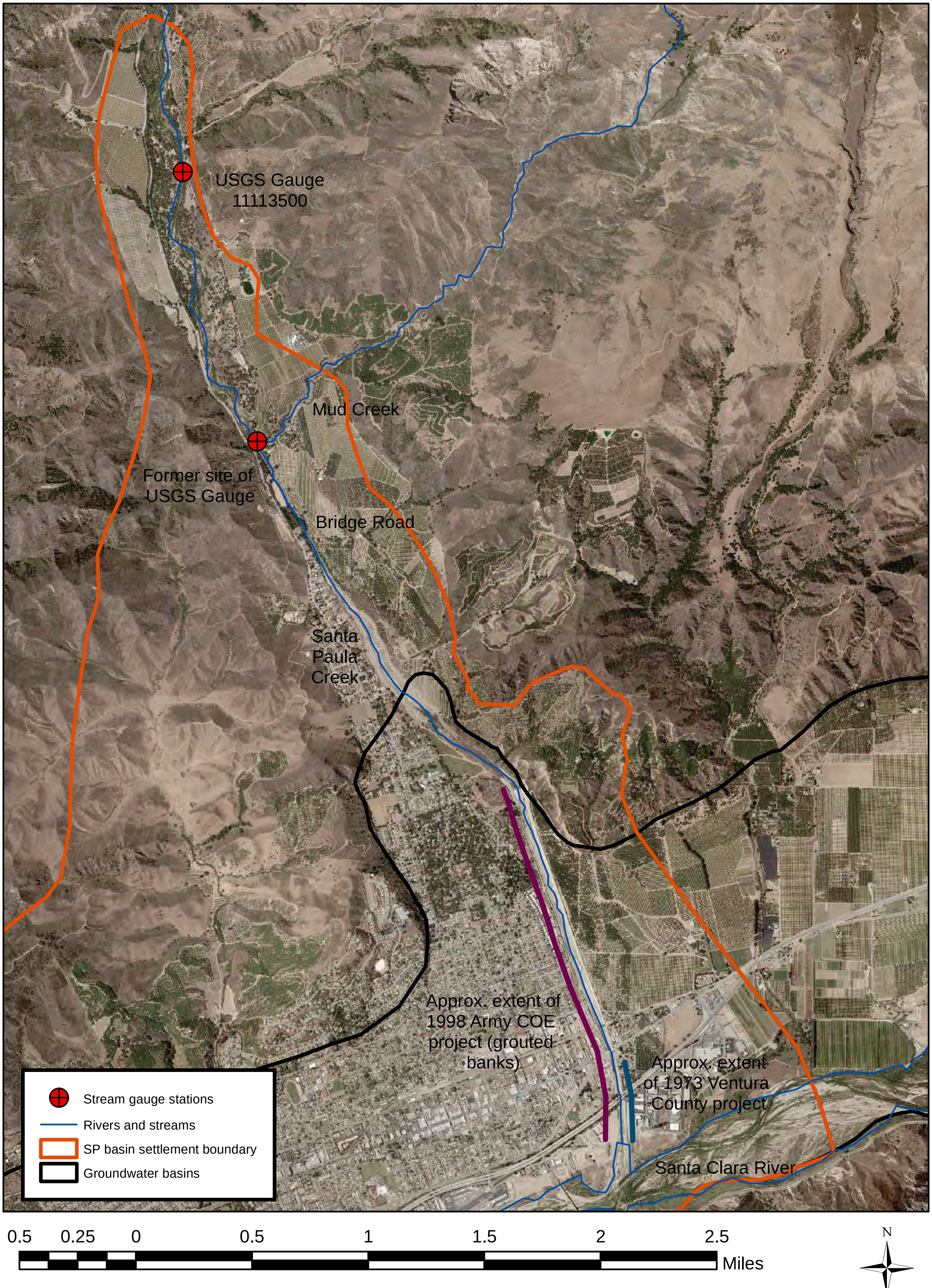


Figure 2. Gauging stations, landmarks and channelization along lower Santa Paula Creek

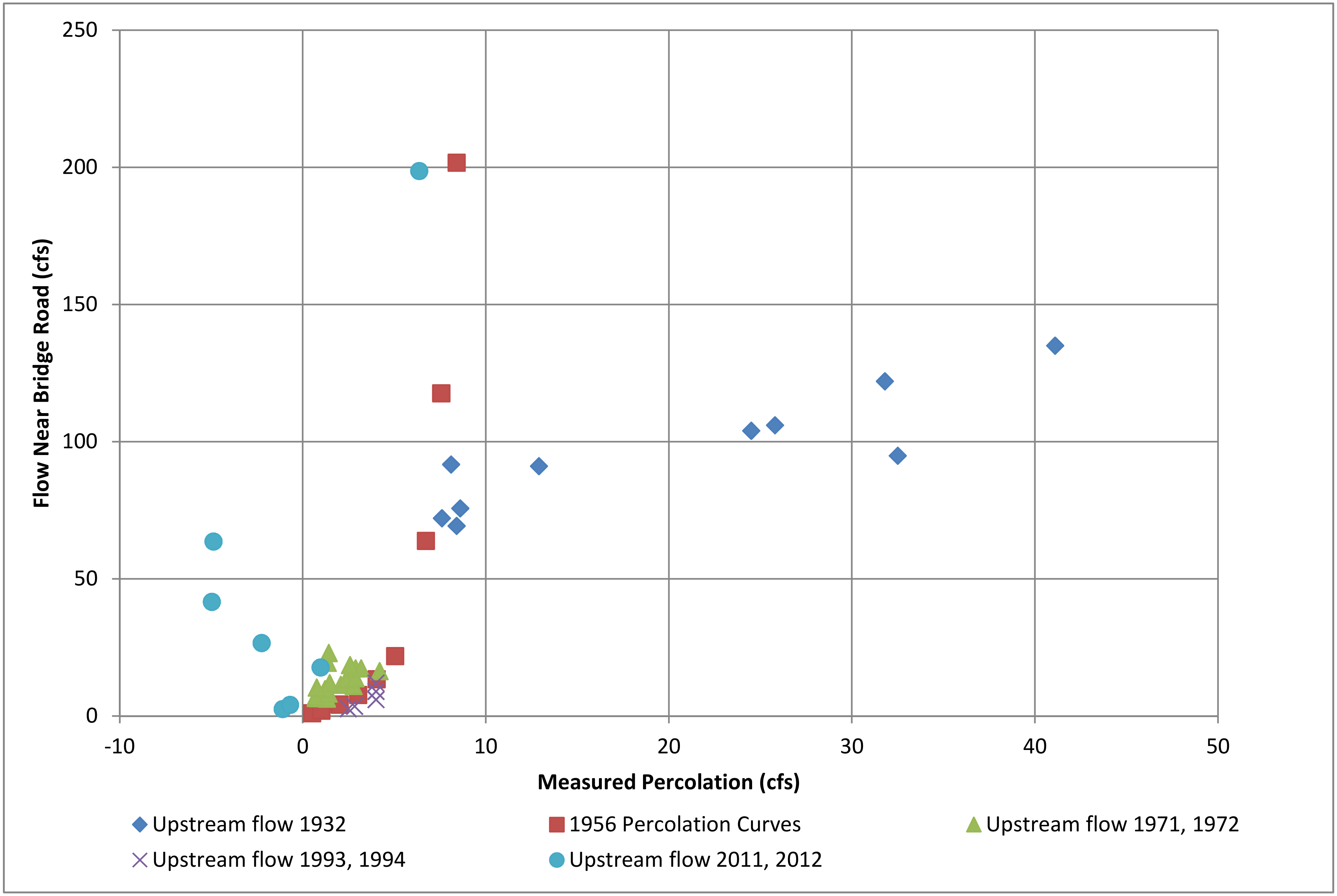


Figure 3. Measured flow and percolation, lower Santa Paula Creek

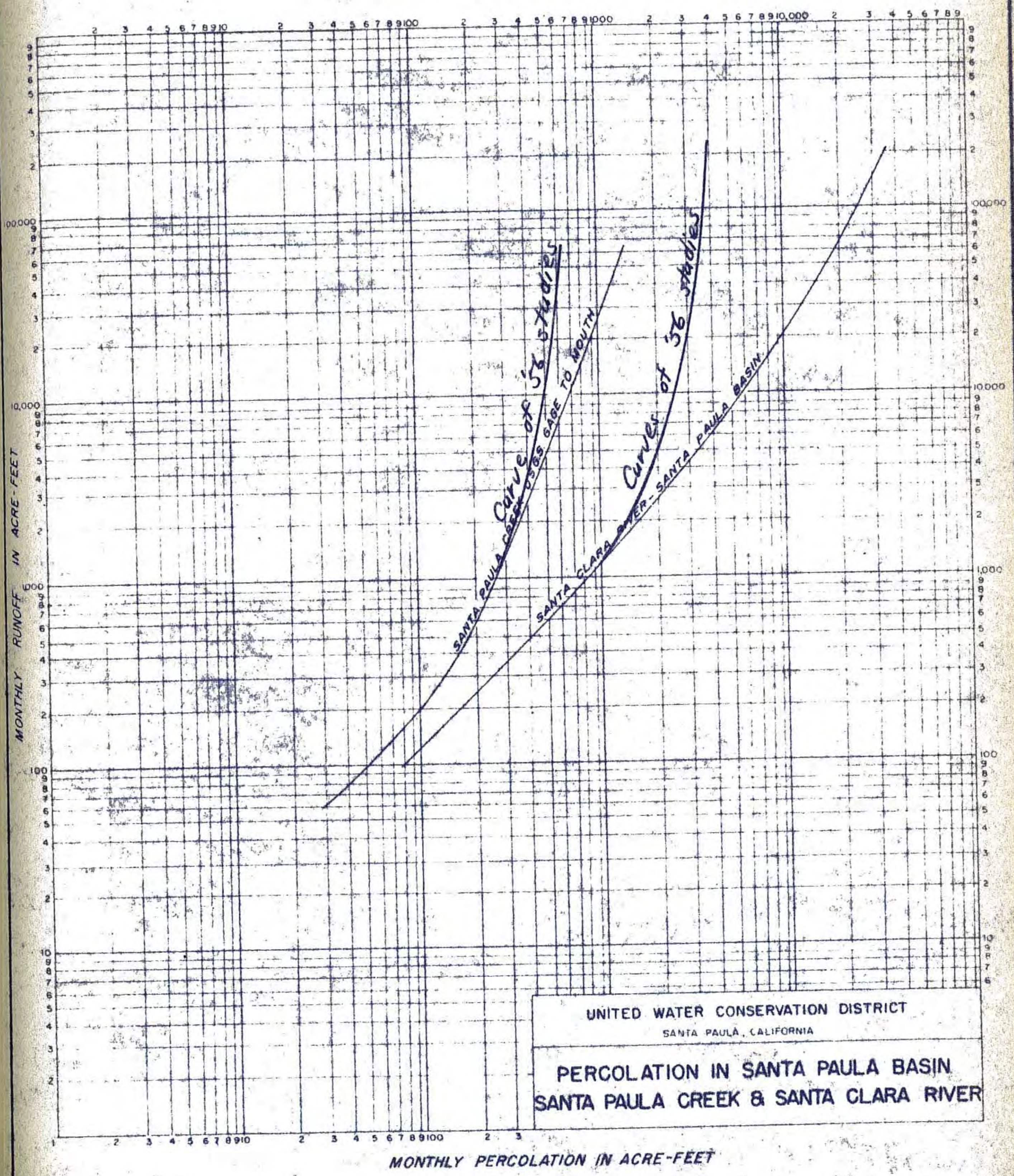


Figure 4. Flow and percolation, lower Santa Paula Creek (UWCD, 1956)

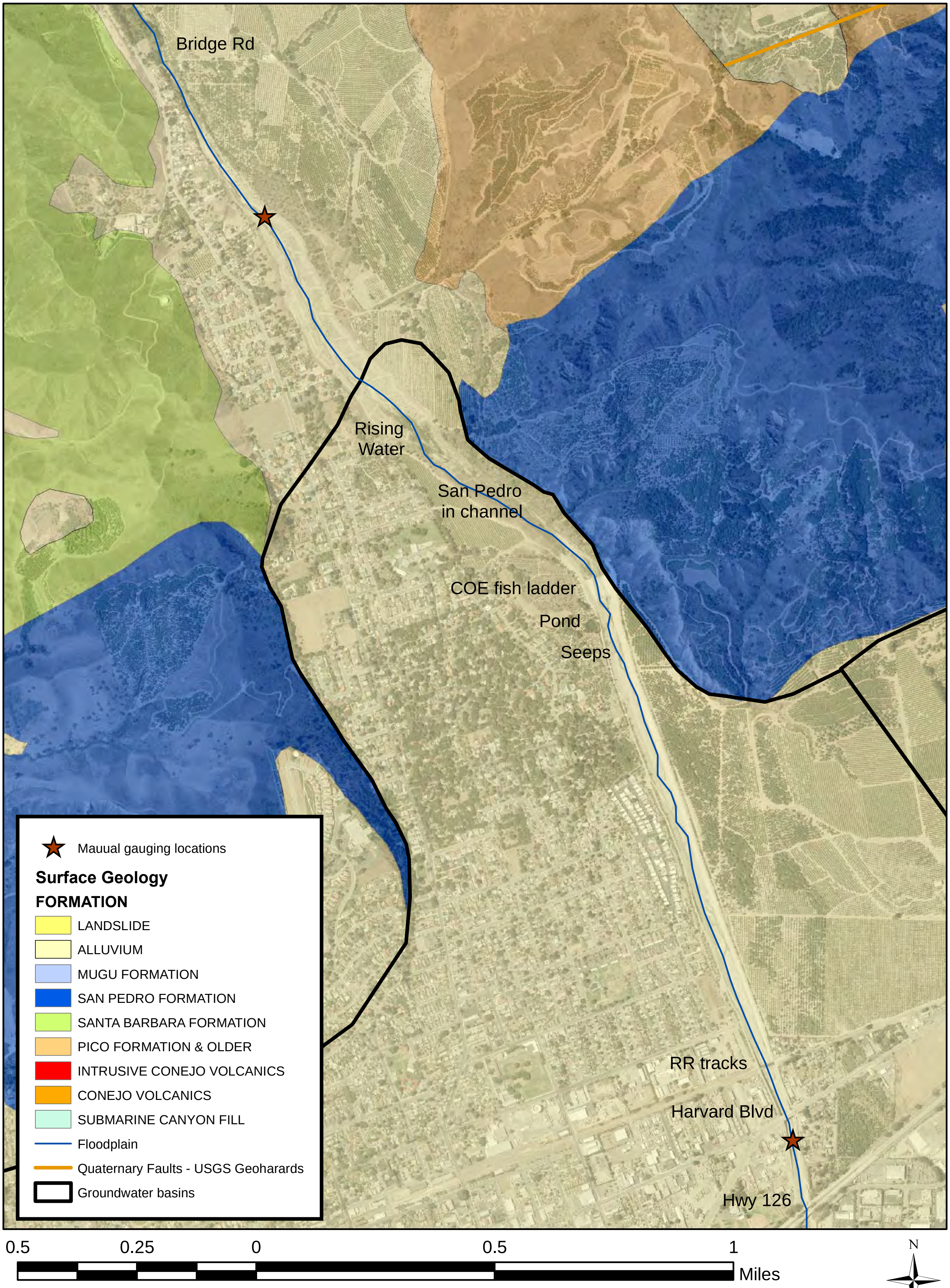


Figure 5. Santa Paula Creek geology, recent gauging locations and selected features

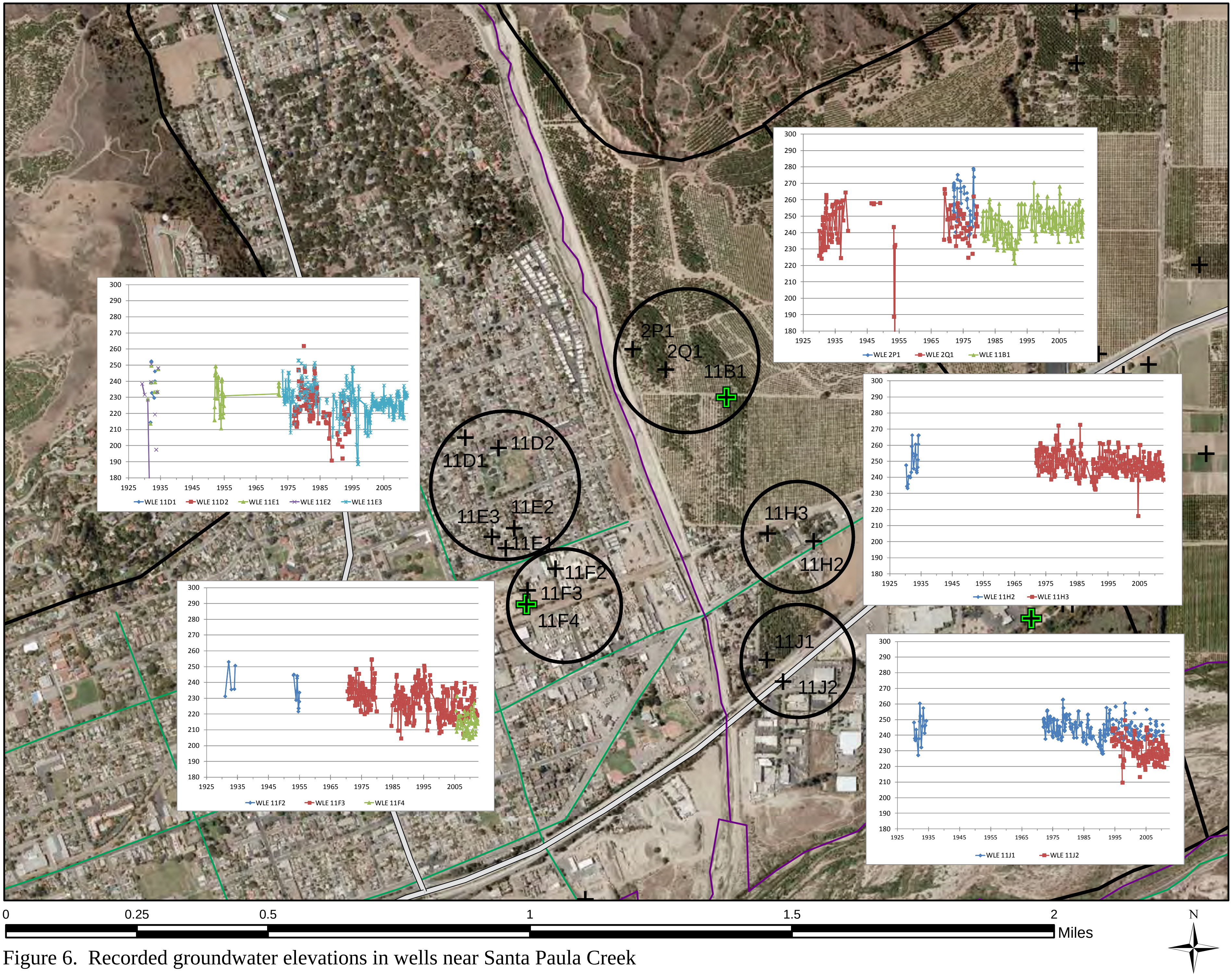


Figure 6. Recorded groundwater elevations in wells near Santa Paula Creek

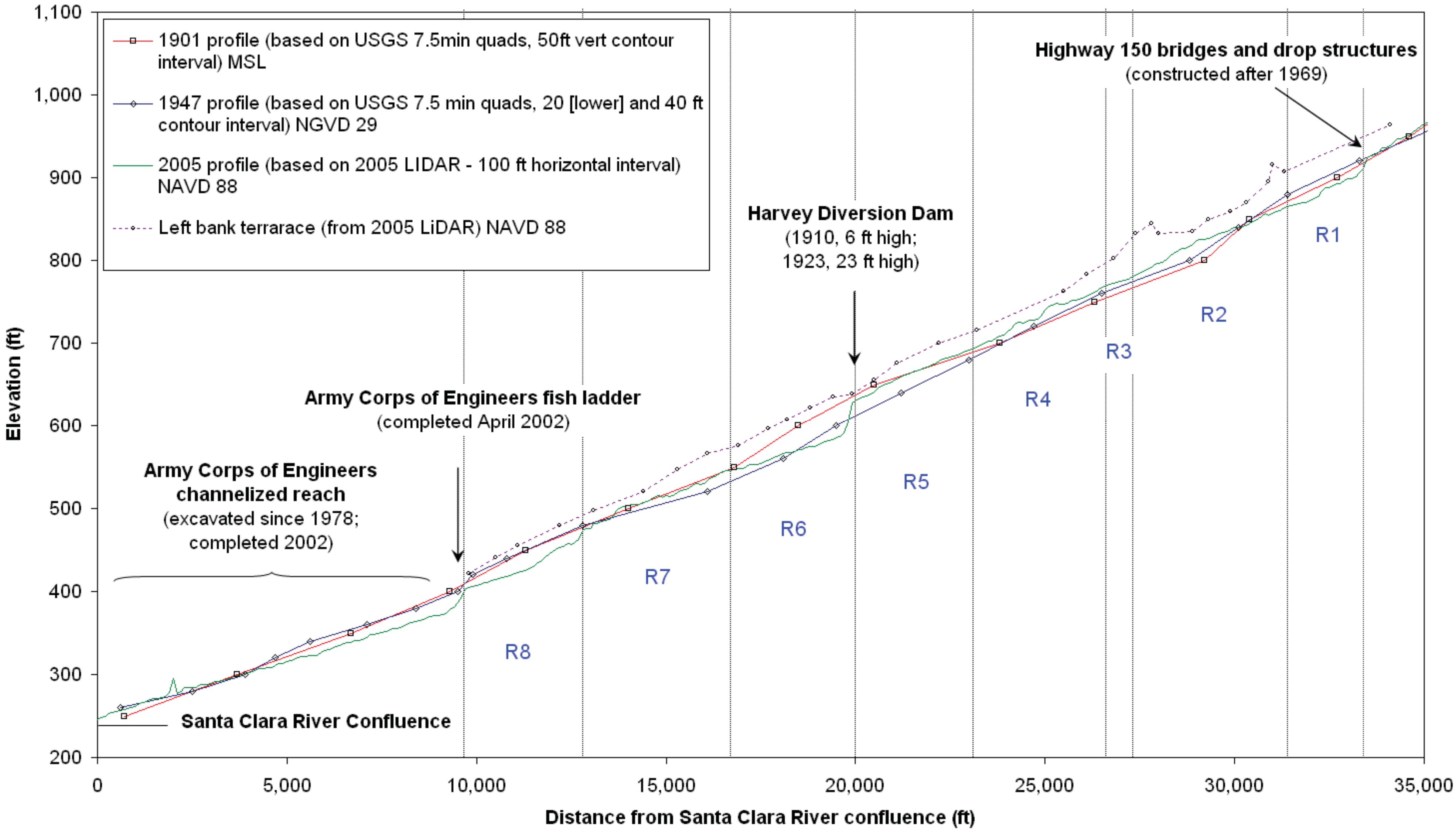


Figure 7.

Longitudinal profiles (1901, 1947, and 2005) for Santa Paula Creek from the Highway 150 bridge to the confluence with the Santa Clara River. (Stillwater Sciences, 2007b)

TABLES

Table 1. Measured flow (CFS) along lower Santa Paula Creek

Study	Date	Near Gauging Station (inc Mud Ck. Flow @ Mile 0)	SP Creek below Bridge Road (Mile 0.55)	Diversion to Spreading Grounds (Mile 2.1)	SP Creek above Spreading intake (Mile 2.1)	Creek between RR and State Hwy (Mile 3.1)	1700 Ft below Highway Bridge (mile 3.55, at SCR)	Percolation	Percent Percolation
DWR Bulletin 46	2/14/1932	135		0			93.9	41.1	30.4%
DWR Bulletin 46	2/15/1932	122		0			90.2	31.8	26.1%
DWR Bulletin 46	2/16/1932	106		0			80.2	25.8	24.3%
DWR Bulletin 46	2/17/1932	104		0			79.5	24.5	23.6%
DWR Bulletin 46	2/18/1932	94.9		0			62.4	32.5	34.2%
DWR Bulletin 46	2/19/1932	91.1		0		78.2		12.9	14.2%
DWR Bulletin 46	2/20/1932	91.7		0	84		83.6	8.1	8.8%
DWR Bulletin 46	2/22/1932	75.7		0			67.1	8.6	11.4%
DWR Bulletin 46	2/23/1932	72.1		0			64.5	7.6	10.5%
DWR Bulletin 46	2/24/1932	69.3		0			60.9	8.4	12.1%
1953 curve, UWCD		1.01					0.50	0.50	50.0%
1953 curve, UWCD		2.02					1.01	1.01	50.0%
1953 curve, UWCD		4.20					2.18	2.02	48.0%
1953 curve, UWCD		7.73					4.71	3.03	39.1%
1953 curve, UWCD		13.45					9.41	4.03	30.0%
1953 curve, UWCD		21.85					16.81	5.04	23.1%
1953 curve, UWCD		63.87					57.14	6.72	10.5%
1953 curve, UWCD		117.65					110.08	7.56	6.4%
1953 curve, UWCD		201.68					193.28	8.40	4.2%
1953 curve, UWCD		336.13					326.89	9.24	2.8%
1953 curve, UWCD		504.20					494.29	9.92	2.0%
1953 curve, UWCD		672.27					662.18	10.08	1.5%
1953 curve, UWCD		1008.40					997.98	10.42	1.0%
1971-72 recs, UWCD and VCFCD			6.4			5.1		1.3	20.5%
1971-72 recs, UWCD and VCFCD			6.5			5.6		0.9	13.2%
1971-72 recs, UWCD and VCFCD			6.6			5.3		1.3	19.9%
1971-72 recs, UWCD and VCFCD			6.6			5.9		0.7	10.7%
1971-72 recs, UWCD and VCFCD			7.1			6.4		0.7	10.0%
1971-72 recs, UWCD and VCFCD			8.2			6.8		1.4	17.2%
1971-72 recs, UWCD and VCFCD			9.8			8.6		1.2	12.4%
1971-72 recs, UWCD and VCFCD			10.4			9.6		0.8	7.3%
1971-72 recs, UWCD and VCFCD			11.4			9.3		2.1	18.2%
1971-72 recs, UWCD and VCFCD			12			10.5		1.5	12.2%
1971-72 recs, UWCD and VCFCD			11			8.2		2.8	25.3%
1971-72 recs, UWCD and VCFCD			13.4			11.0		2.4	17.7%
1971-72 recs, UWCD and VCFCD			13.8			10.9		2.9	20.9%
1971-72 recs, UWCD and VCFCD			16.4			12.2		4.2	25.6%
1971-72 recs, UWCD and VCFCD			17.4			14.5		2.9	16.5%
1971-72 recs, UWCD and VCFCD			17.4			14.2		3.2	18.3%
1971-72 recs, UWCD and VCFCD			18.6			16.0		2.6	13.8%
1971-72 recs, UWCD and VCFCD			19.4			18.0		1.4	7.0%
1971-72 recs, UWCD and VCFCD			23			21.6		1.4	6.1%
USGS WRIR 98-4208	8/16/1993		12			8		4	33.3%
USGS WRIR 98-4208	9/2/1993		9			5		4	44.4%
USGS WRIR 98-4208	10/29/1993		6			2		4	66.7%
USGS WRIR 98-4208	8/2/1994		3.57			0.74		2.83	79.3%
USGS WRIR 98-4208	9/24/1994		2.66			0.18		2.48	93.2%
UWCD 2011	4/1/2011		198.66			192.3		6.36	3.2%
UWCD 2011	4/12/2011		63.63			68.51		-4.88	-7.7%
UWCD 2011	4/19/2011		41.64			46.61		-4.97	-11.9%
UWCD 2011	5/2/2011		26.63			28.88		-2.25	-8.4%
UWCD 2011	5/26/2011		17.72			16.75		0.97	5.5%
UWCD 2011	9/8/2011		2.56			3.66		-1.1	-43.0%
UWCD 2012	2/16/2012		4.1			4.8		-0.7	-17.1%

Table 2. Monthly recharge volumes, Santa Paula Creek Spreading Grounds

(Values in Acre-Feet)

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL TOTAL
1930-31	0	0	0	0	128	21	0	66	7	0	0	0	222
1931-32	0	38	20	599	203	1117	214	0	0	0	0	0	2,191
1932-33	0	0	0	0	1275	733	0	0	0	0	0	0	2,008
1933-34	0	0	0	740	189	776	4	0	0	0	0	0	1,709
1934-35	0	0	137	760	937	980	911	434	0	0	0	0	4,159
1935-36	0	0	0	0	131	960	807	73	0	0	0	0	1,971
1936-37	0	0	0	733	45	408	966	722	247	0	0	0	3,121
1937-38	0	0	128	73	196	0	32	321	0	0	0	0	750
1938-39	0	0	0	499	467	570	353	0	0	0	0	0	1,889
1939-40	0	0	0	0	269	484	147	0	0	0	0	0	900
1940-41	0	0	17	469	221	49	0	301	189	0	0	0	1,246
1941-42	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	38	302	3,873	3,933	6,077	3,434	1,851	436	0	0	0	20,166
AVERAGE	0	3	25	323	338	508	286	160	37	0	0	0	1,833

APPENDIX FIGURES

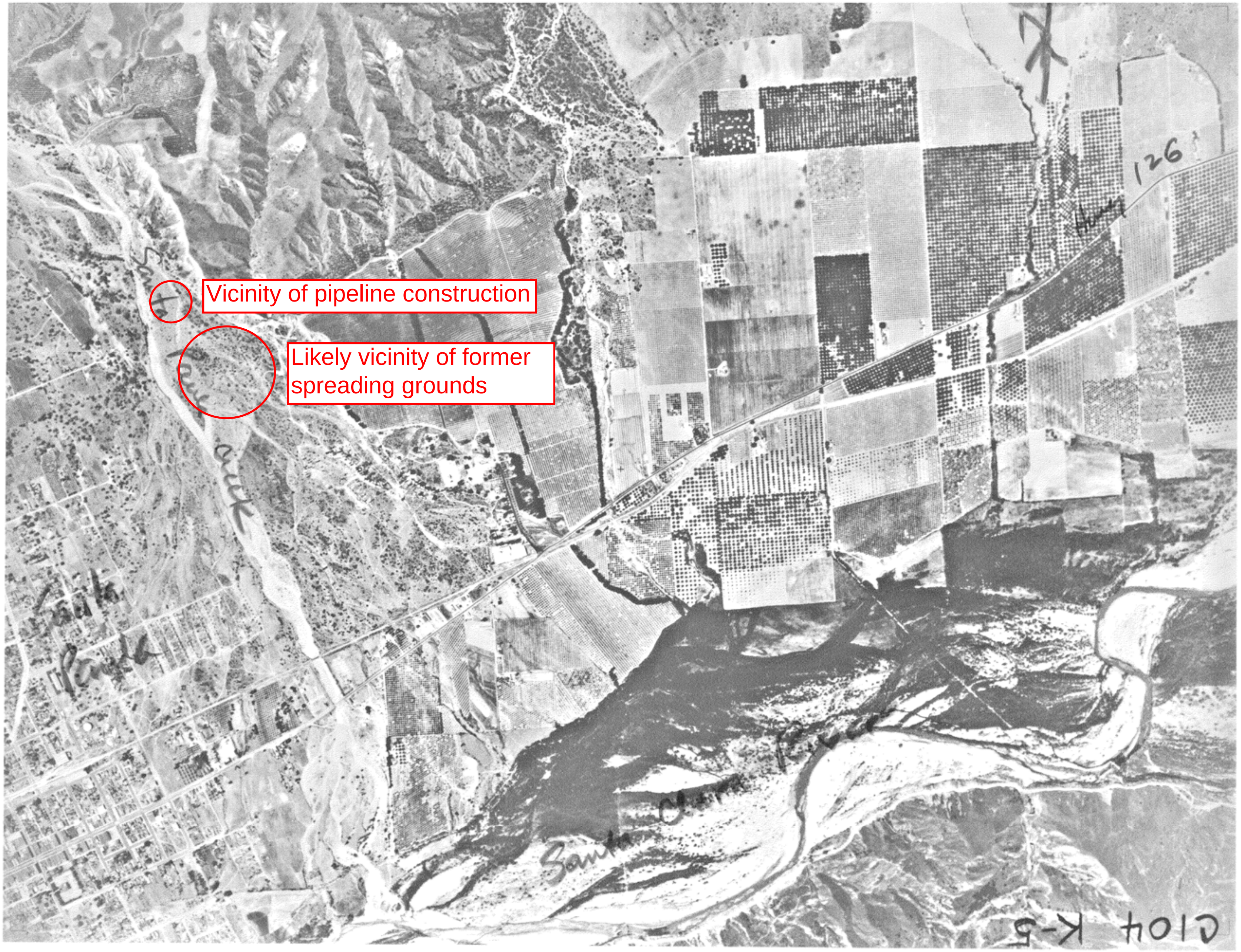


Figure A1. Historic photo of Santa Paula Creek fan, showing location of former spreading grounds.

Figure A2. Historic aerial photo of lower Santa Paula Creek, early 1960s (USACOE, 1967).

Figure A3. Historic aerial of lower Santa Paula Creek, mid-1960s.

Figure A4a. Aerial photo of lower Santa Paula Creek, SCR confluence to mile 1, mid-1960s (USACOE, 1967).

Figure A4b. Aerial photo of lower Santa Paula Creek, mile 1 to mile 2.5, mid-1960s (USACOE, 1967).

Figure A4c. Aerial photo of lower Santa Paula Creek, mile 2.5 to mile 4, mid-1960s (USACOE, 1967).

Figure A5. Former SCWCD Santa Paula Creek spreading basins, head works (top) and basins (bottom).

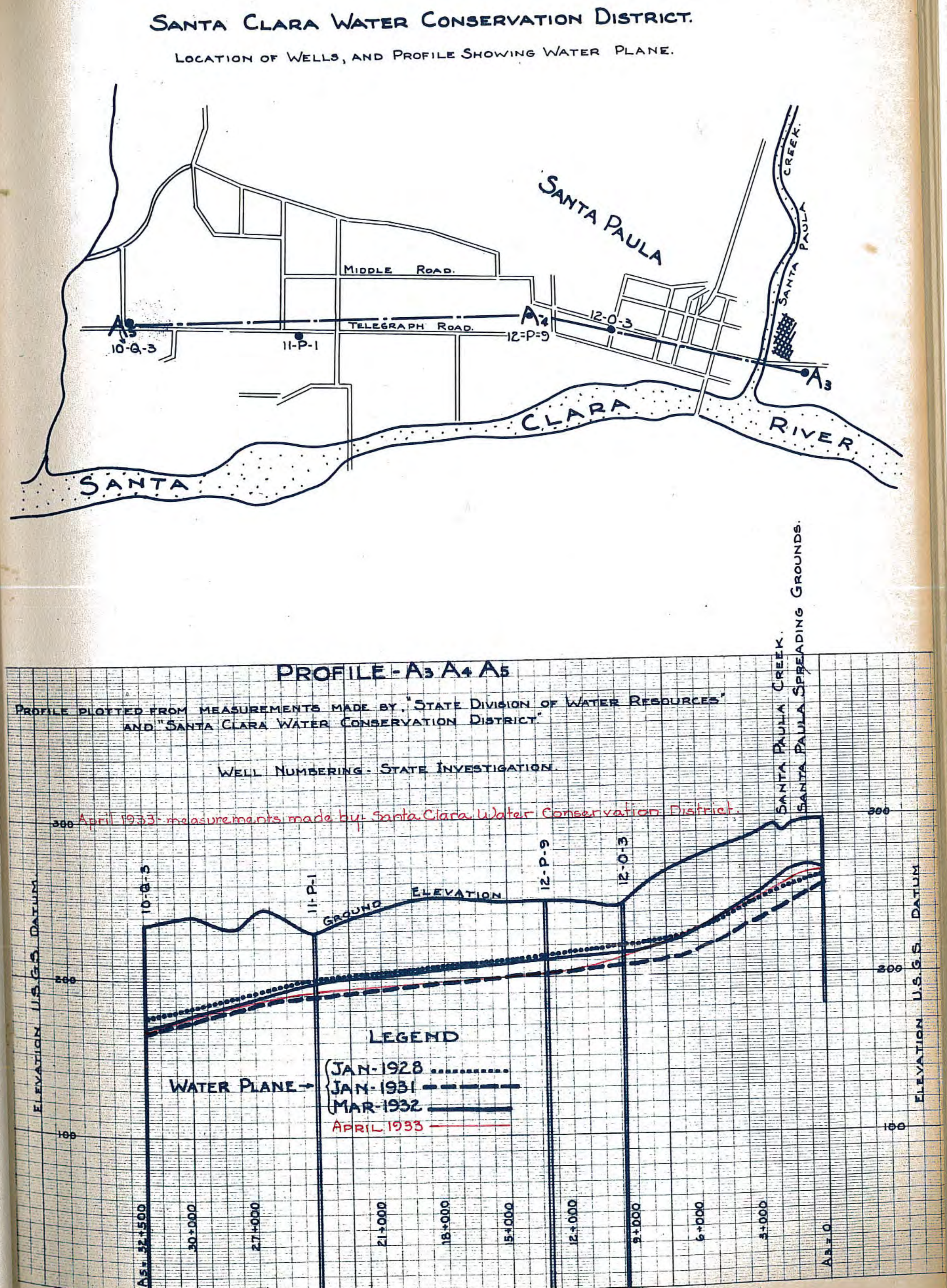


Figure A6. Depiction of groundwater elevations near Santa Paula Creek and Harvard Blvd, 1928-1933 (SCWCD, 1933).

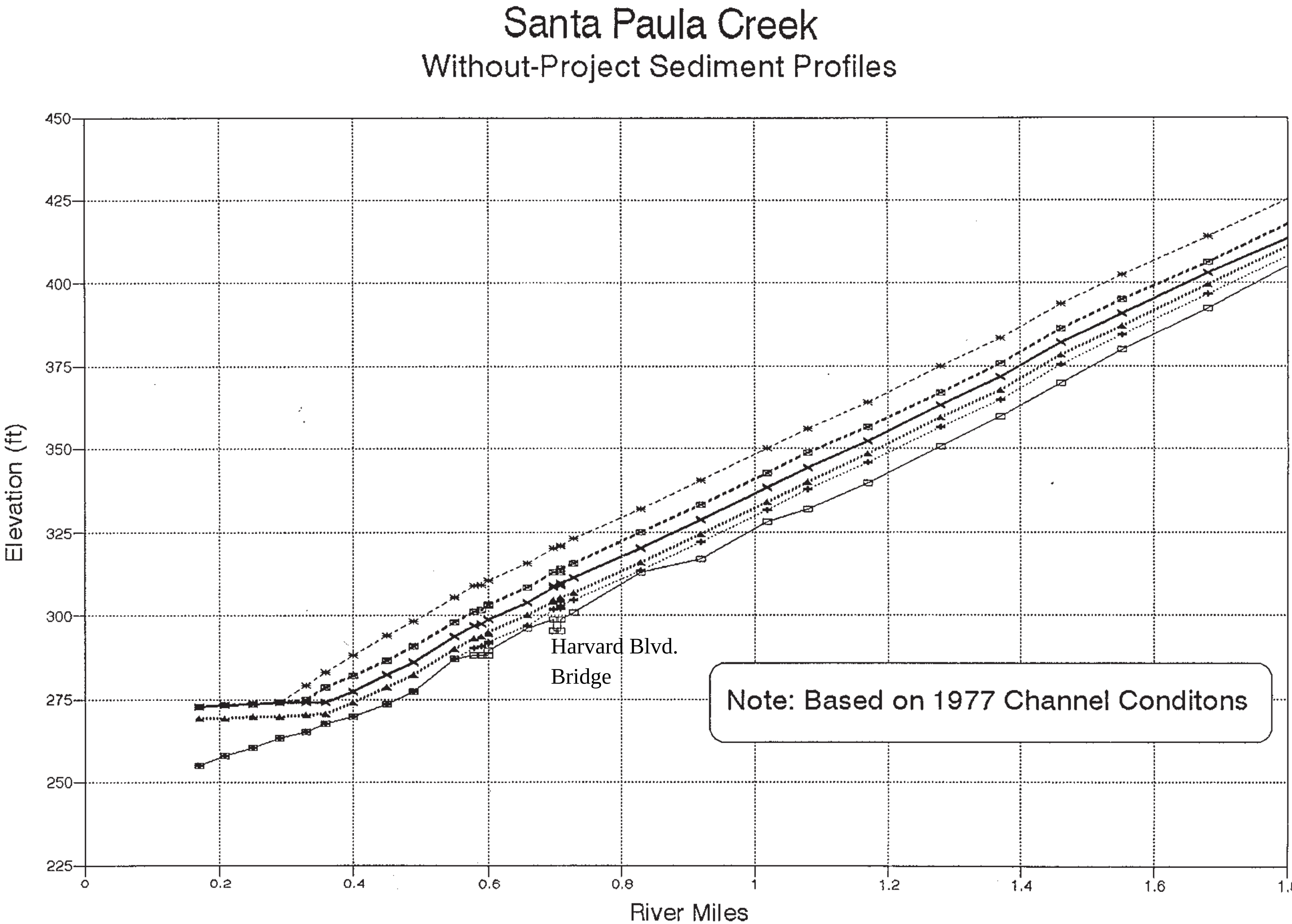


Figure A7. 1977 channel profile (invert) of lower Santa Paula Creek (USACOE, 1995).

Fig. 2

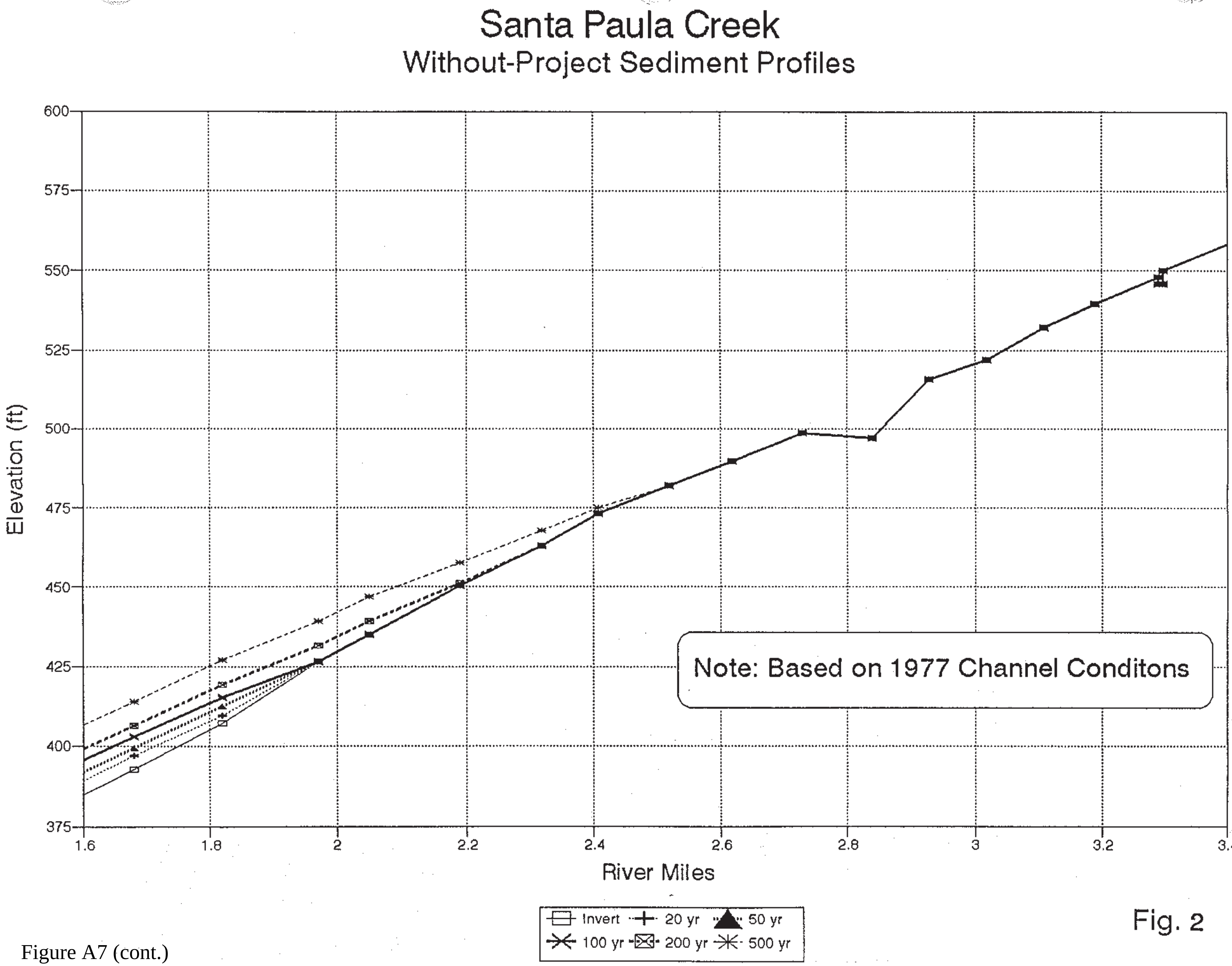


Fig. 2

Figure A7 (cont.)

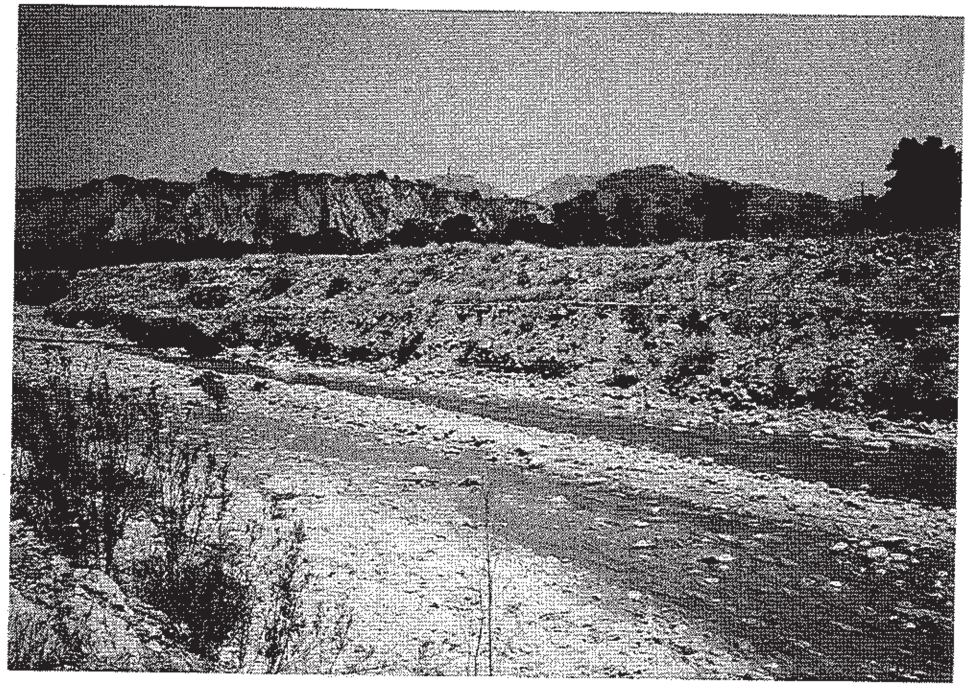


Photo. No. 13. This is a view of the typical channel bottom and bank in the reach upstream of the railroad bridge. June 1992

Photo. No. 14. This view shows the three pipelines that need to be relocated. Texaco's 8-inch crude oil pipeline is located to the left (downstream) of the bridge. The first pipeline to the right (upstream) of the bridge is the 10-inch gas line owned by Shell Pipe Line Corporation and next to it is the 8-inch crude oil pipeline owned by Unocal. (June 1994)

Figure A8. Photos of the lower Santa Paula Creek channel, 1992 and 1994 (USACOE, 1995)

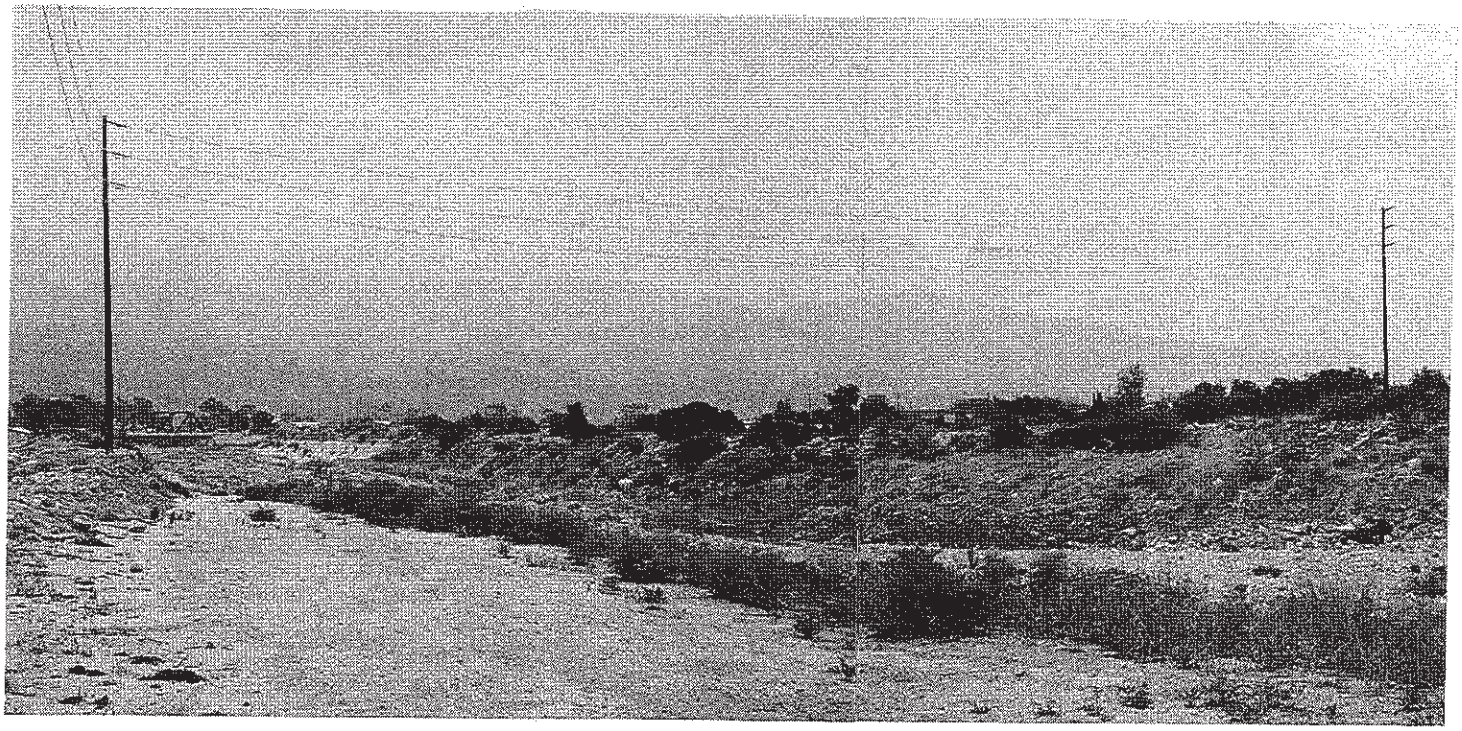


Photo. No. 15 & 16. This view is looking downstream toward the railroad bridge that shows the utility poles that would require relocation. (June 1994)

Figure A8 (continued).

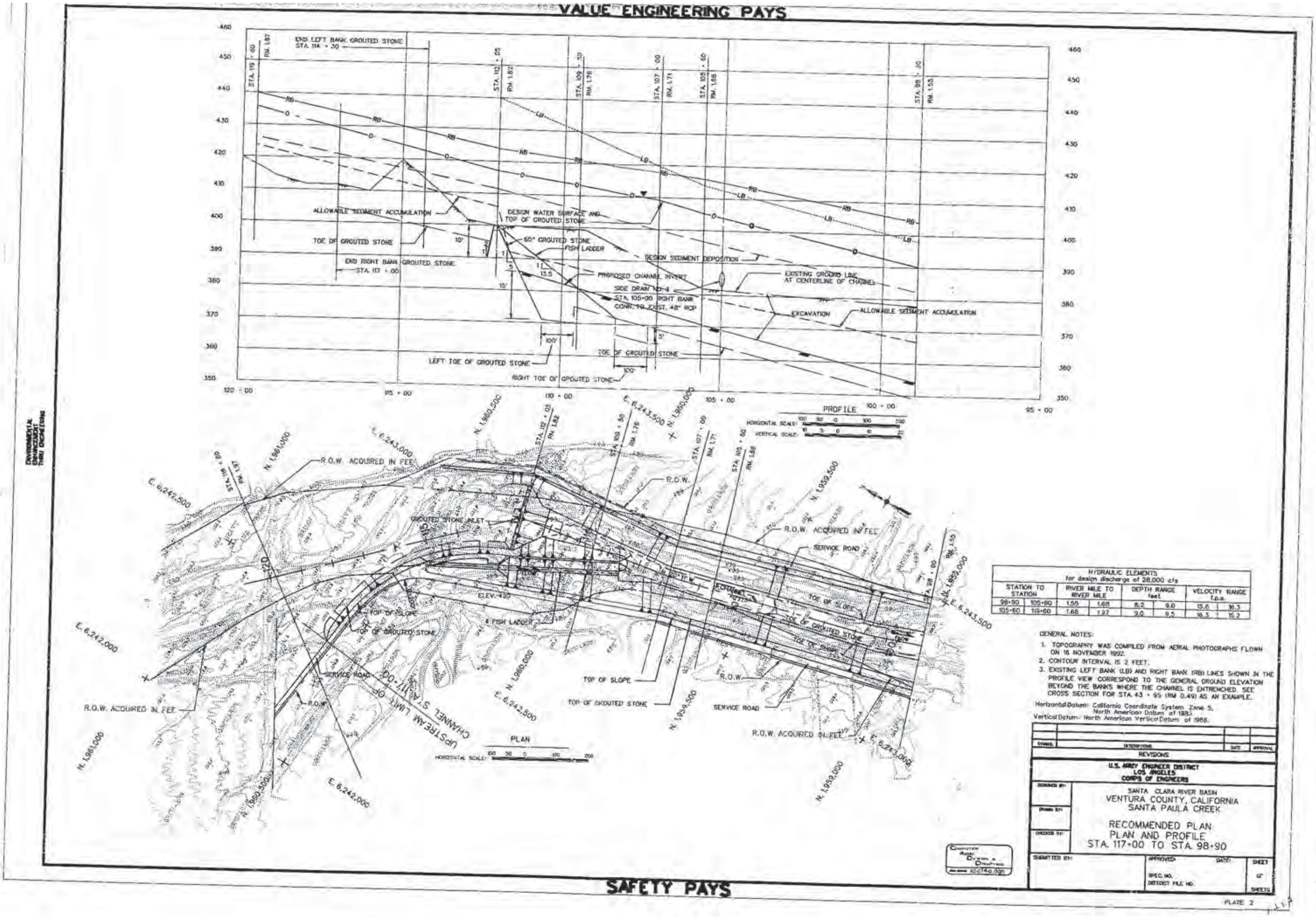
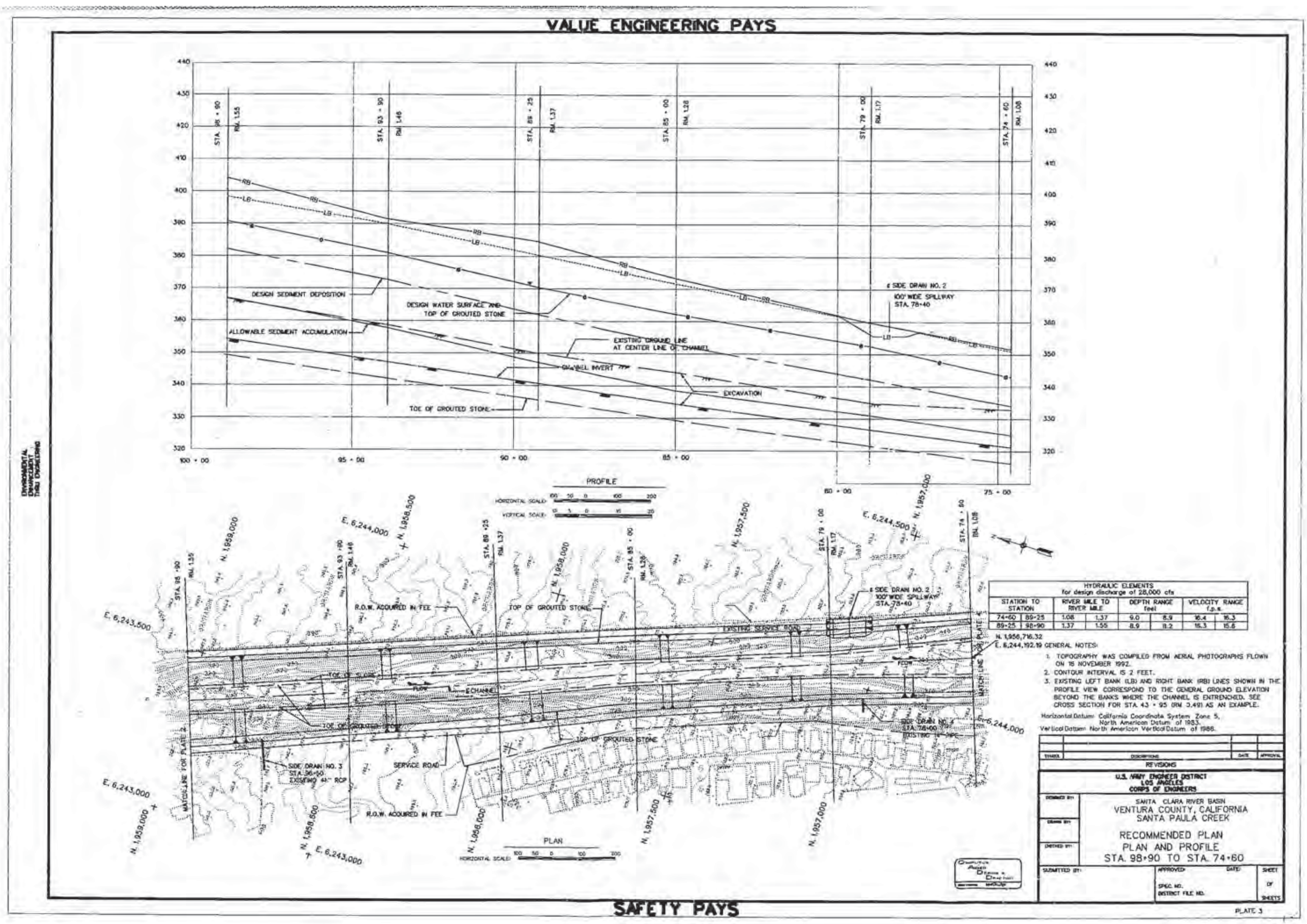


Figure A9. Design channel invert and cross-sections, with existing (prior) channel conditions (USACOE, 1995)



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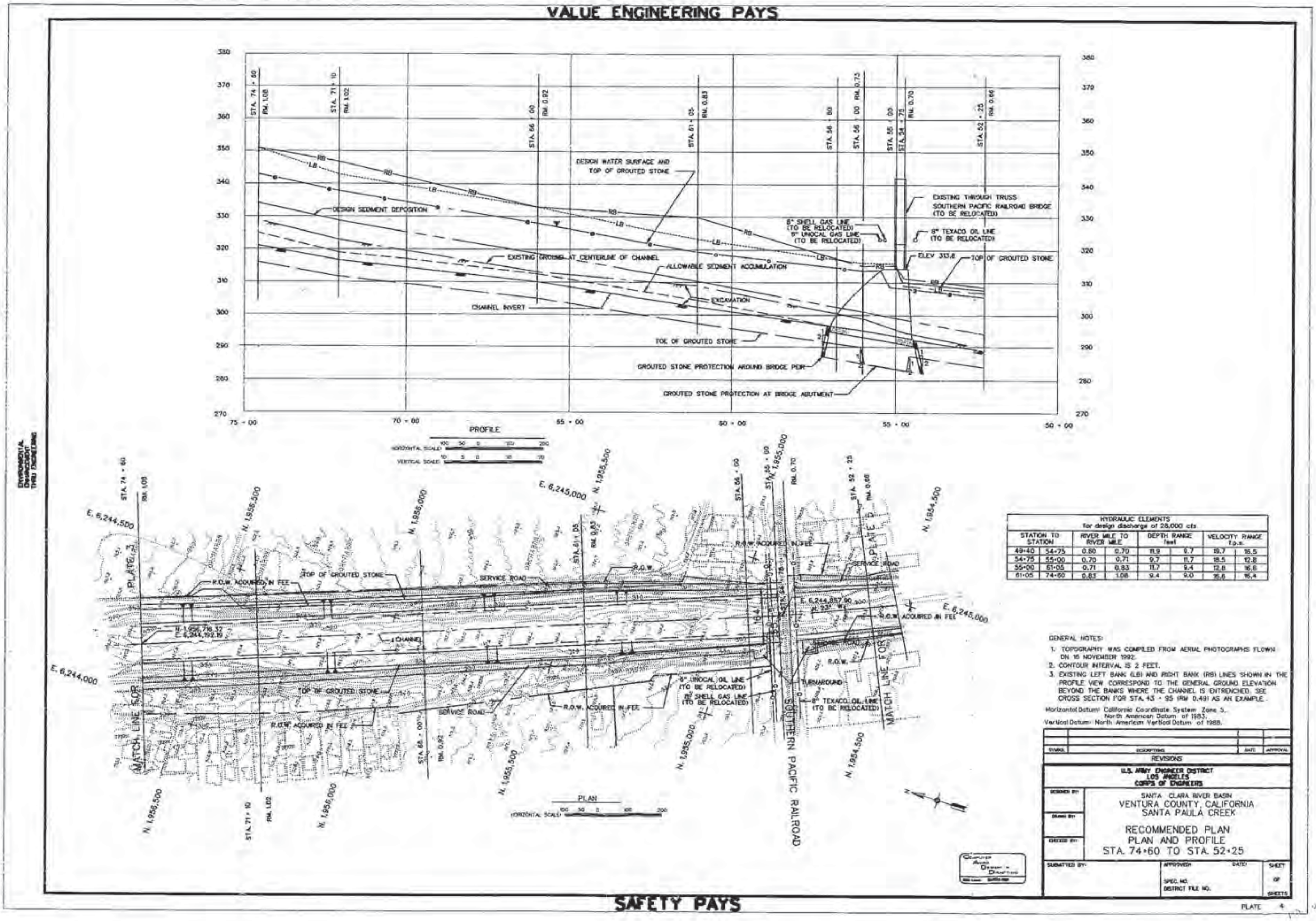

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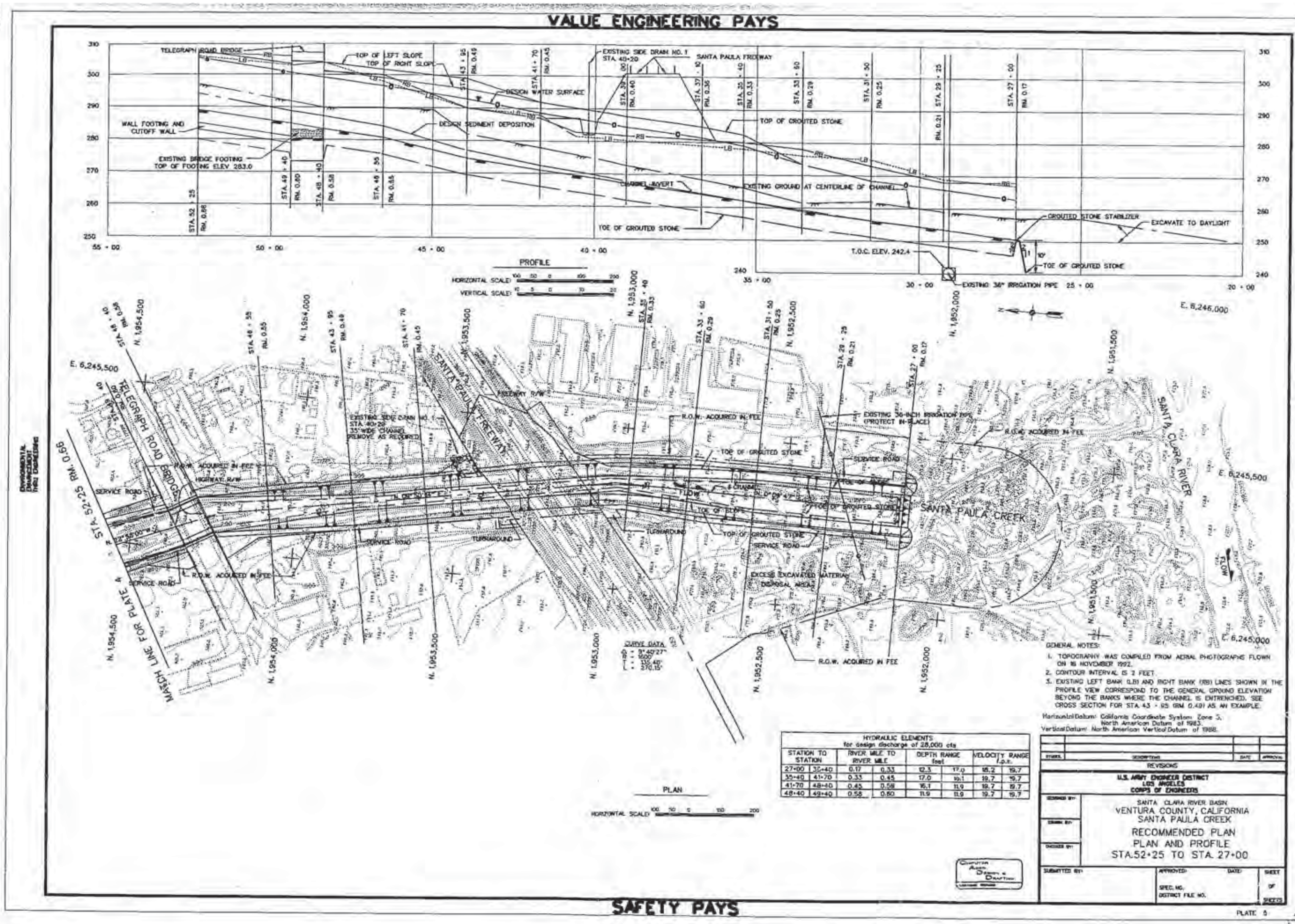

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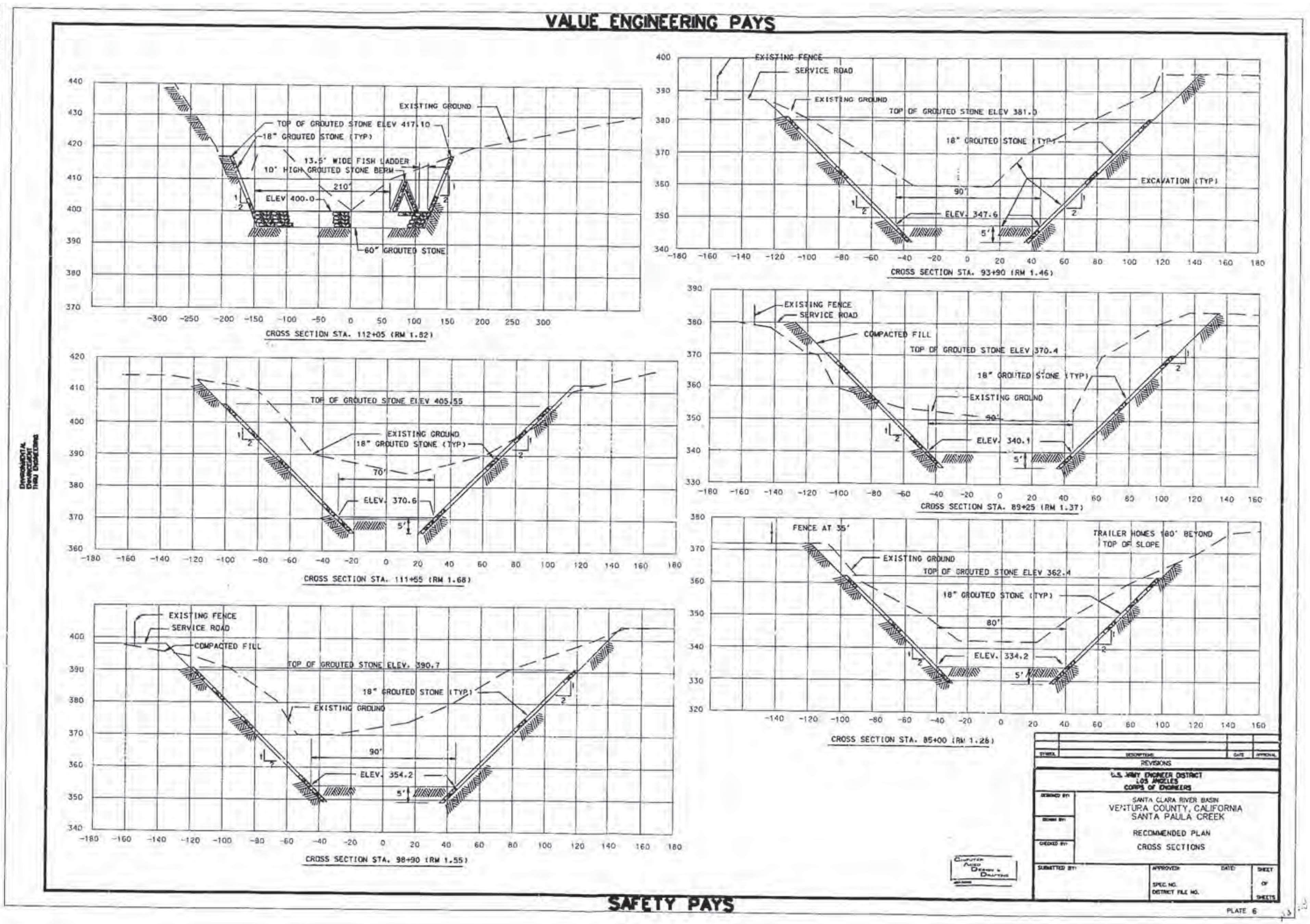

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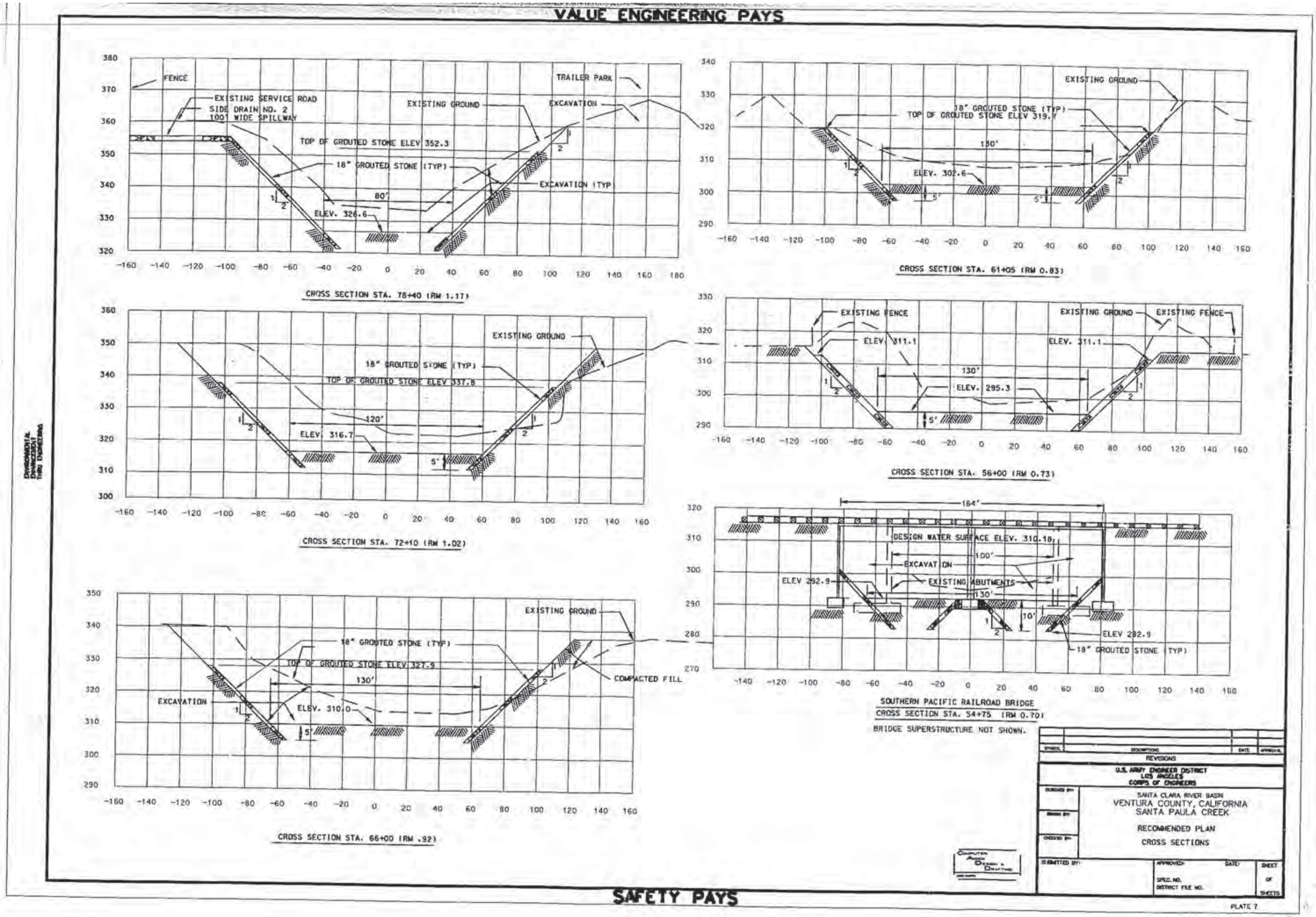

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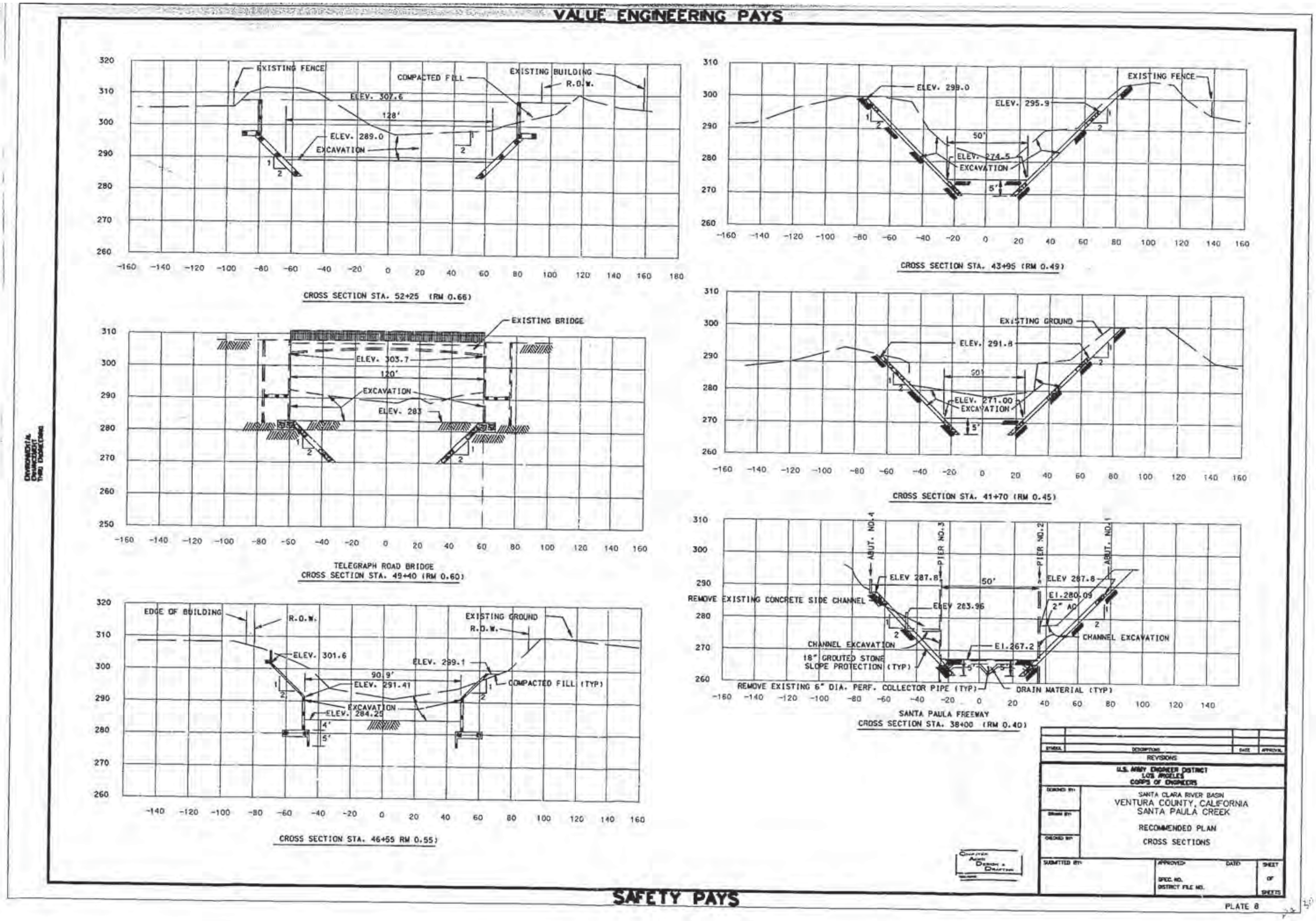

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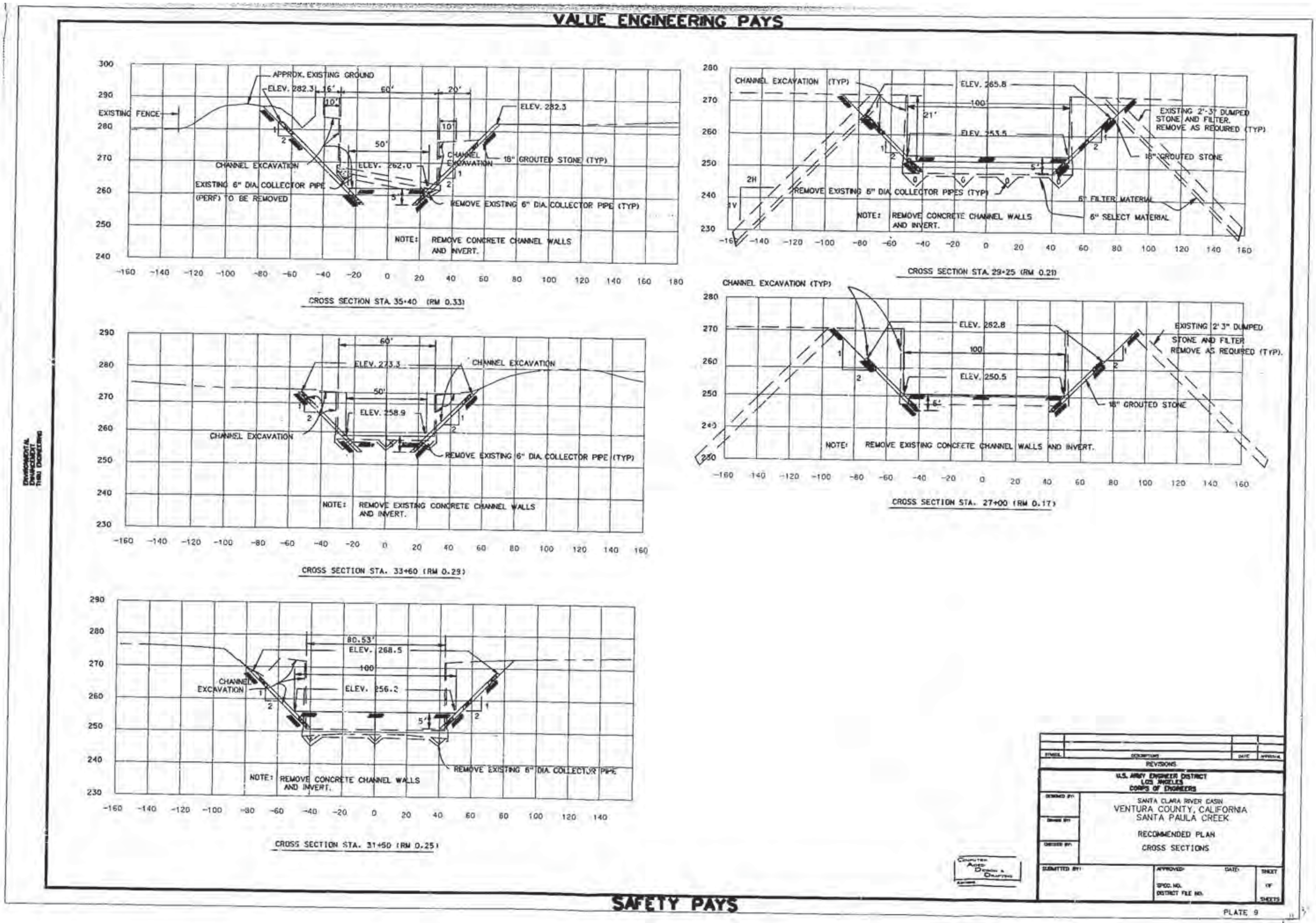

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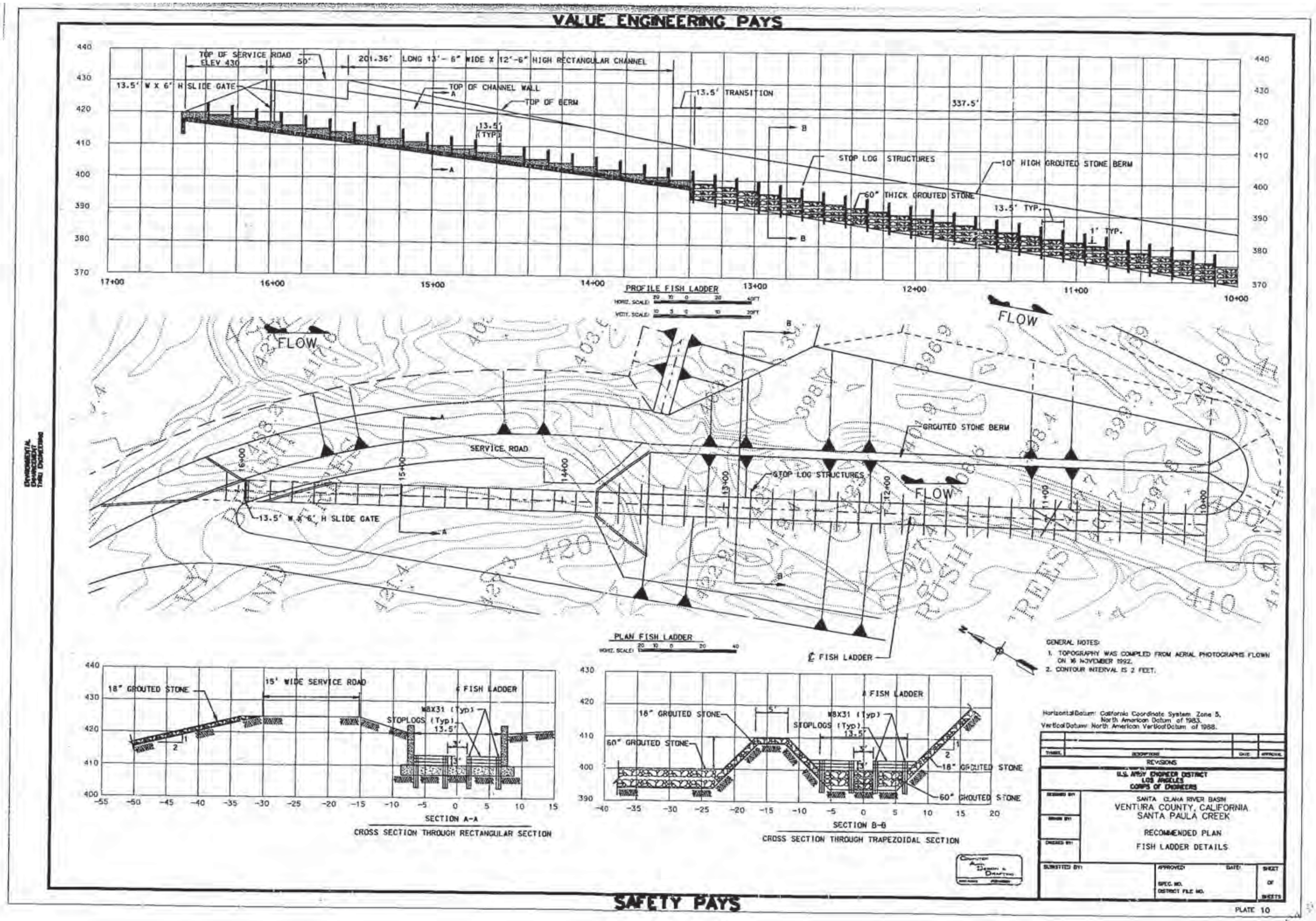

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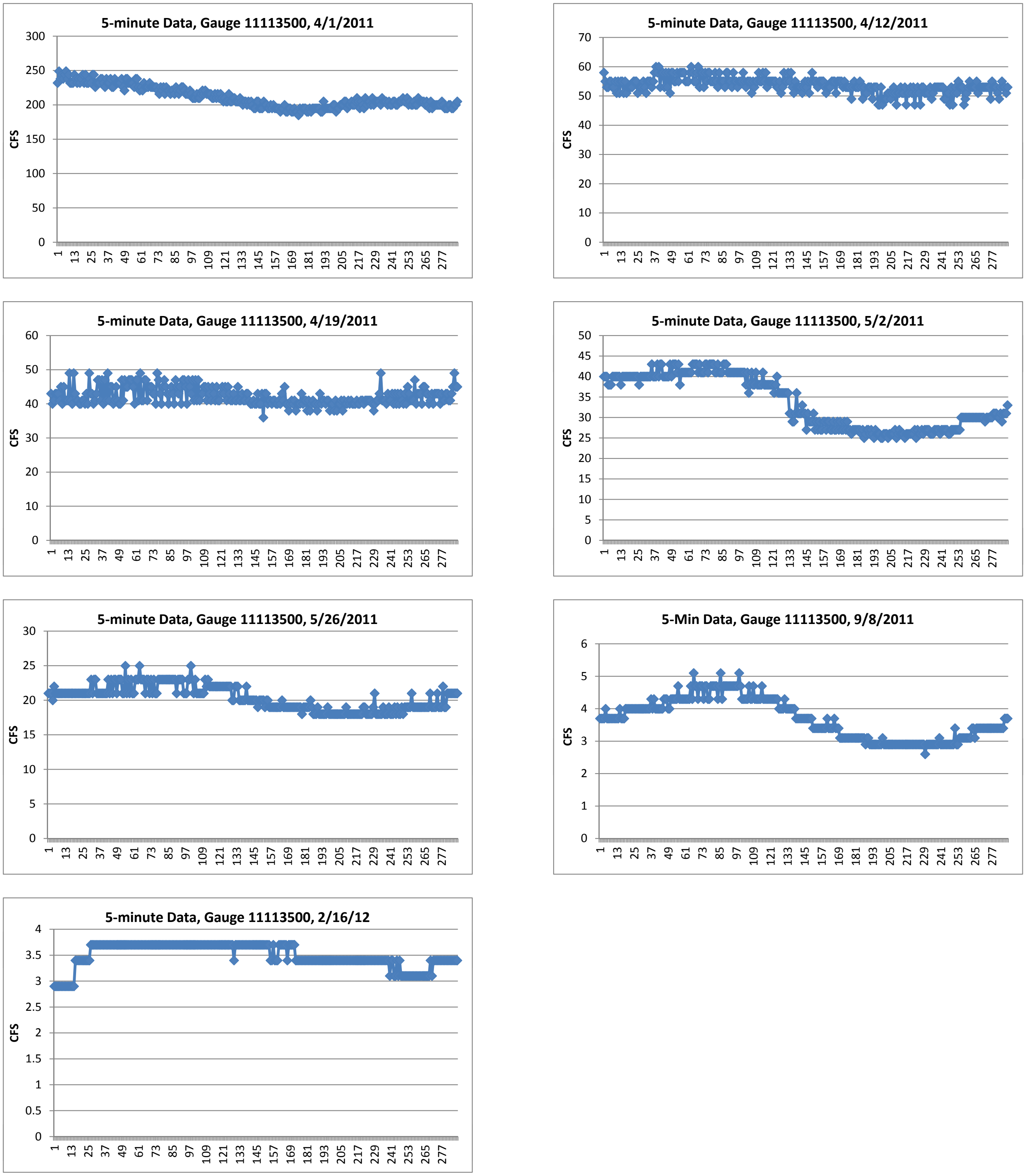

Figure A10. 5-minute flow data from gauge 11113500, Santa Paula Creek near Santa Paula.

Upstream location, looking upstream towards Bridge Road. Flow measured at 199 CFS on April 1, 2011

Upstream location, looking downstream. Flow measured at 199 CFS on April 1, 2011

Figure A11. Photos of lower Santa Paula Creek on April 1, 2011.

Downstream location, looking upstream on April 1, 2011. Flow measured at 192 CFS.

Downstream location, looking downstream on April 1, 2011. Flow measured at 192 CFS.

Figure A11 (continued).

Upstream location on May 26, 2011. Flow measured at 18 CFS.

Downstream location on May 26, 2011. Flow measured at 17 CFS.

Figure A12. Photos of lower Santa Paula Creek on May 26, 2011.

Santa Paula Creek channel, looking upstream near Wilson Ranch on April 1, 2011. Note seeps along the west side of the channel.

Santa Paula Creek channel, looking downstream near Wilson Ranch on April 1, 2011.

Figure A13. Photos of the Santa Paula Creek channel below the COE fish ladder.

Santa Paula Creek channel, looking upstream on April 1, 2011.

Figure A13 (continued).

APPENDIX TABLES

Table A1. Summary of 5-minute records at USGS Gauge 11113500, Santa Paula Creek at Santa Paula

Table A2. Measurement and transect details, UWCD flow gauging, years 2011 and 2012.

Table A1. Summary of 5-minute Records at USGS Gauge 11113500, Santa Paula Creek at Santa Paula

	Stage (feet)			Flow (CFS)					UWCD Manual Measurement
Date	Minimum	Maximum	Average	Minimum	Maximum	Average	Qualification	Notes	2.1 miles downstream*
4/1/2011	72.73	72.85	72.78	185	249	211.15	Approved	Receding flow	198.66
4/12/2011	72.25	72.31	72.28	47	60	53.61	Approved		63.63
4/19/2011	72.13	72.19	72.16	36	49	42.20	Approved		41.64
5/2/2011	71.95	72.05	72.00	25	43	33.55	Approved		26.63
5/26/2011	71.80	71.85	71.82	18	25	20.34	Approved		17.72
9/8/2011	71.61	71.69	71.65	2.6	5.1	3.68	Approved		2.56
2/16/2012	71.54	71.56	71.55	2.9	3.7	3.49	Provisional		4.1

* Manual measurements collected near Mupu Elementary School, downstream of Mud Creek and Canyon Irrigation Diversion

Table A2. Measurement and transect details, UWCD flow gauging, years 2011 and 2012.

Date	Location	Flow (cfs)	Width (ft)	Mean Vel (ft/s)	Max depth (ft)	Mean Depth (ft)	# Stations
4/1/2011	below Bridge Rd	198.66	44.0	3.82	1.78	1.18	28
4/1/2011	below Harvard Blvd	192.30	39.5	4.14	1.50	1.18	24
4/12/2011	below Bridge Rd	63.63	28.0	2.05	1.60	1.11	29
4/12/2011	below Harvard Blvd	68.51	36.0	2.72	1.00	0.70	36
4/19/2011	below Bridge Rd	41.64	27.0	1.61	1.35	0.96	29
4/19/2011	below Harvard Blvd	46.61	28.0	2.30	1.45	0.73	29
5/2/2011	below Bridge Rd	26.63	25.0	1.37	1.30	0.78	27
5/2/2011	below Harvard Blvd	28.88	26.0	2.01	1.00	0.55	27
5/26/2011	below Bridge Rd	17.72	22.0	1.12	1.65	0.72	25
5/26/2011	below Harvard Blvd	16.75	19.0	1.81	0.70	0.49	22
9/8/2011	below Bridge Rd	2.56	9.5	0.54	1.00	0.50	22
9/8/2011	below Harvard Blvd	3.66	10.5	0.86	0.52	0.40	22
2/16/2012	below Bridge Rd	4.10					
2/16/2012	below Harvard Blvd	4.80					