Santa Paula Creek Hydrology & Floodplain Research

Ferndale Lease, Ojai Oil Field – Drill Site No. 7

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Prepared for:
Citizens For Responsible Oil and Gas (CFROG)

County of Ventura
Planning Commission Hearing
PL13-0150
Exhibit A - Santa Paula Creek Report

INTRODUCTION

The cover photo was taken on August 28, 2012, and shows the Santa Paula Creek that encompasses the study reach with Drill Site No. 7 and the avocado orchard on opposite sides of the channel (Source: Google Earth). Figure 1 shows the location of Drill Site No. 7 in the Santa Paula Creek watershed and Ventura County.

Though Santa Paula Creek is known to experience extreme flooding, detailed estimates of the flood reoccurrence intervals and their overbank extent have not been performed in the upper watershed, and there are no stream gaging stations upstream of the Sisar Creek confluence. Drill Site No. 7 has been constructed adjacent to Santa Paula Creek, in the Ferndale Lease of the Ojai Oil Field. There are three existing oil wells (712, 716, and 717) and five new wells proposed for Drill Site No. 7. In this study, various flood stage elevations are estimated for Santa Paula Creek adjacent to Drill Site No. 7, along with distances from these elevations to Drill Site No. 7 and the oil wells (setback distances).

This research was performed by Blue Tomorrow, LLC, an environmental consulting firm that specializes in water resources management. Citizens For Responsible Oil and Gas (CFROG) commissioned Blue Tomorrow to research flood inundation and setback distances from the Santa Paula Creek study reach, and the potential risks of adding oil wells to Drill Site No. 7.

Data Disclaimer: This study was performed for research purposes and to provide information about the study reach, and is not intended to be used for official floodplain determinations and insurance purposes without additional review by a professional engineer. Blue Tomorrow and its contractors are not liable for any damages that may result from the use of data or analysis contained in this study.

EXECUTIVE SUMMARY

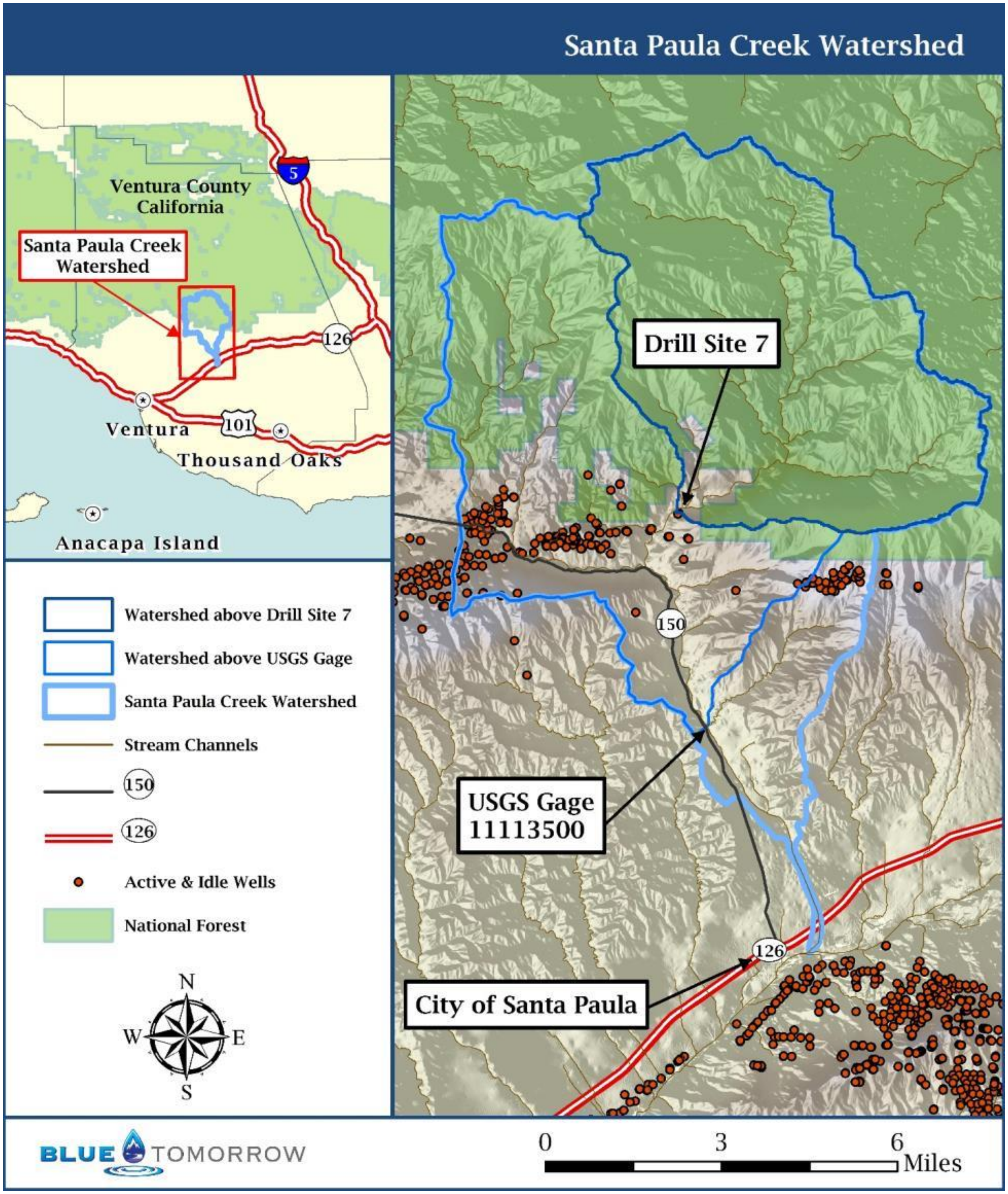
This study was designed to research a reach ("study reach") of the Santa Paula Creek adjacent to Drill Site No. 7 (DS7) in the Ferndale Lease of the Ojai Oil field. Three cross-sectional profiles were surveyed in the study reach, and several discharge estimates were derived (50, 100, 200, and 500-year flood events). Additionally, the hydrology and drainage of DS7 was investigated during a small storm event, and the Santa Paula Creek watershed and study reach are briefly described with regards to climate, geomorphology (channel erosion, deposition, and scour processes), and steelhead habitat.

The Santa Paula Creek watershed has a very steep upper watershed that is a considerable source of sandstone and bedload material to the drainage channels downstream. The steep relief and periodic high-intensity storms leads to flashy discharges and flooding. Santa Paula Creek has diverse geomorphology and habitat characteristics that make it highly productive steelhead habitat. This area is one of the most productive steelhead habitats in the larger Santa Clara Watershed, which has suffered considerable declines in steelhead abundance over the last 100 years due to habitat destruction, fish migration barriers, water quality impacts, and other impacts resulting from urbanization.

To estimate flood stage elevations, the study followed USDA, USGS, FEMA, and USACE protocols and procedures to survey, assess, and model (using HEC-RAS) the study reach of the upper Santa Paula Creek near DS7. The best discharge estimates for the 50 and 100-year flood events at the study reach are 17,200 and 24,200 cubic feet per second (cfs), respectively. These estimates were derived from a Hydrological Simulation Program - FORTRAN (HSPF) model developed by AQUA Terra Consultants for the Ventura County Watershed Protection District (VCWPD). When used with the surveyed cross-sections, these discharge estimates translate to a 100-year flood water height of between 3.9 feet below the top of the DS7 berm at the upstream end of the study reach, to 11.7 feet below the berm on the downstream end of the reach. It is estimated that a discharge of approximately 39,000 cfs would be needed to top the berm on the upstream end of DS7, which has between a 0.5% and 0.2% probability of occurrence in any year.

The outer edge of DS7 is located within 50 feet of the "top of bank" (defined as four vertical feet above the 50-year flood mark in previous County documentation), and the oil wells currently located on DS7 are within 300 feet of the "top of bank". The drain pipe at the northwest corner of DS7 drains about 50 feet downslope to approximately the 100-year flood mark. The Ventura County Non-Coastal Zoning Ordinance states that wells and permanent oil field infrastructure should abide by a 300 foot setback "… unless the permittee can demonstrate to the satisfaction of the Public Works Agency that the subject use can be safely located nearer the stream or channel in question without posing an undue risk of water pollution..." Given the drainage of DS7 and its location near the creek, increasing the amount of oil wells and impervious area may pose a water quality risk if not properly mitigated.

Figure 1 - Location of Drill Site No. 7 in Santa Paula Creek Watershed



Acronyms

DS7	Drill Site No. 7
DOGGR	Department of Oil, Gas, and Geothermal Resources
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
HEC-RAS	US Army Corps of Engineers Hydrologic Engineering Centers River Analysis System
HSPF	Hydrological Simulation Program - FORTRAN
LARWQCB	Los Angeles Regional Water Quality Control Board
USACE	US Army Corps of Engineers
USGS	United States Geological Survey
VCFCD	Ventura County Flood Control District
VCWPD	Ventura County Watershed Protection District
XS-A	Cross-Section A
XS-B	Cross-Section B
XS-C	Cross-Section C

Table of Contents

1.0 | Watershed Overview

Santa Paula Creek is tributary to the Santa Clara River and drains roughly 64 square miles[1]. This study focuses on a reach ("study reach") of the upper Santa Paula Creek, upstream of the Highway 150 bridge-crossing and the confluence with Sisar Creek. The study reach is located in Santa Paula Canyon, upstream of Thomas Aquinas College, directly downstream of the confluences of La Broche Canyon and Echo Falls Canyon, and adjacent to Drill Site No. 7 in the Ferndale oil lease (Figure 1 and 2).

1.1 Study Reach Characteristics

The headwaters of Santa Paula Canyon drainage are found within the steep south-facing slopes of the Topatopa Mountains, and the vegetation cover in the upper watershed is scrub-chaparral and mixed forest[1]. The main stem of Santa Paula Creek originates near Hines Peak (elevation of roughly 6,600 ft or 2,000 m) and flows down a steep (>6% grade) bedrock-laden canyon[1] before joining with the East Fork of the Santa Paula Creek (about 1.6 miles upstream of DS7). Two other intermittent tributaries (La Broche and Echo Falls Canyons) drain into the Santa Paula Creek just above DS7, which has an elevation of approximately 1,130 feet. The Santa Paula Creek tributaries draining upstream of the study reach are designated Hydrologic Unit Code (HUC) #18070102090[2].

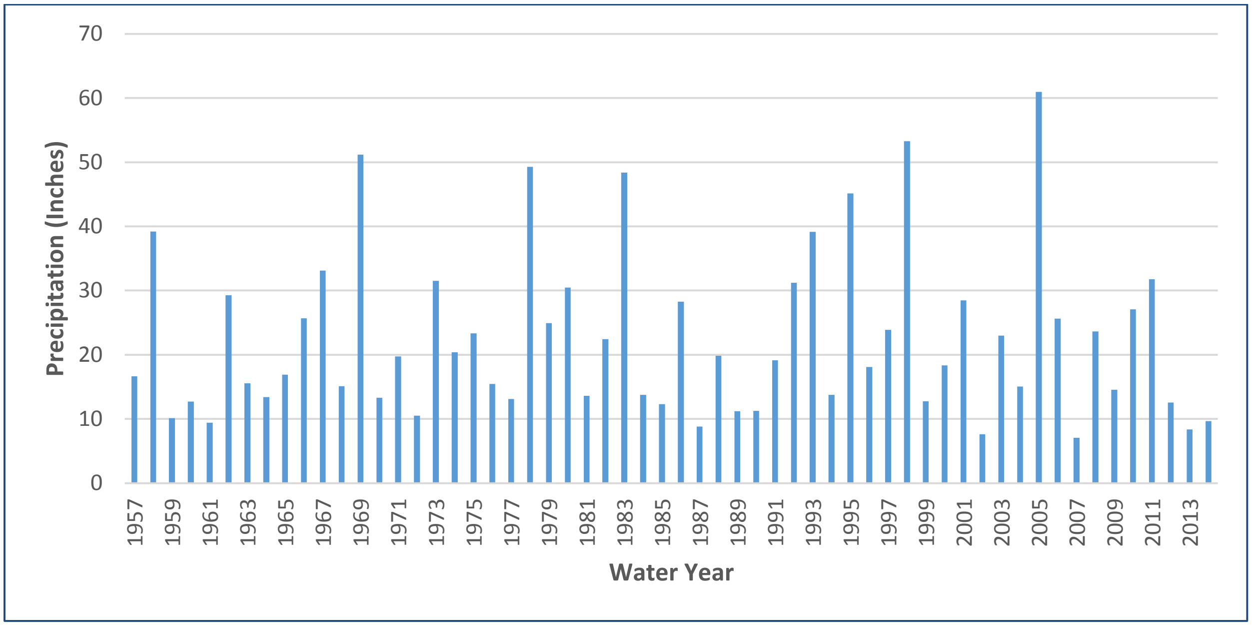
Field surveys conducted for the study identified bankfull indicators in the study reach. Measurement of these indicators showed the bankfull discharge (approximately the 2-year event; or 50% annual reoccurrence probability) to have an estimated stage height of roughly 1.6 to 2 feet above the deepest point in the channel (thalweg), and a width of 25 to 32 feet.

According to the Federal Emergency Management Agency (FEMA), the area encompassing DS7 is classified as Zone D; areas where there are possible but undetermined flood hazards. Limited analysis of flood hazards have been conducted for DS7. Section 3.0 presents estimates of flood heights relative to DS7 and their associated reoccurrence intervals. According to these estimates, the width of the 200-year floodplain widens in the downstream direction along the study reach from approximately 160 to 290 feet.

1.2 Precipitation and Discharge

Precipitation in the Santa Paula Creek watershed primarily occurs from November through April and is highly variable. The area is known to experience multi-year droughts and periodic high-intensity storm events (correlated to the El Nino-Southern Oscillation phenomenon)[1]. Figure 2 shows the annual precipitation registered at the Ferndale Ranch gage, near Thomas Aquinas College, roughly one mile south of DS7.

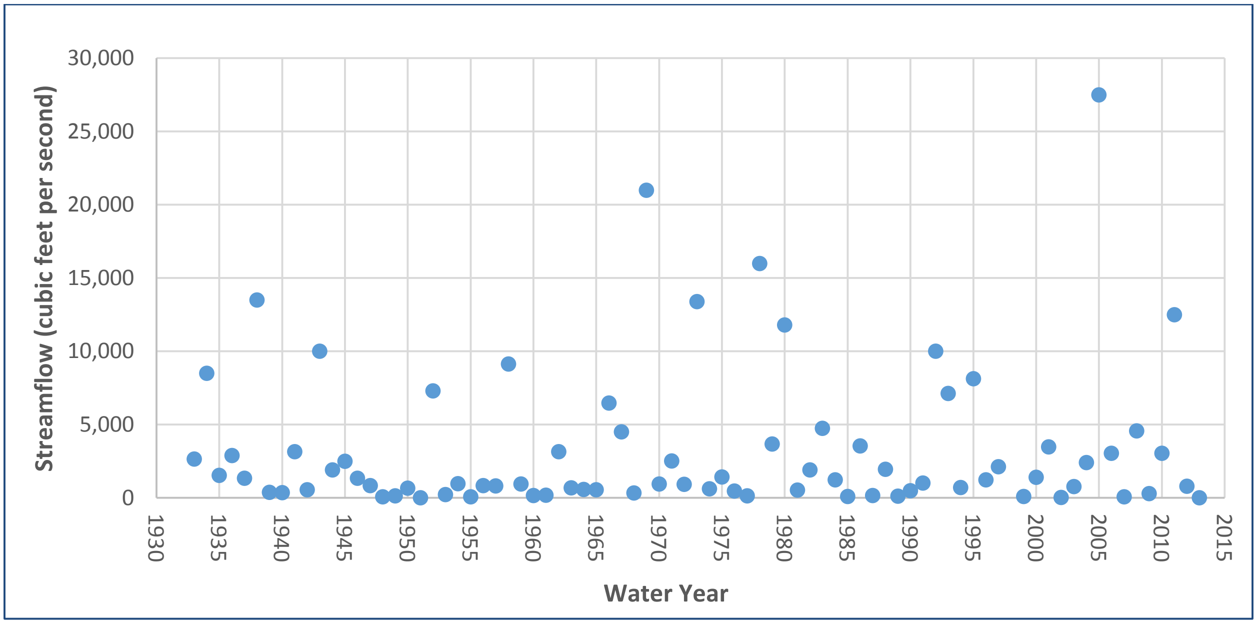
Figure 2 – Annual Precipitation at Ferndale Ranch gage. Data obtained from Ventura County Watershed Protection District (VCWPD) gages 173 and 173A. Gage 173 recorded precipitation amounts from the 1957 through 1979 water years, and gage 173A recorded precipitation amounts from 1980 through the 2014 water year[3].



The 2005 water year had the highest recorded precipitation in the area with 60.69 inches recorded at gage 173A. A total of 22.91 inches fell during a 96 hour period from January 7 through January 11, 2005. The total rainfall on January 10, 2005 was measured at 7.16 inches, with a peak intensity of 2.05 inches for the hour between 7:00 – 8:00 am. The extreme storm events the region periodically faces is intensified in the upper watershed area, and concentrated in the Santa Paula Canyon upstream of DS7.

As a result of these high-intensity storms, Santa Paula Creek is prone to flashy discharges and flooding. Figure 3 shows the Santa Paula Creek peak streamflow for each water year, as measured by the USGS gage near Santa Paula. Streamflow was measured above 10,000 cfs 9 times from 1933 to 2013, and the highest discharge was estimated at 27,500 cfs and recorded on January 10, 2005[4].

Figure 3 – Santa Paula Creek Peak Streamflow at USGS gage. Data obtained from US Geologic Survey gage 11113500 near Santa Paula[4].



1.3 Channel Morphology

Upstream of the study reach and DS7, the Santa Paula Creek channel is braided (Picture 1), due to the steepness of slope and large sediment supply in the upper watershed, and the limited bedload transport of the study reach compared to the upstream supply. The channel substrate along the study reach at DS7 is primarily cobbles (6.4-25.6 cm) and boulders (>25.6 cm) with interspersed gravel deposits. There is an abundance of alder trees in the riparian corridor, and the floodplain is littered with fallen trees, branches, boulders, and other debris (Appendix Section 7.3 – Photo Log).

The morphology of Santa Paula Creek is shaped through the intense storms and flashy discharges, and is highly sensitive to bedrock and infrastructure constrictions[1]. Following the 2005 flood event (the largest recorded discharge), part of the study reach shifted approximately 225 feet to the north (away from DS7) to its present location. The large peak discharges and plentiful headwater sediment production, combined with the natural variations in channel slope and bedrock outcrops, create diverse morphology and habitat characteristics throughout the watershed.

1.4 Santa Paula Creek Steelhead Habitat

The Santa Paula Creek watershed has some of the most productive and high quality steelhead habitat in the larger Santa Clara River watershed[5]. There are many habitat quality indicators in this watershed that suggest the Santa Paula Creek is better habitat than the larger Sespe Creek watershed and its tributaries that drain the Sespe wilderness. These indicators include lower water temperatures, abundance of spawning gravel, low substrate embeddedness, and a high percentage of stream cover. The Santa Paula Creek subwatershed has recently shown to have the second greatest abundance of steelhead trout in the Santa Clara River watershed (after the Sespe creek subwatershed), with Sisar creek accounting for the majority of the population[5].

There are many factors that can impact steelhead populations such as barriers that are known to impede migration up the Santa Paula Creek[5]. Another limiting factor is increased fine sediment production, which can originate from roads and has been linked to declines in Coho and other salmonids in the Pacific Northwest[6,7]. Fine sediment can increase water turbidity causing stress, and fill in the interstitial pores in gravel, embedding it, and reducing the flow of oxygen through spawning gravels, which in turn reduces egg and larval survival and aquatic invertebrate production [7,8,9].

2.0 | STREAM DISCHARGE ESTIMATES

This section describes the methods used to estimate the flood magnitude for the 50, 100, 200, and 500-year reoccurrence intervals (annual reoccurrence probability of 2%, 1%, 0.5%, and 0.2%) for the study reach adjacent to Drill Site No. 7 (DS7). The flood discharge estimates were used to calculate the flood stage height for three cross-sections located in the study reach (the methods and analysis for estimating stage height are described in Section 3.0).

The estimates of flood discharge for the study reach range from 7,100 to 17,200 cfs for the 50-year event, and 9,800 to 24,200 cfs for the 100-year event (Table 2). The highest estimates are considered the best and were taken from a HSPF model of the Santa Paula Creek. The model was calibrated to the downstream USGS gage and takes into account precipitation, topography, soils and other physical conditions influencing hydrology in the watershed, to derive the estimates. USGS regional regression equations were also used to derive estimates, but appear to be underestimating discharges in this watershed.

2.1 Estimating Discharge

There are several methods that flood frequency and magnitude can be estimated, but there is still considerable uncertainty even in the best methods due to the lack of long-term and accurate observations. The method for estimating reoccurrence intervals that is widely used and accepted in the United States is the Guidelines for Determining Flood Flow Frequency described in Bulletin 17B, and involves a Log-Pearson Type III regression analysis of gaged annual peak discharge data. The longer the gage record the better the estimate, but as a rule-of-thumb, gage records of less than 10 years should not be considered for Bulletin 17B analysis. The uncertainty only increases when estimating flood discharges at ungaged sites.

One method recommended by the USGS and FEMA for Estimation of Flood Magnitude and Frequency at Ungaged Sites involves regionalized regression equations based on the Bulletin 17B analysis of many stream gages within a hydrologic region. The uncertainty in this regression method of estimation can be reduced if nearby stream gages are considered, and proper weighting is used to refine the estimate generated by the USGS regression equations.

Another method that can be used to estimate flood frequency and magnitude at ungaged sites involves watershed modeling. Physical watershed modeling that takes into account several watershed variables and parameters known to affect stream discharge can be an accurate estimation method, especially when properly calibrated to one or more downstream gages that have a sufficiently long data record. Watershed modeling can be very time consuming and was not undertaken for this study, but estimates were derived from a Hydrological Simulation Program FORTRAN (HSPF) modeling study of the Santa Clara River watershed developed by AQUA Terra Consultants for the Ventura County Watershed Protection District (VCWPD)[10].

Section 2.2 first considers the flood frequency and magnitude at the USGS stream gage (#11113500) downstream of DS7 and compares several estimation methods. This gage has over 80 years of peak discharge records and is a good reference for estimating discharge at ungaged sites upstream (such as DS7). Section 2.3 then covers the different methods used and estimates derived for the study reach.

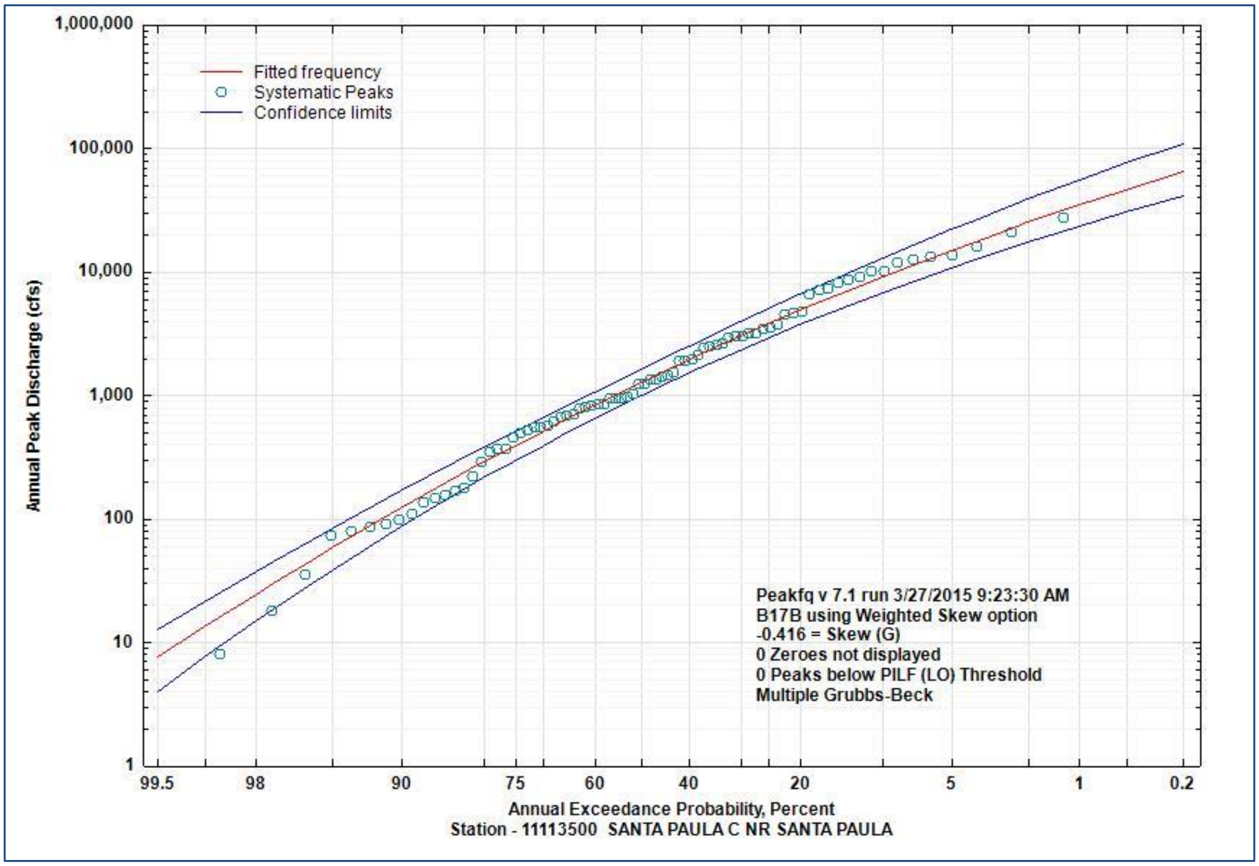
2.2 Estimating Flood Frequency and Magnitude at USGS Gage 11113500 near Santa Paula

Four methods were considered and analyzed to estimate the flood magnitudes at the USGS gaging station on the Santa Paula Creek near Steckel Park: 1) Bulletin 17B; 2) USGS Regression; 3) Weighted USGS Regression and Bulletin17B; and 4) the HSPF model. USGS gage (#11113500) has a relatively long record (80+ years) and is an appropriate gage for the application of Bulletin 17B. Therefore, Bulletin 17B was considered a relatively suitable estimate to compare with results from other methods. The USGS regression equations were used alone to generate estimates at the gaging site and to generate weighted estimates between the regression results and Bulletin 17B (as outlined in Gotvald et al. 2012)[11]. Additionally, the results from a HSPF model developed by AQUA Terra for the VCWPD are also reported and evaluated (Table 1).

The USGS regression equations were developed to help with flood magnitude estimates in data limited streams and ungagged sites, and are based on the application of Bulletin 17B on a regional scale. In the case of the Santa Paula Creek watershed these regression equations appear to underestimate flood events, with Bulletin 17B estimating the 50-year event at 24,970 cubic feet per second (cfs) and the regression equation estimate at 11,249 cfs (Table 1). The 50-year flood estimate from the USGS regression has been exceeded 7 times between 1933 and 2013 (80 years), or 8.75% of the years on record, indicating the potential underestimation of this 2% probability (50-year) event. The 50-year flood estimate by application of Bulletin 17B has been exceeded once (in 2005) during the period of record, or 1.25% of the years on record. The estimate for the 100 year event by USGS regression has been exceeded 3 times during the period of record, while the discharge estimate based on Bulletin 17B has not been exceeded. The method of weighting the USGS regression with Bulletin 17B produces estimates in the mid-range of the two, but due to the sufficiently long record at this site, Bulletin 17B is considered a better estimate.

Bulletin 17B still has considerable uncertainty even in its application to a gage record of more than 80 years. Figure 4 below shows a Log-Pearson Type III fitted frequency curve applied the 80 year record at the USGS gage (#11113500) on the Santa Paula Creek near Steckel Park. This curve estimates the 50 and 100-year flood discharges (2% and 1% annual probability) to be 24,900 and 34,600 cfs respectively. The upper 90% confidence bounds on this estimate are 38,500 and 55,100 cfs for the 50 and 100-year floods respectively, indicating the level of uncertainty in these estimates.

Figure 4 *–* A Log-Pearson Type III curve fitted to the 80 year annual peak discharge record at the Santa Paula Creek USGS gage (#11113500) located near Steckel Park. This is a flood frequency analysis and output graphic from the USGS PeakFQ program which implements both the Bulletin 17B and Expected Moments Algorithm (EMA) procedures. The confidence limits shown as blue lines represent the 90% confidence interval[12].



The HSPF model of the Santa Paula Creek watershed was calibrated to the USGS gage (#11113500) and precipitation gages throughout the watershed. This model takes into account the physical hydrologic processes within the watershed as well as hydraulic routing through the drainage channels. The subwatershed used in the model generated estimates for the USGS gage (Table 1) was slightly larger than the watershed area reported by the USGS to be above the gage near Steckel Park, which may be responsible for the estimates being slightly larger than those generated by Bulletin 17B.

Table 1 **–** Flood Discharge Reoccurrence Interval Determined for Watershed above USGS Santa Paula Creek Gaging Station (11113500) Located Near Steckel Park. All discharge estimates are in cubic feet per second (cfs).

Method of Flood Discharge Determination	50-Year	100-Year	200-Year	500-Year
USGS Regression*	11,200	15,600	20,900	29,300
Weighted USGS Regression and 17B*	18,800	24,900	32,100	43,800
Bulletin 17B*	24,800	35,300	48,200	69,700
HSPF model – sub-basin 834 (area 39.9mi^2)	27,700	39,000	52,500	76,100

Discharge estimates are rounded to the nearest 100 cfs.
*The results presented here are those published online by the USGS. The regression procedures and equations used for estimation are found in Gotvald et al. 2012 for the southern coastal region[11]. These regression equations were calibrated with stream gage data through water year 2006. Gotvald et al. 2012 also includes methods for weighting B17 and the regression results[11].

2.3 Estimating Flood Frequency and Magnitude at Drill Site No. 7

The three methods used to estimate flood magnitude at the DS7 study reach were: 1) USGS regression equations; 2) a weighted estimate using the USGS regression equation estimates and the weighted flow estimates from the downstream USGS stream gage from Table 1; and 3) results from the HSPF model. Table 3 presents the flood magnitude estimates from two sub-basins from the HSPF model that primarily cover the watershed above DS7. Sub-basin 831 is slightly smaller than, and fully enveloped by, the watershed above DS7, while sub-basin 832 is slightly larger with the drainage outlet at the confluence of Sisar Creek just below Thomas Aquinas College [13]. The estimates for these two sub-basins were used to estimate the discharge at DS7 by assuming a linear watershed area-discharge relationship.

The estimates from the HSPF model are considerably larger than those generated from the USGS methods outlined in Gotvald et al. 2012, but due to the physical modeling undertaken to generate these estimates they are considered to be the most appropriate. The HSPF model uses VCWPD data and design storm methodology, and the model was calibrated using long-term records from precipitation and stream gages throughout the Santa Clara River watershed. A reason for the discrepancy between the estimates from the model results and the USGS regression methodology could be that this watershed is potentially an outlier in terms of its hydrologic characteristics. The watershed above DS7 receives some of the most intense rainfall in Ventura County, and has a very extreme elevation relief. The estimates from the HSPF model are most similar to the estimates generated by Bulletin 17B for the downstream gage, and may be close to Bulletin 17B generated estimates at the DS7 study reach if a stream gage was present there.

Table 2 **–** Flood Discharge Estimates for Watershed above DS7. All discharge estimates are in cubic feet per second (cfs).

Method of Flood Discharge Determination	50-Year	100-Year	200-Year	500-Year
USGS Regression*	7,100	9,800	13,200	17,900
Weighted USGS Regression and Weighted USGS gage Estimate*	7,800	10,600	14,100	19,100
Estimate from HSPF model	17,200	24,200	32,600	47,300
Discharge estimates are rounded to the nearest 100 cfs. * The regression procedures and equations used for estimation are found in Gotvald et al. 2012 for the southern coastal region. These regression equations were calibrated with stream gage data through water year 2006. Gotvald et al. 2012 also includes methods for weighting B17 and the regression results[11].				

Table 3 **–** Ventura County HSPF model Flood Discharge Estimates for Watershed above DS7.[13] All discharge estimates are in cubic feet per second (cfs).

Model sub-basin	Drainage Area (mi^2)	50-Year	100-Year	200-Year	500-Year
831 – basin outlet above DS7	17.43	15,215	21,400	28,783	41,773
832 – basin outlet below DS7 at confluence with Sisar Creek	23.49	17,988	25,300	34,029	49,386
Estimated discharge at DS7 using linear watershed area-discharge relationship	21.8	17,215	24,213	32,566	47,263

3.0 | Flood Stage Estimates

This section describes the methods and results used to estimate flood stage height (average water surface elevation perpendicular to the direction of flow) for flood discharges with different reoccurrence intervals in the Santa Paula Creek study reach adjacent to Drill Site No. 7 (DS7). To come up with detailed estimates of the flood stages, field surveys were performed to develop cross-sections, measure channel slope, and investigate and document channel roughness. Other sources of information were also taken into account including relevant reports and studies, and current and historical aerial imagery.

Three cross-sections of the Santa Paula Creek adjacent to DS7 were surveyed and used with the discharge estimates from Section 2.0 to estimate the flood stage height for the 50, 100, and 200-year events (annual reoccurrence probability of 2%, 1%, and 0.5%). The US Army Corps of Engineers Hydrologic Engineering Centers River Analysis System (HEC-RAS) was used to estimate the flood stage and generate profile graphics[14].

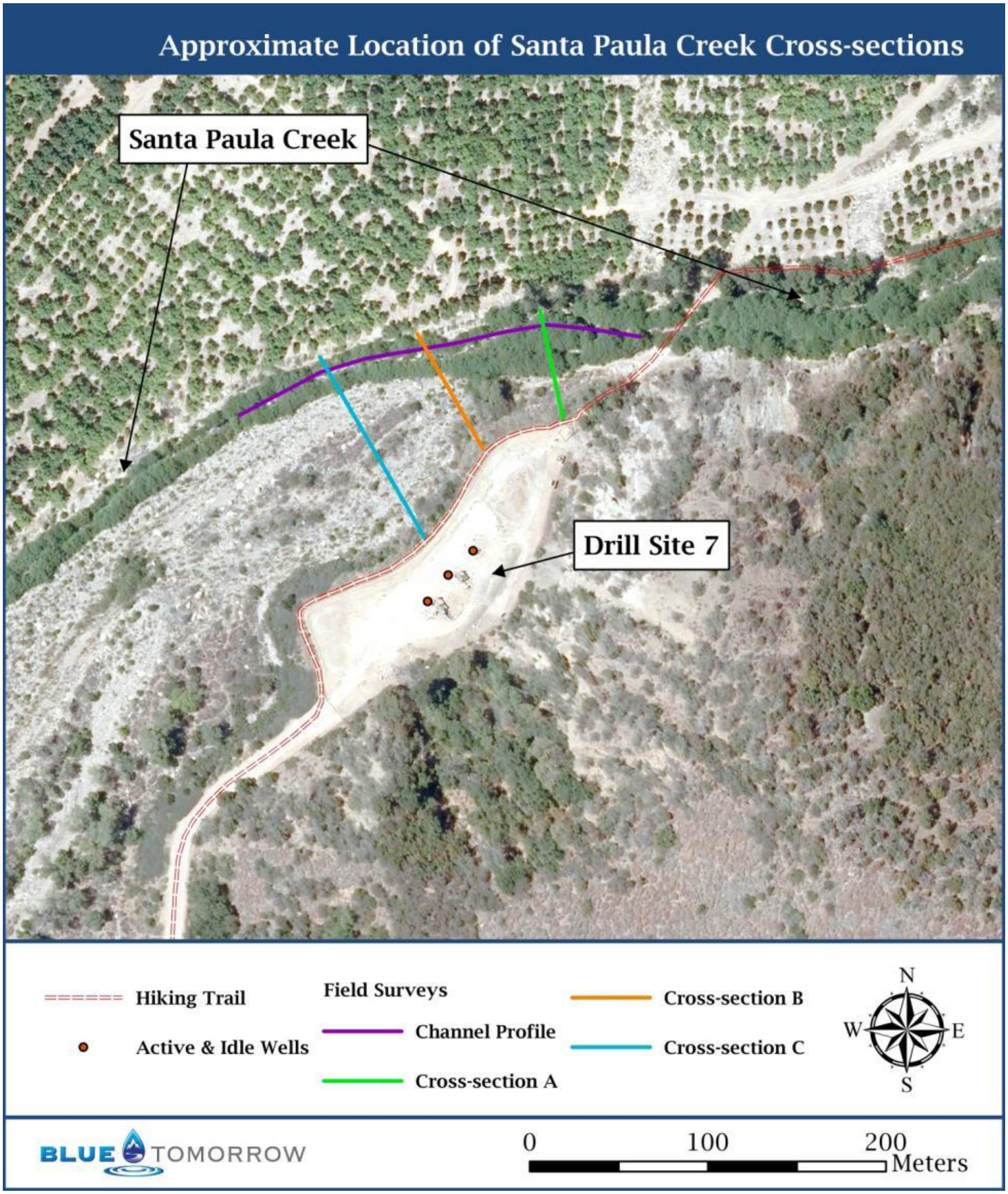
For the discharge estimates from the HSPF model prepared by AQUA TERRA Consultants for the VCWPD (Table 2) the 100-year flood stage was estimated at 3.9 feet below the top of the berm surrounding the well pad at the furthest upstream cross-section (XS-A, Figure 5), and 11.7 feet below the pad berm at the furthest downstream cross-section (XS-C, Figure 5). The difference between the upstream and downstream estimates indicates the main risk of flooding in the DS7 study reach is at the upstream end where the channel is narrower and the difference between the channel bottom and well pad berm is the least. A sensitivity analysis of the HEC-RAS results was also performed using other higher and lower roughness scenarios.

3.1 Cross-Section Locations

Three cross-sections were surveyed across Santa Paula Creek towards the upstream side of DS7 (Figure 5). The cross-sections were sited near the upstream end of DS7 as the stream channel is narrowest upstream and then quickly widens in the downstream direction. The objective was to capture this change in the dimensions of the cross-sections and investigate the most upstream sections of the reach, which were expected to have the highest flood stage.

The distance between XS-A and XS-B is approximately 200 to 240 feet, and the distance between XS-B and XS-C is approximately 135 to 150 feet apart. Because there is a slight curvature in the study reach, cross-sections are closer together on the inside of the curve, where they start at the DS7 fence line. Cross-sections were surveyed on March 19, 2015 using a laser level for the floodplain overbank areas and a level line for the stream channel and riparian areas where vegetation was very dense and inhibited the use of the laser. Cross-sections are zeroed on the left bank (facing downstream) at the chain-link fence of DS7, and the vertical datum was set at zero elevation at the highest point on the left bank at XS-A. Refer to Section 7.1 of the Appendix for additional survey information and cross-section data.

Figure 5 – The approximate locations of cross-sections relative to DS7 and the Santa Paula Canyon public hiking trail. Background image is 2010 USGS ortho-imagery; Active & Idle wells are provided by the California Department of Conservation, Department of Oil, Gas, and Geothermal Resources (DOGGR), downloaded March 2015.



3.2 Selection of Peak Discharge

Methodology and results of discharge estimates are presented in Section 2.0, and used to estimate the flood stage at XS-A, B, and C. The estimates generated by the Santa Clara River HSPF modeling study results are considered the most reliable (see Section 2.0 for further detail). This model was calibrated to USGS gage #11113500, and the estimates generated by the application of Bulletin 17B at this gage align closely with the HSPF model results.

The use of the HSPF model results is further supported by comparing the HEC-RAS water surface results for the HSPF estimate of the 50-year storm at DS7 to the scour marks left by the 2005 storm. The 2005 storm was estimated to generate a peak discharge of 27,500 cfs at the downstream USGS gage near Santa Paula, which is approximately the 50-year event at that gage site. The scour marks left in 2005 near DS7 align closely with the estimated water surface generated by HEC-RAS with the HSPF estimates as seen in Figures 6-11.

3.3 Channel Slope, Channel Roughness, and Modeled Flow Conditions

Several parameters of the stream characteristics are needed to model the flood stage for various discharge reoccurrence intervals. The following information includes the assumptions (and justifications) used to model the flood stages at cross-sections A, B, and C.

3.3.1 Channel Slope

During field surveying for the cross-sections, a longitudinal profile of the stream channel was surveyed from 40 meters upstream of cross-section A (XS-A) to 40 meters below the most downstream cross-section (XS-C), extending a total of 192.5 meters (Figure 5). This profile shows the channel has a slope of 3.6% towards the upstream end of the reach, and a slope of 3.1% towards the downstream end. The flow in this reach is primarily supercritical, and an upstream slope of 3.3% was used as a boundary condition. Google Earth imagery and measurements taken over a longer distance up and down stream verified this slope as a reasonable estimate for the area.

3.3.2 Channel Roughness

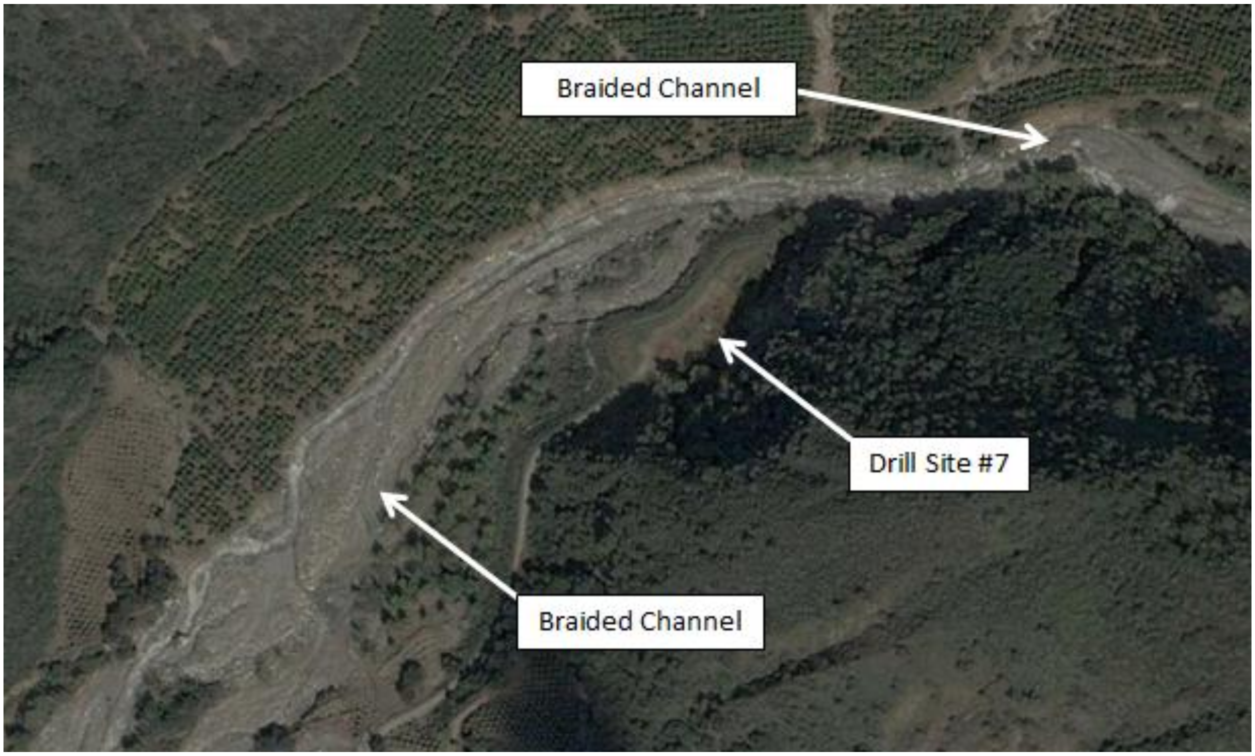
Roughness coefficients (Manning's n) were estimated from field observations and existing literature. A Geomorphic Assessment of the Santa Paula Creek conducted by Stillwater Sciences assumed a Manning's n of 0.05 for cross-sections located further downstream below the confluence with Sisar Creek and the Highway 150 bridge. The channel upstream near DS7 is steeper and rougher with larger substrate, and therefore a value of 0.05 was used and assumed as a minimum possible roughness across the channel.

Higher roughness coefficients are justified for the study reach. This reach is cobble-boulder-gravel with many boulders being up to or greater than 5 feet in diameter, as seen in XS-C (Figure 8 & 11) at distance 210 feet, where one of these large boulders was included in the cross-section. The riparian vegetation along the DS7 study reach is dense and would provide considerable roughness until flows become strong enough to rip out the trees and vegetation. Roughness coefficients for dense riparian vegetation and scrub on the floodplain and overbank areas can be 0.1 or higher. Another factor that would affect roughness in this reach is the large amount of sediment that is mobilized during large discharge events. This sediment and debris can have a “bulking” effect on the flow, which can cause an increase in the roughness coefficient.

During the 2005 flood event, aerial imagery shows that riparian vegetation was scoured out, leaving little to no vegetation between the high water marks from this event (Picture 1). It can be assumed that this is likely to happen again during a flood of similar magnitude (50-year event) or greater, but the vegetation that is currently present may be more or less resistant to scour than the vegetation that was cleared by the 2005 event.

For these reasons, flood stage was estimated for three roughness coefficient scenarios: 1) assuming vegetation is scoured out during a large event and roughness is approximately uniform across the channel with a low roughness of 0.05; 2) vegetation is scoured and roughness is uniform at 0.07; and, 3) vegetation is not scoured and roughness is non-uniform, retaining 0.05 in the channel and 0.1 for the vegetated floodplain and overbank areas. The scenario using a roughness of 0.07 across the channel is considered to be the most realistic roughness scenario, but results and cross-sections from the other roughness scenarios have been included in Section 7.2 of the Appendix to show how roughness influences the stage height, and the uncertainty with selecting this parameter.

Picture 1 – Aerial image of the reach of Santa Paula Creek near Drill Site No. 7 after the January 2005 flood. The photo shows that riparian vegetation in the floodplain and stream channel has been scoured and washed downstream. The photo also shows the braided stream channel indicating the large amount of bedload material and geomorphic activity in this reach. Photo was taken in February 2005. Image courtesy of Google Earth.



3.3.3 Modeled Flow Conditions

For this study, a steady state flow condition was modeled to determine the water surface elevation. Unsteady flow conditions may occur and be justified in this area due to potential flash flooding events when stream discharge may change rapidly over time. Modeling a flood wave in unsteady flow conditions was unnecessary for achieving the objectives of this study. Flow was modeled as a mixed subcritical and supercritical flow, but was primarily supercritical in all cross-sections (except for certain discharge estimates and roughness scenarios at XS-C) due to the relatively steep channel in this reach and the flow velocities that are expected.

3.4 Cross-Sections and HEC-RAS Results

The surveyed cross-section data was entered into the US Army Corps of Engineers Hydrologic Engineering Centers River Analysis System (HEC-RAS) to model the hydraulics of the study reach, estimate flood stage, and produce cross-sectional profiles[14]. Two profile graphics were produced for each cross-section for this study (Figures 6-11). One of the profiles depicts the estimate using a uniform channel roughness of 0.07 (figures 6, 7, and 8), and the other profiles (figures 9, 10, and 11 found in Section 7.2 of the Appendix) depict the other roughness scenarios and some of the uncertainty associated with estimating stream hydraulics in this reach.

3.4.1 HEC-RAS Results

The greatest potential for flooding DS7 occurs at the upstream end of the reach where the channel is narrowest (Figures 6 and 9). As the flood waters move downstream from XS-A to XS-C the channel widens and flow velocities decrease. The flood stage for the 100 -year event (HSPF model estimate of 24,200 cfs) is 3.9 feet below the top of the well pad at XS-A and drops to 11.7 feet below the top of the pad at XS-C. Given the roughness of 0.07 across the channel, a discharge of approximately 39,000 cfs would be needed to top the upstream banks of DS7, but his doesn't take into account erosion of the banks that may occur during a discharge of this magnitude. Estimation of the 200-year event (0.5% probability of occurrence in any year) shows the stage reaching 1.76 feet below the top of the berm, which could potentially flood DS7 due the proximity of the trail ramp to the upstream side of the drill site.

Figure 6 *–* HEC-RAS calculated water surface results for the 50, 100, and 200-year events at cross-section A (XS-A) with a roughness coefficient of 0.07. Depicted facing downstream, this is the most upstream cross-section with the greatest chance of flooding over the leftbank and onto Drill Site No. 7.

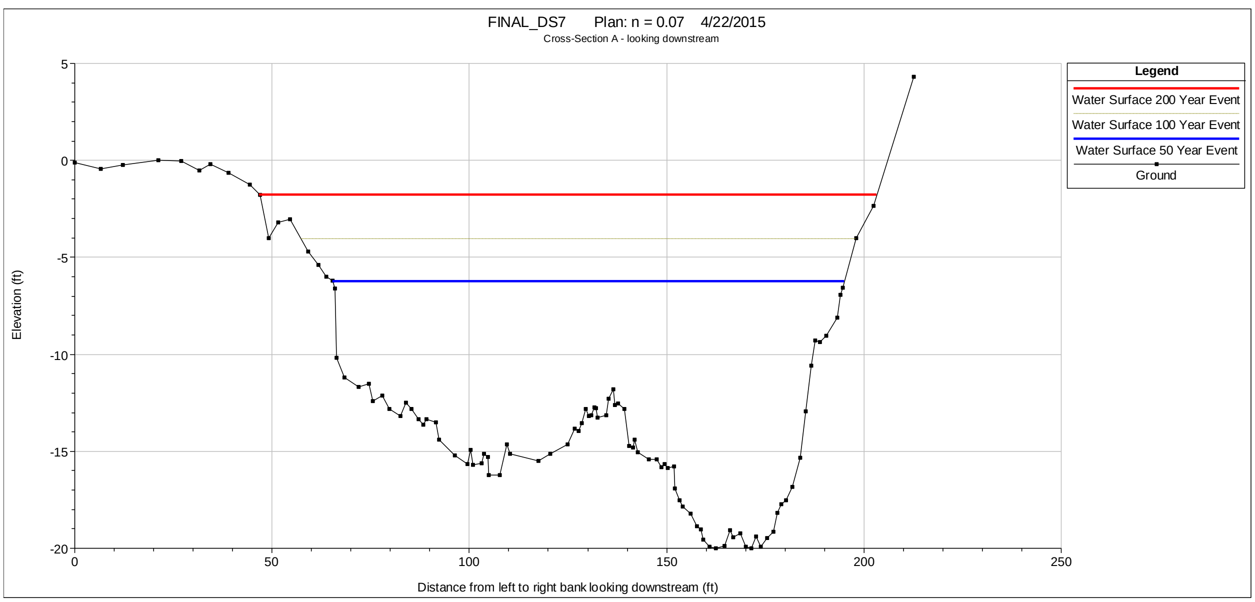


Figure 7 - HEC-RAS calculated water surface results for the 50, 100, and 200-year events at cross-section B (XS-B) with a roughness coefficient of 0.07. Depicted facing downstream, this is the middle of three cross-sections in the modeled reach.

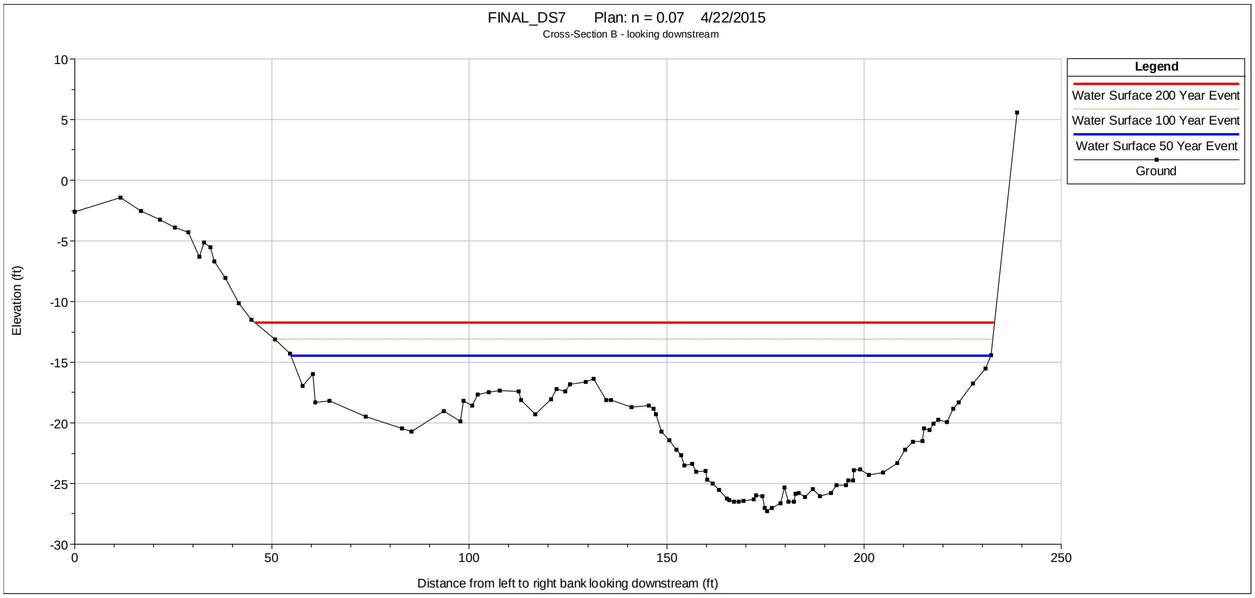
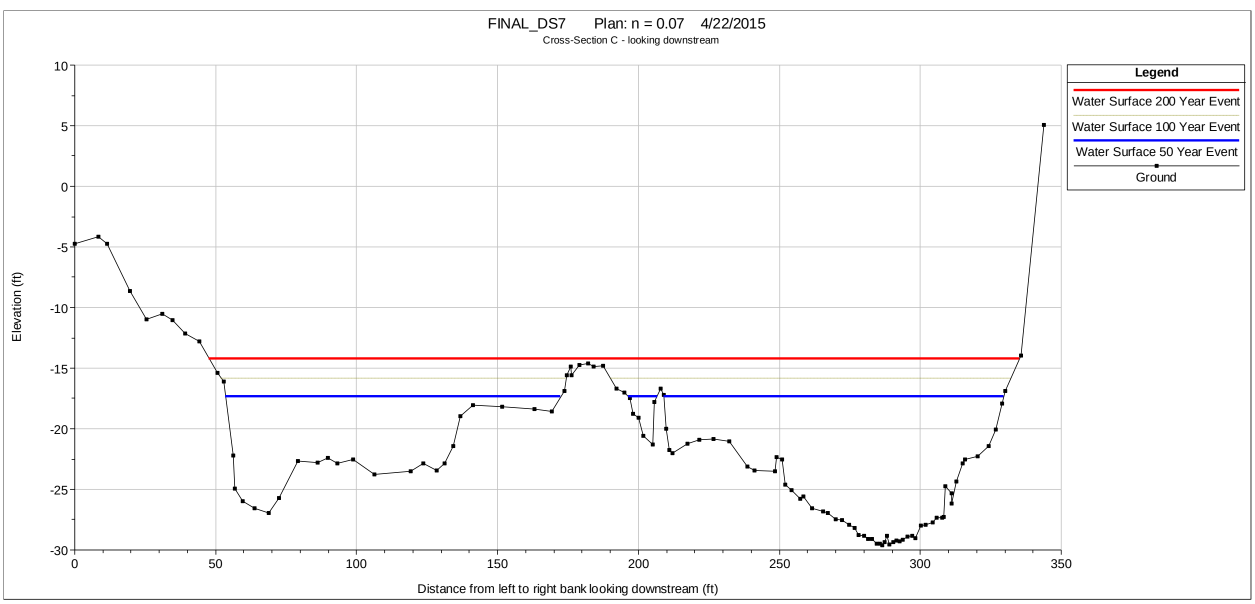


Figure 8 - HEC-RAS calcualted water surface results for the 50, 100, and 200 year events at cross-section B with a roughness coefficient of 0.07. Depicted facing downstream, this is the most downstream cross-section (XS-C) and the leftbank is inline with the middle of three oil wells currently located on Drill Site No. 7.



3.4.2 Model Uncertainty

As discussed in the discharge section of this study, although the HSPF model is assumed to produce reasonable estimates, there is considerable uncertainty in determining the flood discharge for various return intervals. This uncertainty is compounded when estimating channel roughness and calculating stage height (therefore a range of possible roughness scenarios were evaluated). In addition, this reach is a braided stream and very geomorphically active during large discharge events (as demonstrated from the 2005 flood by the large amount of scour and the realignment of the stream channel by as much as 225 feet, Picture 1). It is unclear how large boulders and bedload material will be scoured and deposited in this reach and affect flows during these large discharge events.

4.0 | Setback Distances

The Ventura County Non-Coastal Zoning Ordinance specifies setback distances for oil production operations from "redline channels". According to Sec. 8107-5.61 of the ordinance, "No well shall be drilled and no equipment shall be permanently located within: d) 300 feet from the edge of existing banks of "Red Line" channels as established by the Ventura County Flood Control District (VCFCD)."[15] In 2003, the VCFCD changed its name to the Ventura County Watershed Protection District (VCWPD).

Santa Paula Creek, the East Fork of Santa Paula Creek, Echo Falls Canyon, and La Broche Canyons are all watercourses under the jurisdiction of the VCWPD and classified as a redline channels per the Comprehensive Plan for Flood Control[16,17].

The VCWPD utilizes the 100-year storm event as a determination of the defined bed of waters flowing in a defined direction. In a memorandum dated February 12, 2015 from the Ventura County Public Works Agency, Development and Inspection Services Division, the "top of bank" adjacent to DS7 was defined as four vertical feet above the 50-year storm water mark[18]. This memorandum also specified that the five additional wells proposed to be drilled at DS7 are required to be setback a minimum of 100 feet from the "top of bank" [18].

Table 4 shows the distances from the various flood elevation estimates generated by the three roughness scenarios using the HSPF derived discharge estimates. Using the best estimate (n = 0.07) of the 100-year flood, the fenced area of DS7 is less than 58 feet from the height of the 100-year flood mark at Cross-Section A (XS-A), and within 52 feet at Cross-Sections B and C (XS-B & XS-C). The edge of DS7 is closer using the determination of four vertical feet above the 50-year flood stage as the "top of bank" (within 48 feet at XS-A, 43 feet at XS-B, and 46 feet at XS-C).

XS-C is perpendicular to the channel and in-line with well 716. DS7 has a maximum width of 182 feet[18]. Any well sited on DS7 will be within the 300 foot setback requirement specified by Part D of Sec. 8107-5.61, using the maximum width of DS7, along with the distances noted in Table 4.

Table 4 - Horizontal Distances from Top of Bank to Edge of Drill Site No. 7

Top of Bank	Cross-Section A (ft)	Cross-Section B (ft)	Cross-Section C (ft)
100-Year High	48.84	49.67	51.63
100-Year Low	65.31	54.54	53.70
100-Year Best	57.34	50.96	51.87
50-Year + 4' High	47.19	42.11	45.37
50-Year + 4' Low	49.16	45.08	49.94
50-Year + 4' Best	47.40	42.33	45.65
100 and 50-year flood stage heights have been determined using the HSPF model for stream flow and three Manning's n scenarios: High) 0.1 for the overbank (floodplain area) and 0.05 for the channel (high water mark for each event); Low) 0.05 across the entire channel (low water mark for each event); and Best) 0.07 across the entire channel (low water mark for each event)			

5.0 | Drill Site No. 7 Hydrology

Ferndale oil lease Drill Site No. 7 (DS7) is constructed at the base of a northwestern facing hillside. DS7 is roughly 80,000 square feet and has a perimeter berm designed to control runoff from the well pad[20]. There is a drain located on the southwestern corner of DS7 that consists of two parts: 1) a 6 inch diameter pipe with a valve that goes from inside the fenced area to outside of DS7; and 2) a 24 inch diameter culvert located outside of DS7, which the 6 inch pipe discharges into. The culvert then discharges approximately 53 feet downslope approximately to the "top of bank" as defined by the VCWPD and estimates from this study. The culvert discharges no more than 50 to 75 feet from the abandoned low-flow channel of the Santa Paula Creek (which moved during the 2005 flood) and may pose a water quality risk during stormwater runoff events, especially if the creek shifts back in the future.

On April 7, 2015, DS7 was observed from 1:00pm until 4:30pm, during which time approximately 0.4 inches of rainfall occurred in the area (as registered by a precipitation gage at the Santa Paula Canyon-Ferndale Ranch near Thomas Aquinas College). While the rainfall intensity was enough to cause ponding on the well pad area closest to the wells (Picture 4), and some overland flow started to occur in the surrounding area, there was not enough rainfall for stormwater to reach the well pad drain.

The installation of the prosed 5 wells would result in the creation of approximately 2,000 square feet of new impervious surface[20]. Increasing the number of wells and operations on the pad will likely lead to greater potential for spills, and the impervious surface will lead to increased surface runoff and discharge through the drain pipe and culvert, thereby increasing the chance of well pad generated pollutants reaching the creek.

As seen in Picture 3 there is what appears to be clays and silts depositing near the drain pipe on DS7 (seen dried and cracked on the surface). These silts and clays are potentially being transported during storm events when surface runoff is occurring from the un-vegetated and disturbed areas closer to the wells (seen in Picture 4). Organic pollutants generated on well pads such as DS7 are carcinogenic and can bound and be carried with these fine sediments when surface runoff occurs.

Picture 2 – Western edge of Drill Site No. 7 facing the drain. Ponding from previous storm event. Picture taken on March 6, 2015 at 10:00 am.

Picture 3 – Western edge of Drill Site No. 7 facing the drain. No ponding near the drain. Silts and clays appear cracked from swelling and shrinking due to moisture accumulation and evaporation. Picture taken on April 7, 2015 at 4:12 pm

Picture 4 – Edge of Drill Site No. 7 at XS-C, facing well #717. Ponding visible on the graveled area of the well pad, around the wells, and towards the gated entrance of the well pad. Picture taken on April 7, 2015 at 4:10 pm

6.0 | References

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7.0 | Appendix

7.1 Field Surveys and Cross-Sectional Profiles

Three cross-sectional profiles and one longitudinal profile were surveyed in the Santa Paula Creek adjacent to Drill Site No. 7 (DS7) in the Ferndale oil lease. These surveys followed standard field survey techniques such as those outlined in Harrelson et al. 1994[21]. The locations of the cross-sections were selected to focus on the upstream end of DS7 due to the greater susceptibility of flooding in this part of the reach. Additional considerations in selecting cross-section locations included: safety, access, and capturing representative cross-sections to show the changes in the channel profile and cross-sectional area along this study reach.

A laser level was used to survey differences in elevation in the floodplain overbank areas, but due to very dense riparian vegetation that inhibited the use of the laser, a level line was used to measure differences in elevation in the riparian corridor and stream channel. The level line was a lightweight string that was pulled tight between stakes on the stream banks and leveled with a bubble level. Care was taken to ensure no leaves, vegetation, or anything else was in contact with the string and the line was as level as possible during measurement. Tape measures and lines were placed along each segment of the cross-section and the directional bearing recorded and adjustments were made to ensure segments of the cross-section were in a straight line along the same bearing.

The elevation and distance measurements were corrected for all laser survey turning points and to integrate floodplain and riparian corridor measurements into a seamless profile at each cross-section. Distance measurements for each cross-section are measured from left-bank to right-bank (facing downstream), and the furthest left-bank point (zero feet distance) was at the fence line surrounding DS7. The benchmark or datum to which elevation was corrected to (zero feet elevation) was the highest point on the left-bank of cross-section A, the most upstream cross-section. All elevation measurements are referenced to this point and reported as negative feet relative to this point. The data for each surveyed profile are found below in Tables 5 and 6.

7.1.1 GPS Coordinates of Profiles

Due to dense vegetation and trouble acquiring GPS satellites on the day surveys were conducted these GPS locations may have uncertainty up to +/- 15 feet or more. Latitude and Longitude were recorded and are reported in decimal degrees.

Table 5 – GPS Coordinates of Right and Left Bank Extent of Cross-Sectional Profiles

	Cross-Section A	Cross-Section B	Cross-Section C
Right-bank extent			
Latitude	34.439624	34.439541	34.439464
Longitude	-119.082482	-119.083171	-119.083665
Left-bank extent			
Latitude	34.4392	34.439067	34.438699
Longitude	-119.082455	-119.08283	-119.083146
Upstream Start of Longitudinal Profile: 34.439529 (Latitude), -119.082039 (Longitude)			

Table 6 – Presents the cross-sectional data for the three cross-sections surveyed for this study. Station data (distance from drill site fence on left-bank) was collected using a meter tape and converted to feet, elevation was collected as decimal feet using a surveying rod (stadia rod).

Cross-section A			Cross-section B			Cross-section C		
Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes
0.00	-0.13		0.00	-2.57		0.00	-4.76	
6.56	-0.45		11.65	-1.41		8.53	-4.14	
12.14	-0.22		16.73	-2.52		11.48	-4.73	
21.16	0		21.65	-3.25		19.52	-8.61	
26.90	-0.03		25.43	-3.87		25.43	-10.95	
31.66	-0.5		28.87	-4.26		31.00	-10.53	
34.45	-0.21		31.66	-6.28		34.61	-11.05	
39.04	-0.64		32.81	-5.13		39.21	-12.16	
44.29	-1.27		34.45	-5.54		44.29	-12.76	
46.92	-1.78		35.43	-6.72		50.52	-15.42	
49.21	-4.02		38.22	-8.08		52.82	-16.11	
51.51	-3.21		41.50	-10.12		56.10	-22.19	
54.56	-3.05		44.78	-11.47		56.92	-24.94	
59.19	-4.71		50.85	-13.1		59.71	-25.97	
61.68	-5.38		54.46	-14.3		63.65	-26.56	
63.65	-5.98		57.74	-16.92		68.90	-26.96	
65.29	-6.21		60.37	-15.97		72.51	-25.72	
65.94	-6.61		61.02	-18.34		79.07	-22.64	
66.27	-10.17		64.47	-18.19		86.29	-22.81	
68.41	-11.18		73.82	-19.46		89.90	-22.39	
71.85	-11.69		83.01	-20.45		93.18	-22.86	
74.57	-11.5		85.30	-20.72		98.75	-22.55	
75.62	-12.42		93.50	-19.04		106.30	-23.79	
77.89	-12.12		97.77	-19.88		119.09	-23.48	
79.72	-12.8		98.59	-18.21		123.69	-22.88	
82.45	-13.18		100.72	-18.57		128.28	-23.46	
83.92	-12.48		102.20	-17.64		131.23	-22.85	
85.40	-12.8		104.82	-17.49		134.19	-21.4	
87.14	-13.36		107.78	-17.34		136.81	-18.99	
88.39	-13.61		112.53	-17.38		141.40	-18.08	
89.21	-13.33		113.19	-18.12		151.74	-18.19	
91.47	-13.51		116.80	-19.31		163.22	-18.38	
92.26	-14.39		120.73	-18.06		169.13	-18.55	
96.29	-15.23		122.05	-17.24		173.65	-16.87	
99.57	-15.67		124.34	-17.42		174.61	-15.58	
100.26	-14.92		125.49	-16.83		175.85	-14.85	
100.92	-15.68		129.59	-16.62		176.18	-15.58	
103.02	-15.63		131.40	-16.38		179.13	-14.75	
103.67	-15.12		134.68	-18.13		182.09	-14.6	
104.66	-15.28		135.83	-18.14		184.06	-14.89	
104.92	-16.23		141.08	-18.71		187.34	-14.78	

Table 6 Continued

Cross-section A			Cross-section B			Cross-section C		
Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes
107.78	-16.22		145.51	-18.6		192.26	-16.72	
109.42	-14.66		146.72	-18.82		194.88	-17	
110.30	-15.13		147.38	-19.28		197.01	-17.45	
117.45	-15.48		148.59	-20.71		198.16	-18.75	
120.57	-15.11		150.75	-21.41		199.97	-19.09	
125.00	-14.65		152.40	-22.23		201.61	-20.58	
126.61	-13.84		153.67	-22.67		205.05	-21.31	
127.79	-13.95		154.53	-23.51		205.71	-17.78	
128.44	-13.54		156.43	-23.38		208.01	-16.72	
129.40	-12.8		157.45	-24		208.99	-17.22	
130.25	-13.2		159.97	-23.93		209.97	-19.97	
130.87	-13.14		160.20	-24.65		210.86	-21.73	
131.69	-12.74		161.58	-24.97	BF	212.11	-22.03	
132.05	-12.77		163.25	-25.49		217.52	-21.23	
132.55	-13.27		165.35	-26.24	WE	221.46	-20.93	
134.68	-13.13		165.85	-26.34		226.71	-20.82	
135.24	-12.29		167.06	-26.49		232.28	-21.01	
136.45	-11.81		168.34	-26.52	TW	238.52	-23.1	
136.81	-12.63		169.52	-26.41		241.14	-23.46	
137.73	-12.54		172.05	-26.3		248.36	-23.48	
139.27	-12.83		172.74	-25.98		249.02	-22.36	
140.52	-14.71		174.18	-26.03		250.98	-22.56	
141.54	-14.82		174.80	-27.04		251.97	-24.58	
141.83	-14.41		175.46	-27.26		254.27	-25.07	
142.68	-15.03		176.61	-27		257.38	-25.77	
145.47	-15.43		178.77	-26.6	WE	258.53	-25.58	
147.54	-15.42		179.89	-25.32		261.48	-26.55	
148.72	-15.83		180.94	-26.49		265.58	-26.8	
149.57	-15.66		182.25	-26.47		267.06	-26.92	
150.36	-15.88		182.74	-25.87		269.85	-27.47	
151.84	-15.77		183.40	-25.78		272.15	-27.53	
152.07	-16.9		185.07	-26.11		274.77	-27.95	BF
153.28	-17.51		187.01	-25.47		276.57	-28.16	
154.13	-17.83	BF	188.81	-26.02		278.22	-28.75	
156.00	-18.23		191.57	-25.75		280.02	-28.86	
157.64	-18.85		193.14	-25.15	BF	281.56	-29.06	WE
158.73	-19.03		195.47	-25.13		282.81	-29.08	
159.28	-19.56	WE	196.06	-24.75		284.45	-29.49	
160.89	-19.9		197.15	-24.74		285.70	-29.45	
162.53	-19.98		197.44	-23.9		286.42	-29.58	
164.63	-19.88		198.98	-23.82		287.34	-29.38	
166.01	-19.07		201.28	-24.28		288.22	-28.83	
166.86	-19.43		204.89	-24.1		288.98	-29.54	
168.64	-19.21		208.40	-23.34		290.32	-29.38	
170.05	-19.91		210.50	-22.21		291.50	-29.2	
171.42	-19.99	TW	212.47	-21.55		292.65	-29.27	
172.70	-19.41		214.73	-21.49		293.80	-29.13	WE
173.88	-19.9		215.16	-20.43		295.54	-28.88	
175.52	-19.48		216.70	-20.58		297.05	-28.83	
177.07	-19.13	WE	217.68	-20.09		298.13	-29	
178.15	-18.17		218.80	-19.73		300.30	-27.99	
178.97	-17.74	BF	220.96	-19.91		302.00	-27.92	BF
180.35	-17.54		222.60	-18.83		304.46	-27.73	
181.76	-16.82		224.02	-18.29		305.91	-27.37	
183.89	-15.32		227.62	-16.73		307.74	-27.34	
185.27	-12.92		230.91	-15.52		308.40	-27.28	
186.61	-10.58		232.22	-14.43		308.89	-24.73	
187.70	-9.3		238.78	5.57	EE	311.02	-25.3	
188.78	-9.37					311.12	-26.16	
190.52	-9.04					312.89	-24.33	
193.27	-8.1					315.12	-22.87	
194.03	-6.95					315.78	-22.56	
194.69	-6.58					320.47	-22.27	
198.13	-4.01					324.15	-21.46	
202.40	-2.34					326.64	-20.08	

Table 6 Continued

Cross-section A			Cross-section B			Cross-section C		
Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes	Station (ft)	Elev. (ft)	notes
212.57	4.32					328.90	-17.93	
						330.05	-16.87	
						335.63	-13.95	
						343.83	5.05	EE

Notes Key:
BF – Bank Full, estimated from geomorphic marks in the field this is the height of the estimated 2-year discharge event.
WE – Waters edge at the time of survey, March 19, 2015.
TW – Thalweg, the deepest point in the channel.
EE – estimated elevation and distance, at cross-section B and C the last point on the right bank was estimated using the measurement rod because it was a sheer cliff of approximately 20 of more feet that drops from the avocado orchard.

Table 7 – Presents the longitudinal stream profile data surveyed for this study. Station data (distance downstream) was collected using a meter tape and converted to feet, elevation was collected as decimal feet using a surveying rod (stadia rod). This profile begins approximately on the downstream edge of the public hiking trail stream crossing, 131 feet (40 meters) upstream of cross-section A. The profile follows the centerline between water's edge and the banks of the main channel.

Longitudinal Profile		
Station (ft)	Elev. (ft)	notes
0.00	-14.21	
28.54	-15.18	
47.24	-16.48	
82.02	-17.19	
116.80	-19.08	
131.56	-19.37	XSA
159.45	-22.39	
201.12	-22.35	
232.94	-23.62	
259.84	-23.8	
288.06	-24.73	
311.68	-25.34	
334.97	-25.67	
344.16	-26.06	XSB
366.14	-27	
402.23	-27.35	
428.81	-28.14	
455.05	-28.8	
471.78	-28.93	
484.81	-29.45	XSC
494.42	-29.73	
511.81	-30.87	
531.82	-32.14	
570.87	-31.87	
586.29	-32.04	
631.56	-35.35	

Notes Key:
XSA – Intersect with cross-section A at 168.1 feet distance from left bank extent (chain-link fence).XSB – Intersect with cross-section B at 153.8 feet distance from left bank extent.
XSC – Intersect with cross-section C at 263.2 feet distance from left bank extent.

7.2 Additional Flood Stage Estimates

The following profiles depicts low and high roughness scenarios used to gage the sensitivity of the flood stage to various Manning's n coefficients, and demonstrate the uncertainty associated with estimating stream hydraulics in this reach. Refer to Section 2.0 and 3.0 for more about these estimates.

Figure 9 - HEC-RAS calculated water surface results for the 50, 100, and 200 year events at cross-section A with a low (n=0.05 across channel) and high (n=0.05 in channel and 0.1 in floodplain) roughness senerio. Depicted facing downstream, this is the most upstream cross-section with the greatest chance of flooding over the leftbank and onto Drill Site No. 7.

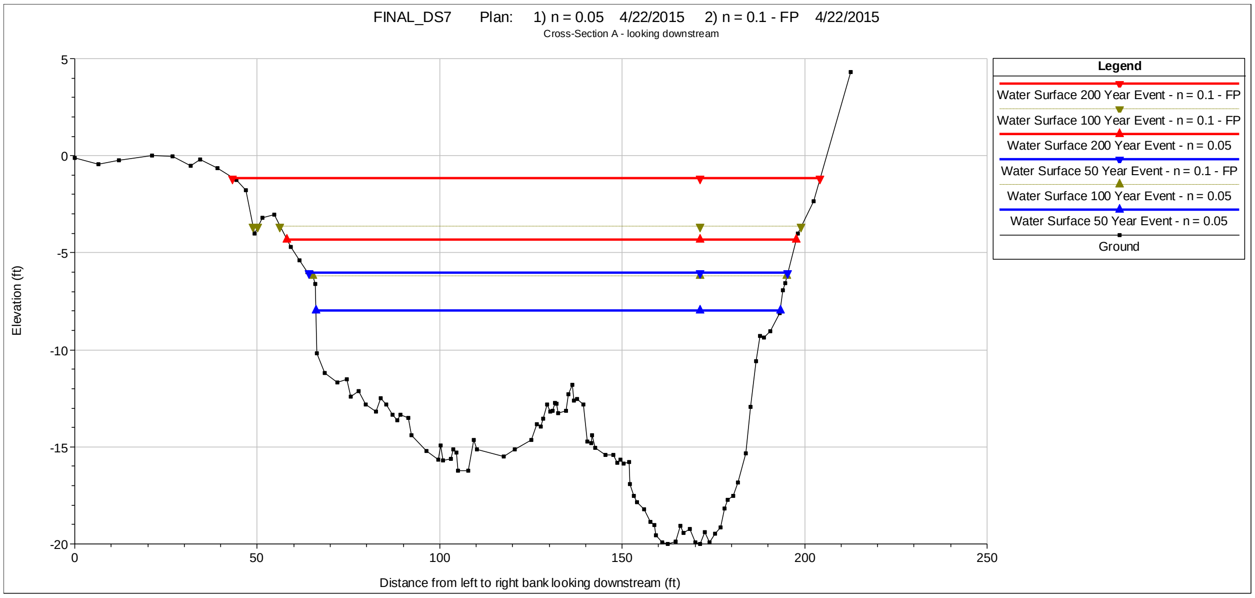


Figure 10 - HEC-RAS calculated water surface results for the 50, 100, and 200 year events at cross-section B with a low (n=0.05 across channel) and high (n=0.05 in channel and 0.1 in floodplain) roughness senerio. Depicted facing downstream, this is the middle of three cross-sections in the modeled reach.

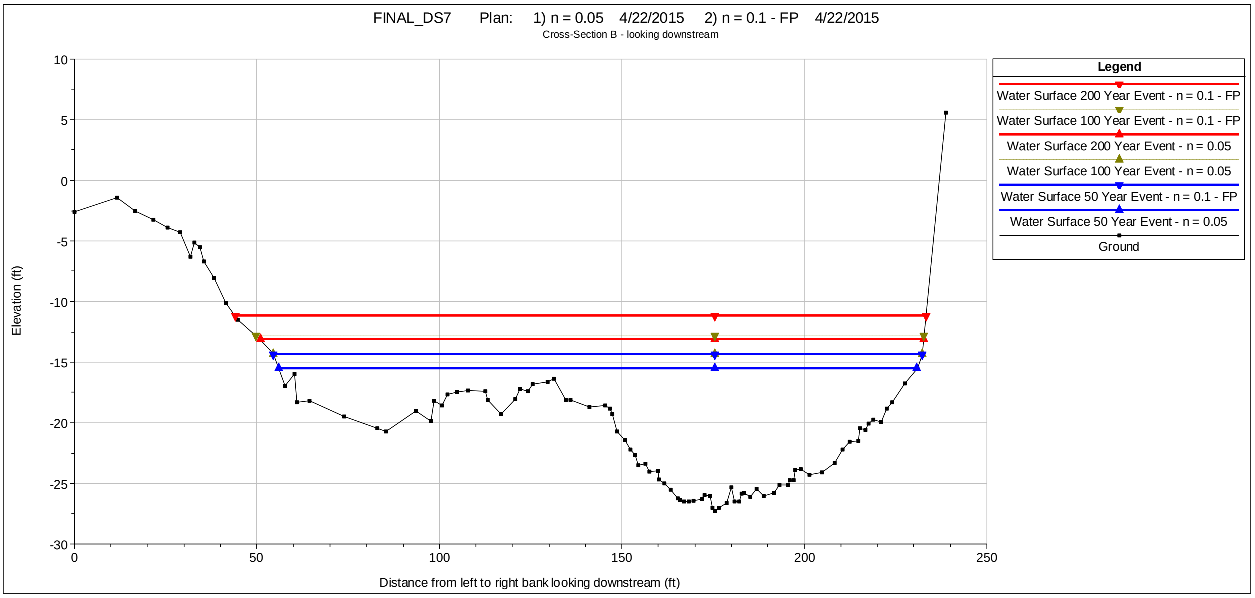
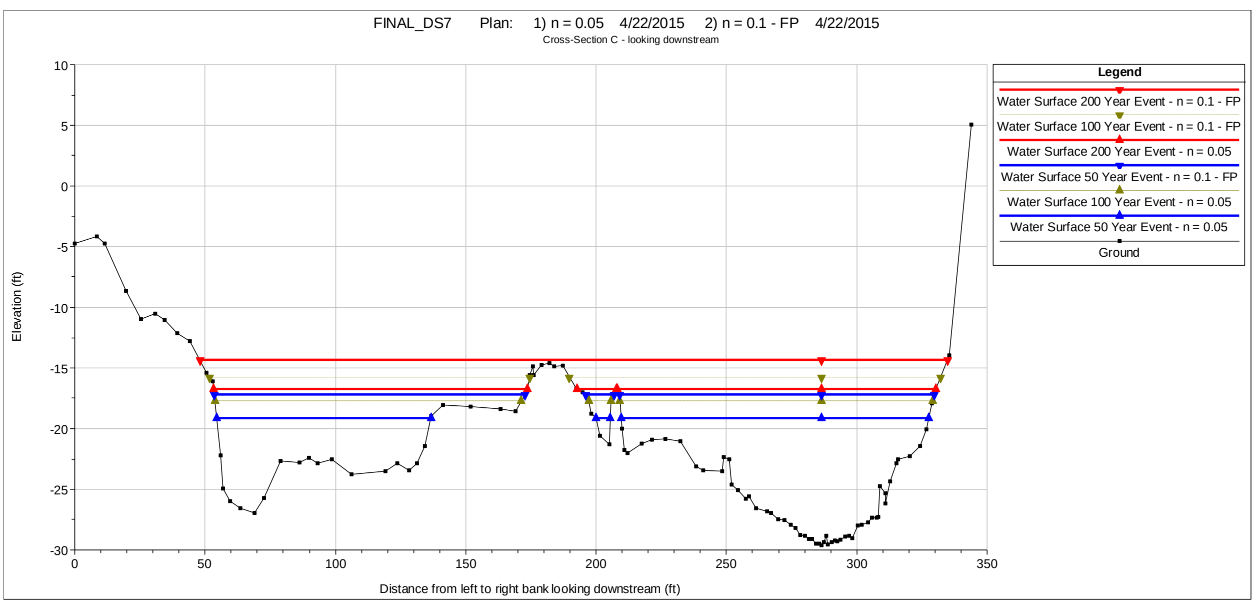


Figure 11 - HEC-RAS calcualted water surface results for the 50, 100, and 200 year events at cross-section B with a low (n=0.05 across channel) and high (n=0.05 in channel and 0.1 in floodplain) roughness senerio. Depicted facing downstream, this is the most downstream cross-section and the leftbank is inline with the middle of three oil wells currently located on Drill Site No. 7.



7.3 Photo Log

The following pictures were taken during field surveying and document the locations of the cross-sections. These pictures also show the vegetation and substrate roughness from which roughness coefficients were estimated and used in modeling the flood stage elevation.

Picture 5 – Standing in channel facing left bank looking along cross-section A.

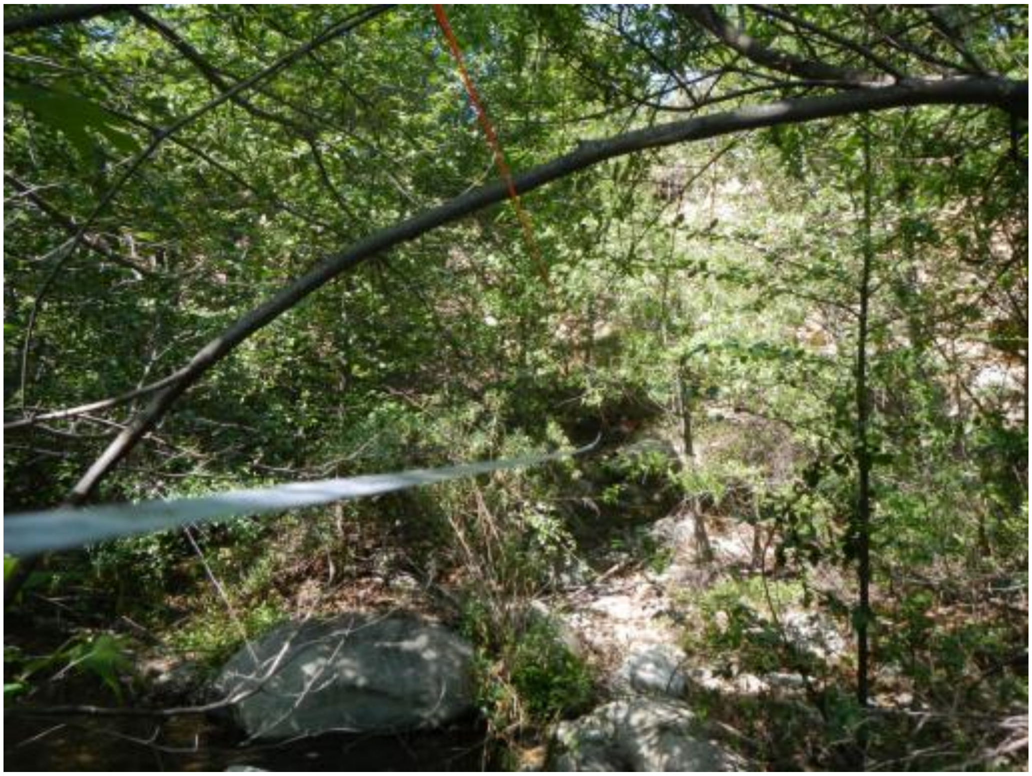
Picture 6 – Standing in channel facing right bank looking along cross-section A.

Picture 7 – Standing in channel at cross-section A facing upstream.

Picture 8 – Standing at waters-edge-left-bank at cross-section A facing downstream.

Picture 9 – Standing in channel facing left-bank looking along cross-section B.

Picture 10 – Standing in channel facing right-bank looking along cross-section B.



Picture 11 – Standing in channel at cross-section B facing upstream.

Picture 12 – Standing at waters-edge-left-bank at cross-section B facing downstream.

Picture 13 – Standing in channel facing left-bank looking along cross-section C.

Picture 14 - Standing in channel facing right-bank looking along cross-section C.

Picture 15 – Standing at waters-edge-left-bank at cross-section C facing upstream.

Picture 16 – Standing at waters-edge-left-bank at cross-section C facing downstream.

Picture 17 – Standing in channel at longitudinal profile upstream start, looking downstream.

Picture 18 – Standing in channel 15 meters downstream of longitudinal profile upstream start looking upstream at longitudinal profile upstream start.

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