Gaviota Creek
Fish Passage and Geomorphic Assessment

Prepared for
California Department of Fish and Game
And
Pacific States Marine Fisheries Commission

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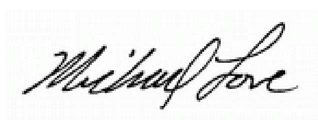

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Table of Contents

APPENDICES

APPENDIX A – Fish passage assessment of two culverts on Highway 101: Upper Gaviota Creek (GA_20) and Las Canovas Creek (CA_GA_1)

APPENDIX B – Hydrologic Calculations

APPENDIX C – Channel Cross Sections

List of Figures

List of Tables

1 Project Description

The following report describes a steelhead migration barrier assessment within lower Gaviota Creek, accompanied by a geomorphic channel assessment and development of preliminary recommendations for treatment of sites. The study stream reach runs through Gaviota Canyon adjacent to Highway 101, from stream mile 0.9 (from the ocean) to mile 2.4. This reach contains 12 concrete grade control structures and two free spanning bridges.

As part of this project, fish passage conditions were also assessed at the Highway 101 culvert on Gaviota Creek (GA_20) and the Highway 101 culvert on Las Canovas Creek (GA_CA_1), a tributary to Gaviota Creek. Both of these culverts are located upstream of the Gaviota Canyon study reach and the results of the culvert assessments are provided in **Appendix A**.

1.1 Project Objective

This report focuses on guiding future actions aimed at improving steelhead passage on Gaviota Creek by providing a detailed description of existing conditions and development of preliminary recommendations. The report includes:

1. An assessment of existing fish passage conditions using the California Department of Fish and Game (CDFG) protocol (Part IX of California Salmonid Stream Habitat Restoration Manual, 2003),
2. An analysis and interpretation of existing channel geomorphology and channel response to realignment and modification associated with the Highway, and
3. Development of preliminary recommendations for improving fish passage and restoring proper channel function.

1.2 Project Background

1.2.1 Gaviota Creek Watershed

Gaviota Creek, a tributary to the Pacific Ocean, is located along the southern coast of Santa Barbara County (Figure 1.1). The 12,877 acres watershed rises from sea level to 2,800 feet in elevation and is the third largest coastal watershed in southern Santa Barbara County, between Jalama Creek to the west and Rincon Creek to the east. Annual precipitation values range from 17 to 21 inches within the drainage.

The lower reach of Gaviota Creek lies within Gaviota State Park, and flows through Gaviota Canyon and into a coastal lagoon. Upstream of the canyon the stream divides into four branches: main stem Gaviota Creek, West Fork Gaviota Creek, Las Canovas Creek, and Las Cruces Creek.

The stream currently supports runs of Southern Steelhead (Stoecker, 2002), a Federally listed endangered species. A large-scale assessment of steelhead migration barriers and existing habitat conditions was conducted by Stoecker et al. in 2002, and included Gaviota Creek and some of its tributaries. Excellent spawning and summer rearing habitat was identified within Las Cruces Creek, which flows into Gaviota Creek approximately 4.4 miles upstream of the ocean. Additionally, habitat suitable for supporting populations of steelhead trout was identified in several other tributaries and one adult steelhead was observed in upper Gaviota Creek, immediately below the Highway 101 culvert (GA_20).

Although the stream system has habitat suitable for sustaining endangered Southern Steelhead, several significant migration barriers located within the lower reach of Gaviota Creek block fish from reaching spawning and rearing habitats. Nearly all of these barriers are located within Gaviota State Park and associated with State Highway 101, which parallels and confines the stream as it flows through Gaviota Canyon to the ocean.

A previous barrier assessment (Stoecker 2002) identified 54 potential barriers within the watershed; 18 of which are considered natural. This earlier assessment relied on qualitative measures to assess each fish passage obstruction and recommended further analysis to develop appropriate fish passage alternatives.

Figure 1.1 – Project location map.

1.2.2 Steelhead Habitat

Of the southern Santa Barbara County coastal streams, Gaviota Creek watershed has the second highest total habitat quantity (23.0 miles of stream length) that was historically accessible to steelhead. In the previous assessment (Stoecker 2002) the watershed ranked 23rd out of 24 for average habitat quality due to extremely poor habitat conditions in the upper Las Cruces and West Fork Creek tributaries, due to high levels of natural and human-influenced erosion and low summer stream flow. However, Gaviota Creek produces relatively high summer base flows and maintains cool water temperatures in the headwaters of the mainstem, Las Canovas Creek, and the lower mainstem. The watershed also contains one of the largest lagoon systems along the southern Santa Barbara County coast, which is ideal for steelhead rearing, food production, and acclimation between fresh and saltwater. Also, the estuary mouth is open to the ocean longer than most streams in the region, providing good access for steelhead adults and smolts. These characteristics make Gaviota Creek one of the highest ranking watersheds within the southern Santa Barbara County coast in terms of steelhead recovery potential and potential productivity.

1.2.3 Steelhead Population Information

Adult steelhead and juvenile O. mykiss have consistently been documented in the Gaviota Creek watershed since at least the 1930's and into the present. In the 1930's California Department of Fish and Game (CDFG) personnel reported "steelhead entered the creek in winter". Long-time resident and owner of the Circle Bar B Ranch, Jim Brown, reported catching "adult steelhead in lower Gaviota Creek in the 1940's" (pers. comm Stoecker 2001). Former CDFG Biologist Ken Sasaki reported in 1986 that "steelhead have continued to run in Gaviota Creek". Former State Park biologist Ronnie Glick reported that CDFG personnel "caught someone with a 6-pound steelhead in lower Gaviota Creek." In 2001, Stoecker observed and photographed a 22-inch adult steelhead in Gaviota Creek.

In addition to historic documentation of adult steelhead sightings in Gaviota, juvenile steelhead have also continually been observed from the early 1900's until present both on the mainstem of Gaviota Creek as well as Las Canovas Creek and the uppermost reaches of Gaviota Creek and the South Fork. O. mykiss were observed inside the lower backwatered section of the Las Canovas Creek Highway 101 culvert in 2001 and 2006. No trout were observed upstream of this impassable culvert during 2001 surveys to the natural upstream limits of this tributary. The Las Cruces Creek was reportedly planted with wild southern steelhead rescued from the Santa Ynez River in 1939. Former CDFG Fisheries Biologist, John Radovich, reported catching a 12-13 inch trout in the lagoon "with a stomach full of gobies" during August 1960. See Stoecker 2002 for a table of additional historic O. mykiss occurrence.

During geomorphic and fish barrier surveys for this project O. mykiss were observed in Gaviota Creek and Las Canovas Creek. Two O. mykiss measuring 7 inches were observed in Gaviota Creek within the reach downstream of Las Canovas Creek at stations G14 and G17. One O. mykiss measuring 5 inches was observed immediately downstream of the outlet of Las Canovas Creek and a large O. mykiss measuring 11 inches was observed 500 feet upstream of Las Canovas Creek. In upper Gaviota Creek, twelve O. mykiss ranging from 5 to 7 inches were observed in the outlet pool downstream of the Highway 101 culvert. In Las Canovas Creek, three O. mykiss measuring 5 to 7 inches were observed inside the backwatered lower part of the Highway 101 culvert. No fish were observed upstream of the impassable culvert on Las Canovas Creek. A total of 7 Southwestern Pond Turtles were observed on Gaviota Creek between the pass and 500 feet upstream of Las Canovas Creek.

1.2.4 Steelhead Migration Barriers within the Watershed

Anthropogenic migration barriers represent one of the most limiting factors to steelhead in Gaviota Creek. Gaviota Creek contains at least 37 anthropogenic fish passage barriers that limit steelhead and other fish in varying degrees (Stoecker 2002). The highest ranking barrier along the entire southern Santa Barbara County coast was identified as the Gaviota Creek box culvert on Highway 101, with 2.45 miles of high quality habitat upstream (31.3% of the historically accessible steelhead habitat within the watershed) and observation of an adult steelhead in the downstream pool during 2001 surveys.

The 7th highest ranking barrier along the entire southern Santa Barbara County coast was identified as the Las Canovas box culvert on Highway 101, with 0.92 miles of high quality habitat upstream (11.7% of the historically accessible steelhead habitat within the watershed). During the survey steelhead were present downstream, but no fish present upstream.

In addition to these two impassable culverts, there are at 14 grade control structures on Gaviota Creek below the Las Canovas Creek tributary that present varying degrees of severity for steelhead passage. Collectively these partial barriers can hinder upstream passage, depending on stream's flow-rate and flow duration.

In addition to physical barriers, a significant low-flow barrier was produced when Gaviota Creek was realigned into an artificial channel and diverted through lower Las Cruces Creek for construction of the Highway 101 and 1 interchange. This earthen channel section of Gaviota Creek does not retain surface flows for as long of a duration as natural reaches up and downstream This drying channel reach reduces the window of opportunity for upstream and downstream steelhead migration.

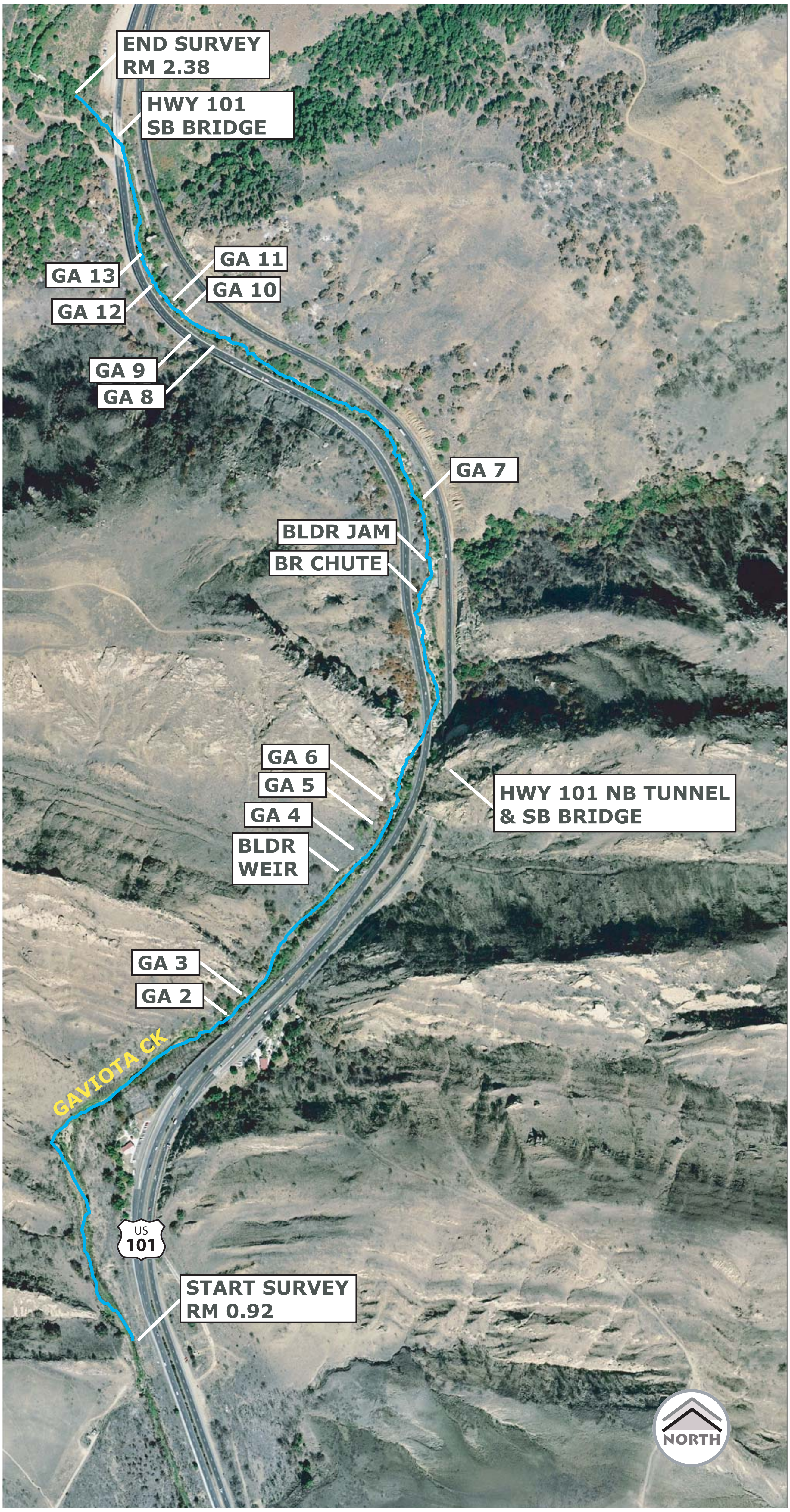
1.2.5 Location of Assessed Migration Barriers

For this project we performed a detailed and quantitative fish passage assessment of 14 grade control structures and a confined bedrock reach located in lower Gaviota Creek adjacent to Highway 101. The 14 grade control structures consisted of 12 concrete drop-structures, a boulder weir constructed prior to the 2002 assessment to improve steelhead passage, and a large boulder jam that is partly held in-place by an adjacent retaining wall (Figure 1.2). Table 1.1 lists the identification code for each grade control structure addressed in this project. When applicable, the identification codes used in the previous assessment were used for this project.

GA_1 is a County maintained bridge crossing located approximately 1,900 feet upstream of the ocean. This crossing is planned for replacement and was not included in this study.

Table 1.1 – Identification code and location of potential migration barriers assessed as part of this study.

Barrier ID Code	Barrier Type	Latitude Longitude (NAD83)	River Miles from Ocean
GA_2	Concrete Grade Control Weir	N 34^0 29’ 7.89” W 120^0 13’ 45.05”	1.32
GA_3	Concrete Grade Control Weir	N 34^0 29’ 8.79” W 120^0 13’ 43.92”	1.34
BLDR_WEIR	Constructed Boulder Weir	N 34^0 29’ 14.79” W 120^0 13’ 38.32”	1.49
GA_4	Concrete Grade Control Weir	N 34^0 29’ 15.34” W 120^0 13’ 37.76”	1.51
GA_5	Concrete Grade Control Weir	N 34^0 29’ 16.77” W 120^0 13’ 36.53”	1.54
GA_6	Concrete Grade Control Weir	N 34^0 29’ 17.66” W 120^0 13’ 36.15”	1.56
BR_CHUTE	Bedrock Chute	N 34^0 29’ 27.49” W 120^0 13’ 34.89”	1.78
BLDR_JAM	Large Boulder Jam	N 34^0 29’ 29.39” W 120^0 13’ 34.54”	1.81
GA_7	Concrete Grade Control Weir	N 34^0 29’ 31.77” W 120^0 13’ 35.01”	1.86
GA_8	Concrete Grade Control Weir	N 34^0 29’ 39.31” W 120^0 13’ 46.71”	2.12
GA_9	Concrete Grade Control Weir	N 34^0 29’ 39.64” W 120^0 13’ 47.50”	2.13
GA_10	Concrete Grade Control Weir	N 34^0 29’ 40.27” W 120^0 13’ 48.56”	2.15
GA_11	Concrete Grade Control Weir	N 34^0 29’ 40.86” W 120^0 13’ 49.25”	2.17
GA_12	Concrete Grade Control Weir	N 34^0 29’ 41.78” W 120^0 13’ 50.05”	2.19
GA_13	Concrete Grade Control Weir	N 34^0 29’ 43.19” W 120^0 13’ 50.75”	2.22



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Location of Grade Control Structures

Figure 2

2 Field and Assessment Methodology

Fieldwork was conducted during the days of October 9th to October 15th 2006 by Michael Love & Associates and Stoecker Ecological. Data collection consisted of surveying, mapping, and describing the channel substrate using Wolman pebble counts along the study reach.

The site survey component of the project involved:

1. Plan mapping of pertinent channel features at identified barriers. Features included encroachment of road embankments, channel alignment, thalweg location, active channel margins, and grade controlling features such as exposed bedrock. Level of detail varied depending on distance from fish barrier, channel type and site conditions.

2. Characterizing streambed material using surface pebble counts in two locations.

3. Surveying a continuous longitudinal channel profile through the project reach (1.45 miles). Detail varied depending on channel character, location of grade controlling features, and distance from identified barriers.

4. Surveying representative channel cross sections at various locations throughout the project reach and across grade control structures.

5. Collecting detailed survey information at culverts and grade control structures following the CDFG assessment protocol.

2.1 Field Methods

Surveys were conducted using a Leica Total Station to collect coordinate and elevation data of the Gaviota Creek channel in the study reach. A traverse was conducted starting downstream of the southbound rest area and continuing upstream to the second bridge crossing for the southbound lanes of Highway 101 (1.45 miles). The horizontal datum for the survey was California State Plane Zone 5. The vertical datum was approximated to the NAVD88 datum.

The survey data was used for mapping, developing longitudinal profile of the channel thalweg, plotting cross sections along the top of each grade control structure and at the downstream tailwater control (contained in Appendix C).

Pebble counts were conducted following the Wolman method to randomly record the size of 100 particles. Two locations were selected for pebble counts, one downstream at the tailwater control for GA2 and a second upstream at GA7.

Plan mapping was performed using field drawings, combined with survey points to assist with scale, to create diagrammatic plans of the grade control structures and adjacent channel.

2.2 Fish Passage Assessment Methods

A fish passage analysis of each grade control and culvert structure was performed to determine the hydraulic environment encountered by adult steelhead, resident trout and juvenile salmonids at various migration flows. The primary hydraulic feature evaluated was the water surface drop over each grade control structure at varying fish passage flows. Since each structure is relatively short (generally 5 to 10 feet in length) and there are well-formed pools above and below each structure, water velocities and depths were not considered in the fish passage analysis.

Hydraulic analysis was performed using the hydraulic models, HEC-RAS 3.1.2 and FishXing3.0. Predicted water surface drops over each structure at fish passage flows were compared to assessment and design criteria established by the California Department of Fish and Game's (CDFG) and the National Marine Fisheries Service (NOAA Fisheries) for adult steelhead, resident rainbow trout, and juvenile salmonids.

2.2.1 Passage Criteria for Grade Control Structures

The fish passage assessment methods used in this study followed the California Department of Fish and Game's fish passage assessment protocol (Taylor and Love, 2003). Since the CDFG protocol was developed for "stream crossings", some modifications to the assessment process were necessary to apply them to grade control structures. Additionally, the CDFG (2002) and NOAAFisheries (2001) fish passage design criteria were also considered when assessing fish passage conditions.

Application First Phase Passage Filter to Grade Controls

Once the necessary field survey data is collected, the fish passage assessment involves a two steps process. The first is to use the **CDFG First Phase Filter**. This is a flow chart that is used to determine if the assessed structures is GREEN, GRAY, or RED. These categories are defined as:

GREEN - The structure provides suitable fish passage conditions for all life stages of salmonids at all migration flows.

GRAY – Passage conditions at the structure are indeterminate and a full hydraulic analysis is required. The structure is likely a partial barrier (blocks certain life stages) and/or temporal barrier (blocks a life-stage at some flows). Further hydraulic analysis will quantify the passage conditions relative to life-stage and flow.

RED – Structure fails to provide suitable passage conditions at all flows for all life-stages of salmonid. The stronger individual fish within the population may be able to pass through the structure at some flows. However, the crossing is considered by CDFG to provide inadequate passage.

Although the first phase filter was originally developed for culverts, the drop height criteria can be applied to grade control structures. The filter defines a RED structure as having a residual (no-flow) drop height greater than 2 feet. Drop heights greater than 2 feet are considered sufficient to hinder or block upstream passage all salmonid life stages. Although a proportion of the adult steelhead population will likely be able to leap over a 2 feet drop at certain flow conditions, this drop height is considered to be excessive and cause undesired migration delay.

Based on current CDFG and NOAA Fisheries design criteria, we chose to defined a residual drop height of 6 inches or less as being GREEN (suitable for passage of adult and juvenile trout)

Hydraulic Analysis of Fish Passage

We modeled hydraulics over each grade control structure to further quantify the water surface drop throughout the range of acceptable fish passage flows. Although the assessment protocol only requires modeling fish passage for the GRAY structures, we selected to model all of the inventoried structures, including those identified as GREEN or RED. Hydraulics were modeled with HEC-RAS 3.1.2 and FishXing 3.0. The fish passage flow range for each life-stage were determined using CDFG criteria. Fish passage flow development is outlined in Chapter 3.

2.2.2 HEC-RAS model development

At fish passage flows the grade control structures function hydraulically as irregularly shaped broad-crested weirs. Most of the grade control structures in the study reach are clustered into distinct groups and the drop over many of the structures is directly influenced by the next downstream structure. HEC-RAS was chosen as the preferred hydraulic model for analyzing most of the structures, since it has the capability of modeling broad-crested weirs of irregular shape and can model an entire channel reach consisting of multiple weirs.

The longitudinal profile and cross sections surveyed at each structure and within the channel were used to create the model geometry. Each drop structure was modeled as a broad crested weir. Default contraction and expansion coefficients of 0.1 and 0.3, respectively, were applied. A broad crested weir coefficient of 2.6 was used for modeling all structures. Estimates of downstream channel slope below the tailwater control were used to define the downstream boundary condition. Since, in most cases, the water depth and velocity within the channel below a grade control structure was completely controlled by the next downstream structure, the impacts of channel roughness on results was negligible at fish passage flows. Estimates of Manning's roughness were most critical for the channel segment below the lowest grade control. Estimates ranged from between 0.040 and 0.050 for fish passage type flows.

2.2.3 FishXing model development

Grade control structure GA7 is located by itself, rather than as part of a series of grade control structures. It was modeled using the FishXing 3.0 software, which is intended for the analysis of fish passage through stream crossings. The tailwater discharge rating curve was developed from the downstream cross section, channel slope, and estimate of Manning's roughness. The grade control structure was treated as a short box culvert and the drop over the structure was analyzed at various fish migration flows.

3 Hydrologic Conditions

Hydrologic calculations involved the compilation of existing flow and precipitation records for estimation of fish migration flows, recurrence intervals of peak flows, and general characterization of seasonal hydrology. Estimates of peak flows associated with 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year recurrence intervals where calculated using standard methods. Fish passage flows were calculated from flow duration curves following procedures outlined in the CDFG assessment protocol.

3.1 Watershed Characteristics

The Gaviota Creek watershed comprises over 12,877 acres and rises from sea level to 2,801 feet in elevation. It is the third largest coastal watershed in southern Santa Barbara County, between Jalama Creek to the west and Rincon Creek to the east. Within a short stream reach four primary tributaries flow together to form the mainstem of Gaviota Creek, which runs south through a narrow canyon before emptying into a relatively large coastal lagoon at the edge of the Pacific Ocean. The tributaries include Las Canovas Creek flowing from the east, upper Gaviota Creek from the northeast, Las Cruces Creek from the north, and West Fork Gaviota Creek from the northwest. Annual precipitation values range from 17 to 21 inches within the drainage.

The watershed contains an estimated 50 miles of roads and only 105 acres, or 0.8% of the watershed is classified as urban and impervious. The watershed is primarily privately owned (73%) with the public lands divided between California State Parks (15%) and the Los Padres National Forest (12%).

3.2 Stream Gage

A historic streamflow gage operated by the USGS and located on Gaviota Creek near grade control GA_ 5 provides twenty years of annual peak flow and daily average flow records (Table 3.1). This flow data was used to characterize hydrologic conditions throughout the project reach.

Table 3.1 – Summary of stream gage information for Gaviota Creek.

USGS Flow Gage Summary	
Station Number	11120550
Stream Name	Gaviota Creek at Gaviota
Latitude	34°29'16"
Longitude	120°13'34"
Record Length	20 years
Years in Operation	1967 – 1986
Drainage Area	18.8 mi^2

3.3 Peak Flows

Two methods were used to estimate peak flows for the Gaviota Creek study reach.:

1. Flow estimates using regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977) were used to predict the 2, 5, 10, 25, 50, and 100-year return period flows. Mean annual precipitation was obtained from Parameter-elevation Regressions on Independent Slopes Model (PRISM).

2. Peak flows associated with the 2, 5, 10, 25, 50, and 100 year recurrence intervals were estimated using the 20 year peak flow record from USGS gaging station on Gaviota Creek. Peak flow estimates were made using a Log-Pearson Type III (LP3) distribution as described in USGS Bulletin 17B - Guidelines for Determining Flood Flow Frequency (1982).

Appendix B contains the peak flow calculations.

Table 3.2 – Summary of two methods to determine peak flood frequency for the Gaviota Creek study reach.

	Return Period of Peak Flow					
Method of Estimation	**2 year (cfs)**	**5 year (cfs)**	**10 year (cfs)**	**25 year (cfs)**	**50 year (cfs)**	**100 year (cfs)**
Regional Regression Equations Waananen & Crippen, 1977	148	605	1,210	2,681	4,244	6,033
Log Pearson Type 3 using Gaviota Creek Annual Peak Flow Record	1,048	2,843	4,632	7,291	9,684	12,348

3.4 Fish Migration Flows

Both the National Marine Fisheries Service (NOAA Fisheries) and the California Department of Fish and Game (CDFG) have design guidelines for fish passage at road-stream crossings (CDFG, 2002; NOAA Fisheries, 2001). The two sets of guidelines were developed together and are functionally equivalent. The guidelines contain recommended fish passage design flows for juvenile salmonids, resident rainbow trout, and adult anadromous steelhead trout. They consist of a lower and upper design flow that encompasses the range of flows for which upstream passage should be provided. Beyond this flow range it is not required to provide suitable passage conditions.

Fish passage design flows are defined in terms of exceedance flows obtained from flow duration curves constructed using daily average flow. Annual exceedance defines the average duration that a flow is equaled or exceeded in a year. For example, flows within a stream are greater than the 33% exceedance flow for one-third of the year, on average.

To determine suitable fish passage flows for use in assessing existing fish passage conditions, a flow duration curve was constructed from the daily average flows measured at the USGS streamflow gate (Figure 3.1).

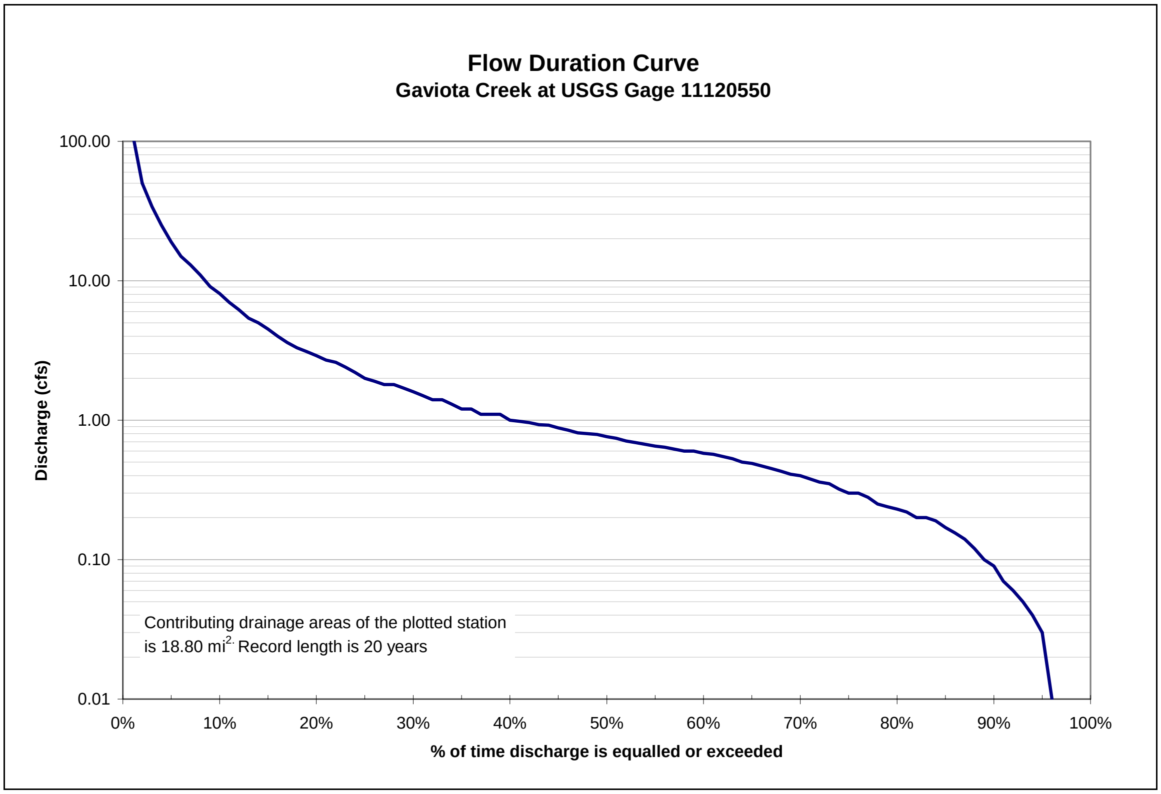


Figure 3.1 - Annual Flow Duration Curve for Gaviota Creek at Gaviota (USGS Gage 11120550).

NOAA Fisheries and CDFG guidelines recommend providing suitable steelhead passage conditions between the 50% and 1% exceedance flows. If the 50% exceedance flow is less than 3 cfs, then the low fish passage flow is set at 3 cfs (Table 3.3). Based on the flow duration curve, the desired lower and upper passage flows for adult steelhead in the Gaviota Creek study reach are 3 cfs and 115 cfs, respectively (Table 3.4).

Table 3.3 - Fish passage design flow guidelines from NOAA Fisheries (2001) and CDFG (2002).

Species and Lifestage	Low Passage Flow	High Passage Flow
Juvenile Salmonids	95% exceedance flow or 1 cfs (whichever is greater)	10% exceedance flow
Adult Resident Rainbow Trout	90% exceedance flow or 2 cfs (whichever is greater)	5% exceedance flow
Adult Anadromous Steelhead	50% exceedance flow or 3 cfs (whichever is greater)	1% exceedance flow

Table 3.4 - Fish passage design flows for Gaviota Creek based on agency guidelines and estimated using the Gaviota Creek flow duration curve.

Species and Lifestage	Low Passage Flows	High Passage Flows
Juveniles Salmonids	1.0 cfs	8.1 cfs
Resident Rainbow Trout	2.0 cfs	19.0 cfs
Adult Anadromous Steelhead	3.0 cfs	115.0 cfs

4 Analysis of Fish Migration Barriers

Fish passage conditions for 12 concrete grade control structures, one constructed boulder weir, one boulder jam, and a bedrock chute were analyzed for this study. Table 1.1 lists the identification codes and location for each analyzed structure. As shown in the longitudinal profile (Figure 4.1), the grade control structures are located in four distinct clusters, or groups:

1. GA_2 and GA_3
2. BLDR_WEIR, GA_4 to GA_6
3. BR_CHUTE, BLDR_JAM and GA 7
4. GA_8 to GA_13

Within each group there is substantial hydraulic and geomorphic interaction between structures. Therefore, analysis of hydraulic and fish passage conditions was conducted for each group.

4.1 Grade Controls GA2 and GA3

Grade controls GA2 and GA3 are located approximately 500 ft upstream of the southbound Highway 101 rest area. They are constructed of concrete and anchored into sandstone bedrock on the right bank and into sacrete and rip rap along the left bank, which forms the embankment for the highway.

GA 2 (Sta 69+50) has a length across the channel of 29 feet, and a width in the streamwise direction of 10 feet (Figure 4.2). The slab thickness is approximately 2 feet and undercut 4.4 feet. The tailwater scour pool created by GA2 is the third largest in the study reach. It is over 100 feet in length and has a residual pool depth of 9.5 feet. A snorkel survey of the pool revealed two southwestern pond turtles.

GA 3 (Sta 70+74) is located 125 feet upstream of GA2. GA 3 is 5 feet wide and anchored to the left bank sacrete revetment. (Figure 4.3). The spillway is located on the left bank along the apron of the sacrete wall. The tailwater below GA3 is hydraulically controlled by GA2, forming a 124 feet long pool (Figure 4.5). The pool width is confined by exposed bedrock along the right bank and the road embankment lined with sacrete along the left bank. The pool has a residual depth of 3.8 feet and contains boulders and bedrock is visible in the bottom. The water is slow moving in the pool and fosters a dense growth of cattails and algae during summer months.

The upstream channel is characterized by steep drops over well-defined boulder step pools. These step pools are likely created by the channel constriction formed by the highway revetment along the left bank and bedrock outcroppings along the right bank.

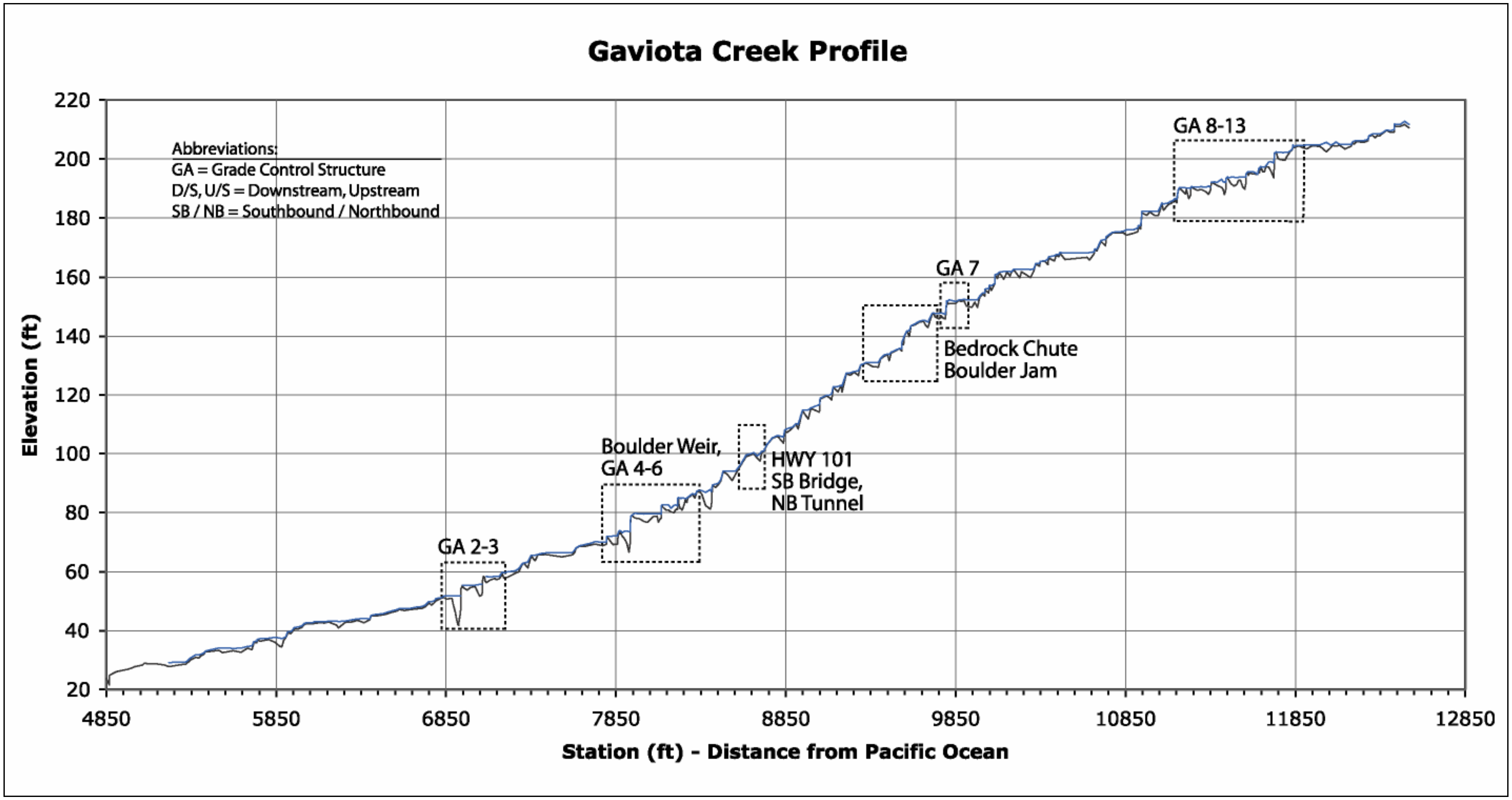


Figure 4.1 – Longitudinal Profile of Gaviota Creek Study Reach. 1.45 miles were surveyed from river mile 0.92 (from the ocean) to river mile 2.37.

4.1.1 Fish Passage Hydraulics for GA2 and GA3

Assessing fish passage conditions over GA2 and GA3 involve determining the water surface drops over each structure at various fish passage flows. To accomplish this, a HEC-RAS model was developed that included grade control structures GA2 and GA3. Model input included surveyed cross sections, the channel slope below the tailwater control (0.017 ft/ft) and an estimate of hydraulic roughness. Mannings roughness (n) of 0.045 was assumed for the reach since the channel is characterized by boulder clusters with dense willow mats and cattail clusters.

Model results predict the water surface drop over each grade control weir at typical adult steelhead passage flows and at the no-flow condition (Table 4.1). From 8.1 cfs to 115 cfs GA2 creates a drop of 4.7 ft. At these same flows the drop over GA3 ranges between 2.9 and 3.3 feet. Since the drop height over GA3 is directly influenced by GA2 (Figure 4.6), rising flows reduce the drop height.

CDFG and NOAA requirements for water surface drops over grade control structures is 1 foot maximum for adult steelhead and 0.5 feet for resident trout and juvenile salmonids. Under all flow conditions, GA2 and GA3 have substantially greater drop heights. These structures are categorized as RED (impeding passage for all fish) under the CDFG assessment protocol and present a substantial impediment to migrating adult steelhead.

Table 4.1 - Water surface drops over GA2 and GA3 at no-flow and typical adult steelhead passage flows.

		Water Surface Drop				
		Flow (Exceedance)				
Station	**Feature**	0 cfs	8.1 cfs (10%)	19 cfs (5%)	50 cfs (2%)	115 cfs (1%)
69+50	GA 2	4.2 ft	4.6 ft	4.6 ft	4.7 ft	4.7 ft
70+74	GA 3	2.9 ft	3.3 ft	3.2 ft	3.0 ft	2.9 ft

Figure 4.2 – Looking upstream at grade control GA2. The structure is anchored to the sacrete revetment wall (right side of photo) and to exposed bedrock on the other side. The tailwater pool was one of four large pools found in the study reach.

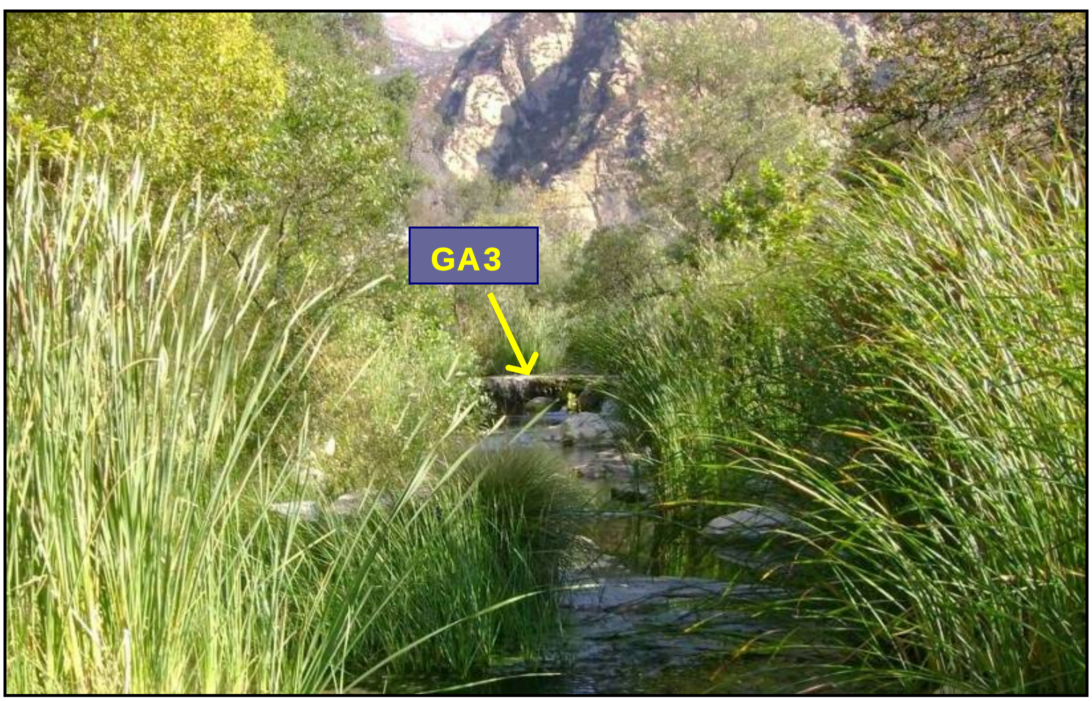


Figure 4.3 – Looking upstream to GA3. Long shallow pool controlled by GA2 gives rise to dense growth of cattails.

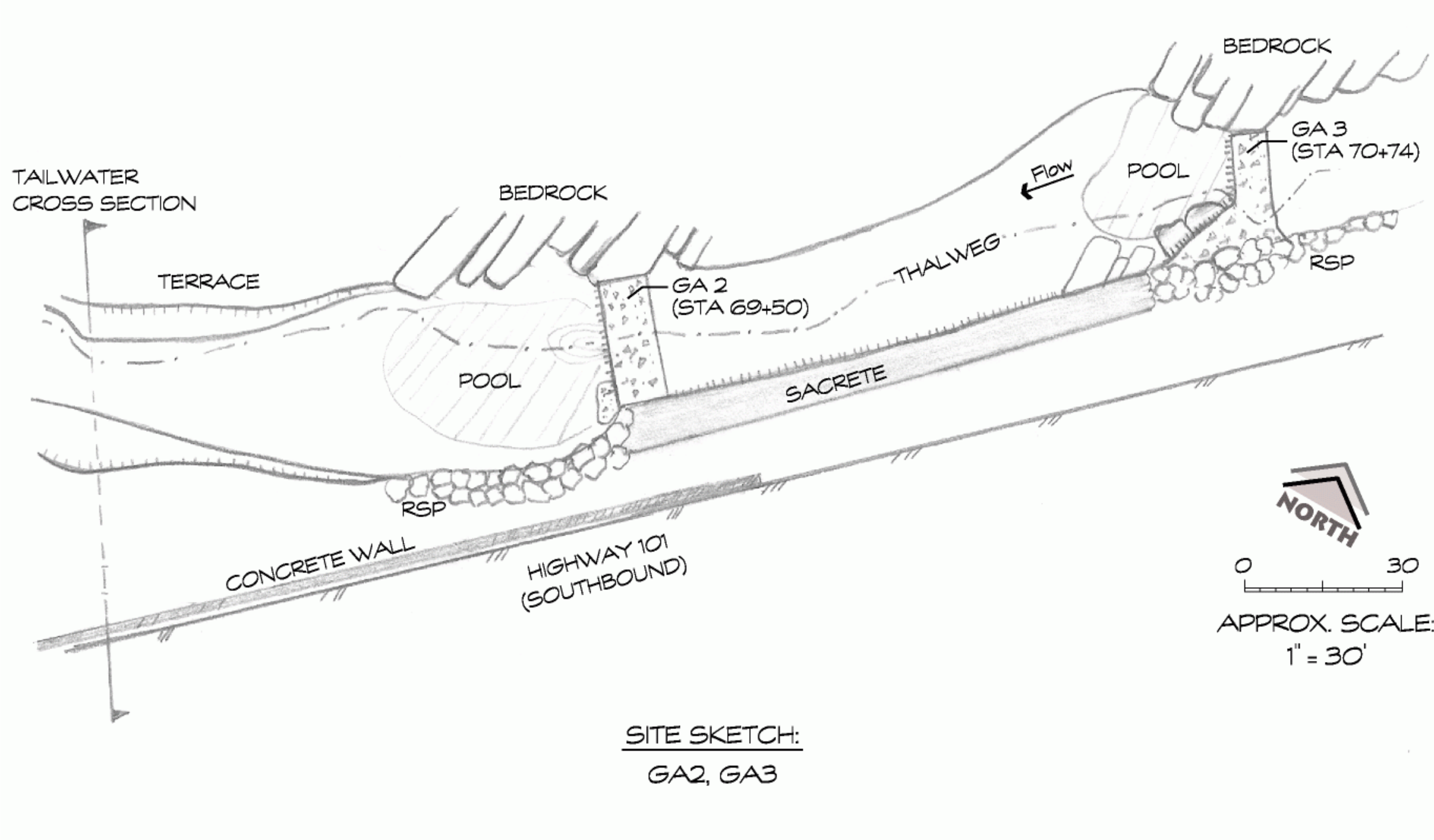


Figure 4.4 – Plan map drawing of the channel reach containing GA2 and GA3.

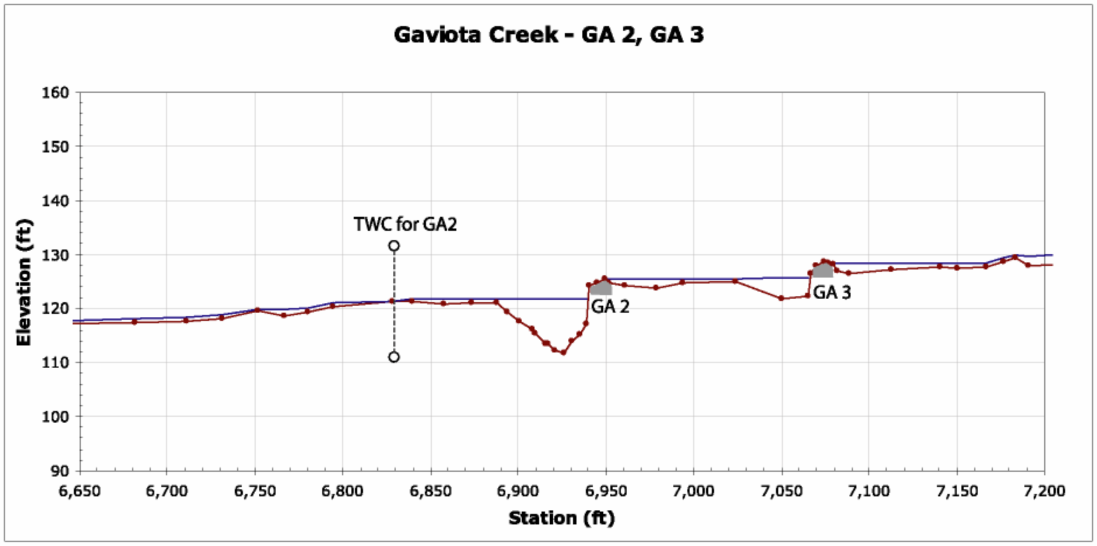


Figure 4.5 – Longitudinal profile showing location of grade controls GA2 and GA3 and the tailwater control (TWC) for GA2. *(Note: elevations shown are based on arbitrary datum)*

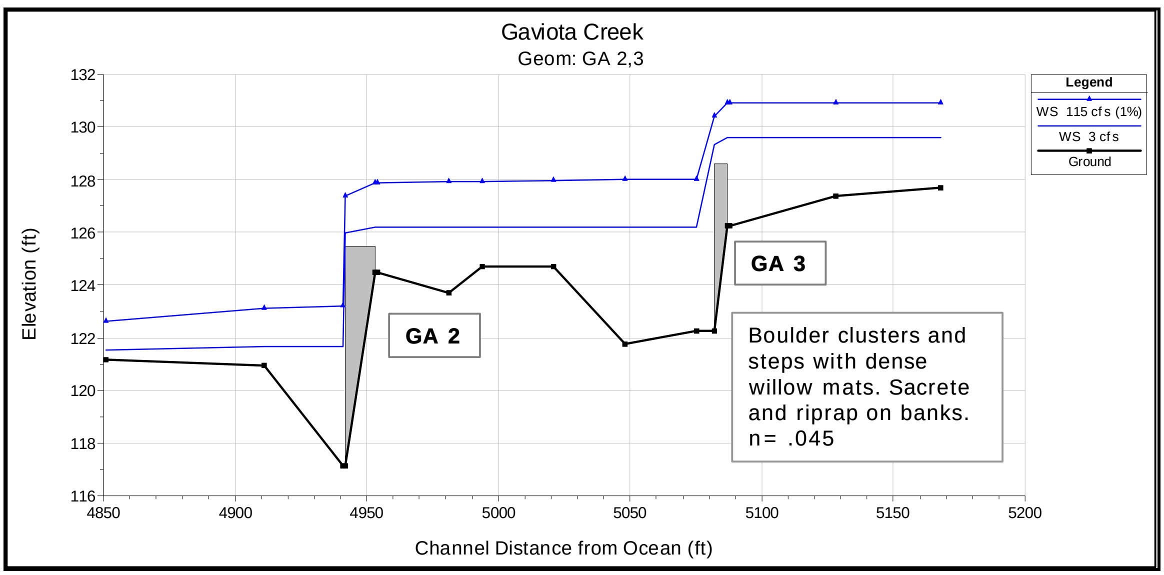


Figure 4.6 – HEC-RAS results showing water surface profiles for GA2 and GA3 at 3 cfs and 115cfs (*note: elevations used in model were based on an arbitrary datum*).

4.2 Grade Controls BLDR WEIR, GA4 through GA6

The constructed boulder weir is located approximately 720 ft downstream of the Highway 101 bridge and tunnel and is followed upstream in sequence by grade controls GA4, GA5, and GA6. At this time we do not have information regarding the construction of the boulder weir but it is our understanding that it, and another weir further downstream, were built by California State Parks to stabilize the channel downstream of GA4 and reduce the drop over GA4 to improve fish passage. The downstream weir has subsequently failed. The remaining boulder weir is constructed of large, approximately 3 ton, rock placed in an upstream facing U shape.

Grade controls GA4 through GA6 are concrete construction, anchored on the left (east) bank into a sacrete revetment wall along the highway embankment. The right bank along this reach is a high terrace with exposed bedrock and large boulders. A hot spring enters the channel between GA5 and GA6 as evidenced by a strong sulfur smell and heavily calcified deposits around the culvert outlet.

BLDR WEIR (Sta 78+68) constructed by the State Parks using 3 ton boulders in an upstream "U" shape. It appears to be stable in its current condition, although it was likely taller when constructed and has subsequently lost some larger boulders. A second boulder weir constructed immediately downstream has completely failed. The remnants of this weir control the tailwater elevation for BLDR WEIR. The residual pool depth below the boulder weir is 2.7 feet.

GA 4 (Sta 79+40) constructed from concrete and anchored on the left bank into a long sacrete revetment wall along the highway. The weir spans 27 feet across the channel and is 8 feet wide. The spillway has been retrofit with railroad ties to act as baffles. The thickness of the structure is 2 feet with 3 feet undercut. On the right bank, the structure has been formed around a large boulder/bedrock outcrop. The tailwater pool is one of the largest found in the study reach and is heavily armored on both banks with 2 to 4 ton RSP. It maintains a residual pool depth of at least 7.4 feet.

GA 5 (Sta 81+22) constructed from concrete and anchored on the left bank into a long sacrete revetment wall along the highway and into a large boulder on the right bank. The weir spans 18 feet across the channel and is 4.5 feet wide. The tailwater pool is a long and stagnant, with algae and cattails dominant in the channel. GA4 is the hydraulic control for the pool below GA5. The pool has a residual depth of 1.2 feet. A 24-inch culvert with highway drainage and a hot spring both enter the channel upstream of GA5.

GA 6 (Sta 82+23) constructed from concrete and anchored on the left bank into a long sacrete revetment wall and a large boulder and into an exposed bedrock outcrop on the right bank. The weir spans 18 feet across the channel and is 5 feet wide. The tailwater pool is a long and stagnant, with algae and cattails dominant in the channel. The pool has a residual depth of 1.6 feet. GA5 is the hydraulic control for GA6. There is a 3-foot wide notch cut into the upstream side of the concrete. Almost no undercut is visible on GA6.

The upstream channel is characterized by steep drops over well-defined boulder step pools. These step pools are created by the channel constriction formed by the highway revetment and bedrock wall at the top of this reach, near the narrow Gaviota Pass. Many of the extremely large boulders appear to be colluvium from the hill slope, and not transported by the stream. The constrictions create small marshy areas upstream of each boulder step.

4.2.1 Fish Passage Hydraulics for Boulder Weir through GA6

Assessing fish passage conditions over the boulder weir and GA4, GA5 and GA3 involve determining the water surface drops over each structure at various fish passage flows. A HEC-RAS model was developed for this reach and model input included surveyed cross sections, the channel slope below the tailwater control (0.004 ft/ft) and an estimate of hydraulic roughness. Mannings roughness (n) of 0.05 was assumed for the reach since the channel is characterized by boulder clusters with dense willow mats and cattail clusters.

Model results predict the water surface drop over each grade control weir at typical adult steelhead passage flows and at the no-flow condition (Table 4.2). With the exception of the boulder weir, the drop heights over each of the grade control structures is controlled by the next downstream structure (Figure 4.12). From 8.1 cfs to 115 cfs the boulder weir maintains a drop of 1.3 ft, and GA4, GA5 and GA6 have average drop heights of 5.0 ft, 3.3 ft and 2.2 ft, respectively.

CDFG and NOAA requirements for water surface drops over grade control structures is 1 foot maximum for adult steelhead and 0.5 feet for resident trout and juvenile salmonids. Under all flow conditions, these four grade controls have substantially greater drop heights. These structures are categorized as RED (impeding passage for all fish) under the CDFG assessment protocol and present a substantial impediment to migrating adult steelhead.

Table 4.2 - Water surface drop for fish passage flows at the BLDR WR, GA4, GA5, and GA6 from HEC-RAS model results.

		Water Surface Drop				
		Flow (Exceedance)				
Station	**Feature**	0 cfs	8.1 cfs (10%)	19 cfs (5%)	50 cfs (2%)	115 cfs (1%)
78+68	BLDR WR	1.7	1.3	1.3	1.3	1.3
79+40	GA 4	5.2	5.1	5.0	4.9	4.8
81+22	GA 5	3.5	3.4	3.3	3.2	3.0
82+23	GA 6	2.3	2.3	2.2	2.1	2.0

Figure 4.7 – Looking upstream at GA4, which is controlled by a boulder weir constructed by CA State parks. GA4 is undercut approximately 3 ft and the banks and pool are scoured and have been reinforced by large rock placed along the highway revetment.

Figure 4.8 – Grade control GA5 located 80 ft upstream of GA4. Note the 36-inch highway drainage culvert and hot spring outlet located at the top of sacrete revetment wall.

Figure 4.9 – Grade control GA6 located 90 ft upstream of GA5.

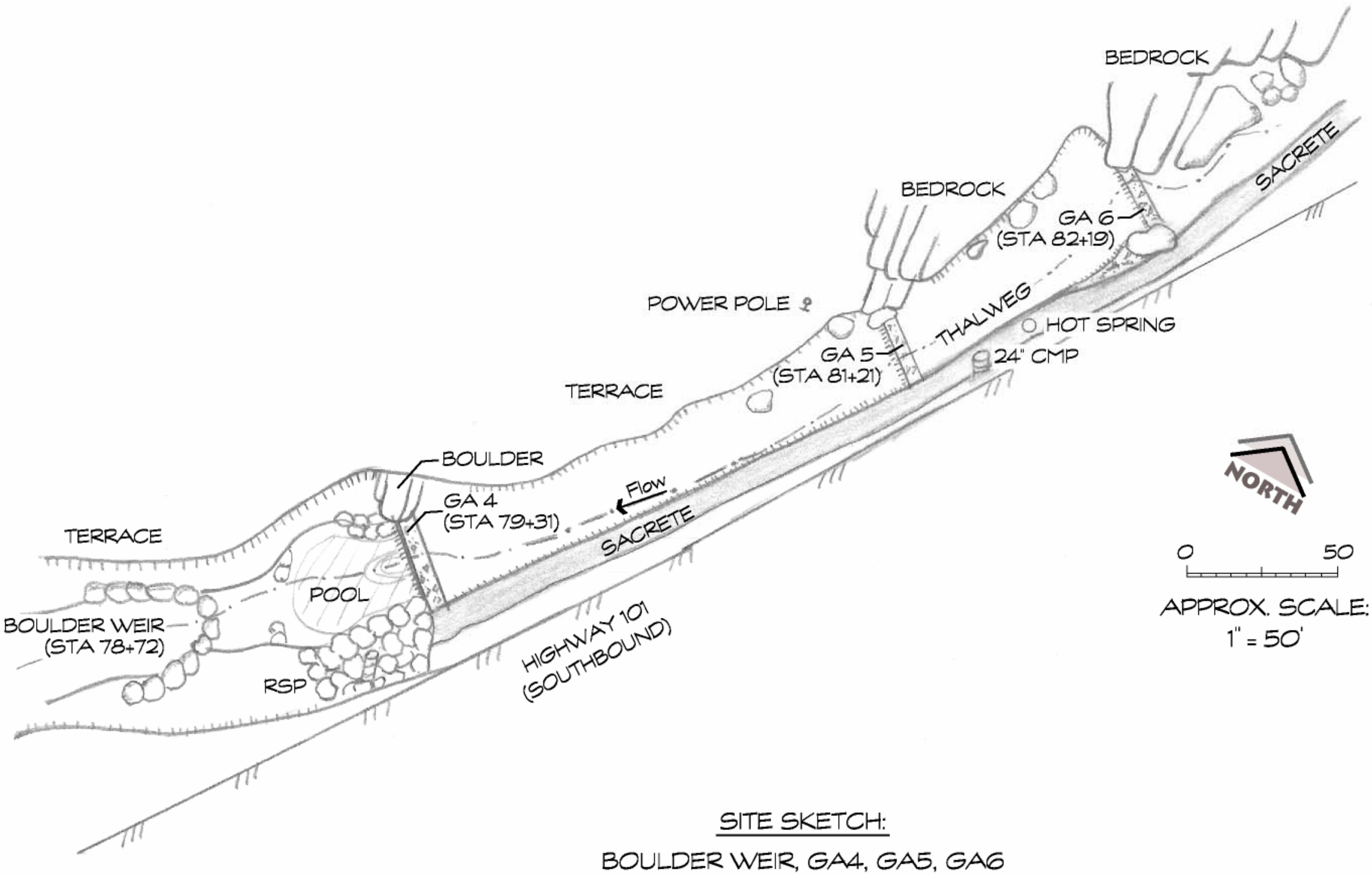


Figure 4.10 – Plan map drawing of the channel reach containing BOULDER WEIR, GA4, GA5, and GA6.

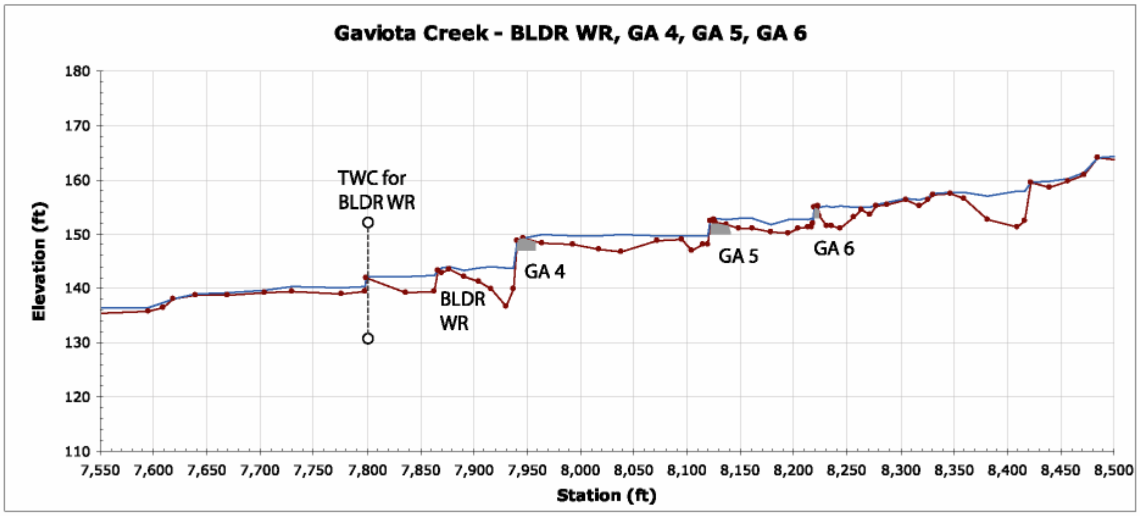


Figure 4.11 – Longitudinal profile showing location of the constructed boulder weir (BLDR_WR), grade controls GA4, GA5 and GA6, and the tailwater control (TWC) below the boulder weir. *(Note: elevations shown are based on arbitrary datum)*

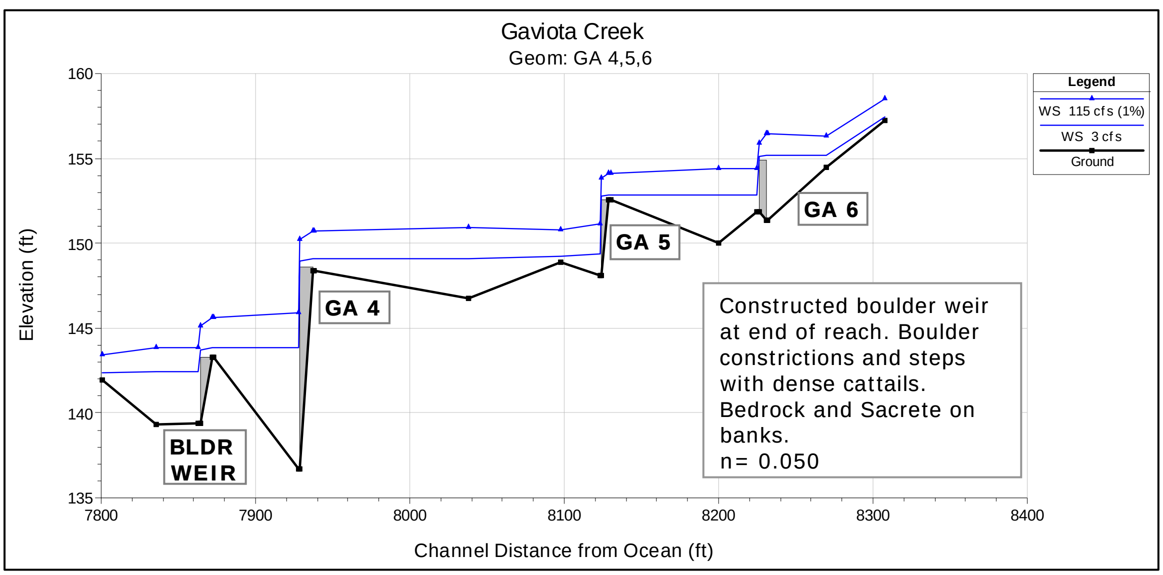


Figure 4.12 – HEC-RAS results showing water surface profiles for the constructed boulder weir, GA4, GA5, and GA6 at 3 cfs and 115cfs. Note the drop over each grade control is influenced by the next one downstream. *(Note: elevations in model are based on arbitrary datum)*

4.3 BR_Chute, BLDR_JAM and GA7

Bedrock chute (BR_CHUTE) between Sta. 91+16 and Sta. 95+38 was identified in the previous steelhead passage inventory and assessment (Stoecker, 2002) as a potential impediment to migrating steelhead. It is a 360 feet long section of channel that consist of a bedrock channel bed and left (east) bank (Figure 4.13). The right bank consists of a vertical concrete retaining wall. The bedrock channel through this section maintains an average slope of 3.7%. Within this section there are numerous bedrock steps and at the time of the survey in early October there were 6 pools that had water depths exceeding 1.5 feet.

Boulder Jam (BLDR_JAM) at Sta. 95+55, is formed by a cluster of about six large boulders that range in size between 5 and 10 feet in diameter, mixed with a number of smaller boulders (Figure 4.14). The boulder jam retains upstream alluvial bed material, forming the transition from a bedrock to alluvial bed channel. The streambed on the upstream side of the boulder jam is roughly 8 feet higher than the downstream bedrock channel bed. The left (east) most boulder is the largest and is partially held in place by the upstream end of a concrete retaining wall. Additionally, there is rebar doweled into the boulder that is connected to the retaining wall. Immediately upstream of the boulder is a 90 inch diameter corrugated metal culvert outlet for a tributary the drains a 0.7 mi^2 watershed. Flow has scoured the right bank creating a low-flow side channel with several steps and a pool.

GA7 at Sta. 98+02 is a 4 feet wide by 2 feet thick concrete beam that spans the channel (Figure 4.15). It is 48 feet long and is skewed at roughly a 45-degree angle to the channel centerline. GA7 has an 80 ft long shallow pool and a 4 ft drop. The residual pool depth below GA7 is 2.0 feet. The grade control is undercut by more than 7 feet. It appears that this structure was originally constructed to protect a now-abandoned pipeline crossing (observed embedded in the concrete) from scour, which explains the skew to the channel alignment.

4.3.1 Fish Passage Conditions for Bedrock Chute, Boulder Jam, and GA7

Bedrock chute (BR_CHUTE) contains numerous hydraulic roughness elements, pools spaced an average of 60 feet apart, and the slope of the bedrock chute is no steeper than the downstream channel. The complexity of the channel bed makes it extremely difficult to model the fish passage hydraulics. However, because of its similarity to the adjacent channel, the bedrock chute appears to be no more of a impediment to upstream migration than the natural step pool and boulder cascade channel reaches downstream.

Boulder Jam (BLDR_JAM) contains a low-flow channel along the right bank. These types of side channels are frequently present in large boulder and log jams and can provide sufficient conditions to allow upstream steelhead passage under certain flow conditions. Because of the hydraulic complexity associated with these types of structures, passage assessment is typically based on professional judgment and monitoring.

The bottom end of the channel along the right side of the boulder jam contains a 2 ft to 3 ft drop onto sloping bedrock which does not contain a pool for steelhead to leap from. It is our professional judgment that steelhead are only capable of swimming through the passageway along the right (west) bank at moderate to high flows and that the jam is a barrier at both low flows (due to lack of a jump pool) and extremely high flows (due to velocity and turbulence in the side channel).

Boulder jams are transitory, and will typically break-apart and reform during large flood events. Additionally, side channels typically evolve and become larger over time, improving passage conditions. However, since it was assessed in 2001, there has been little change to the shape and condition of the boulder jam.

GA7 was modeled using FishXing 3.0, software intended for the analysis of fish passage through stream crossings. The grade control structure was treated as a short box culvert and the drop over the structure was analyzed at various fish migration flows. The water surface drop over GA7 ranged from 4.1 feet at zero flow to 3.2 at the adult steelhead high passage flow of 115 cfs. (Table 4.3).

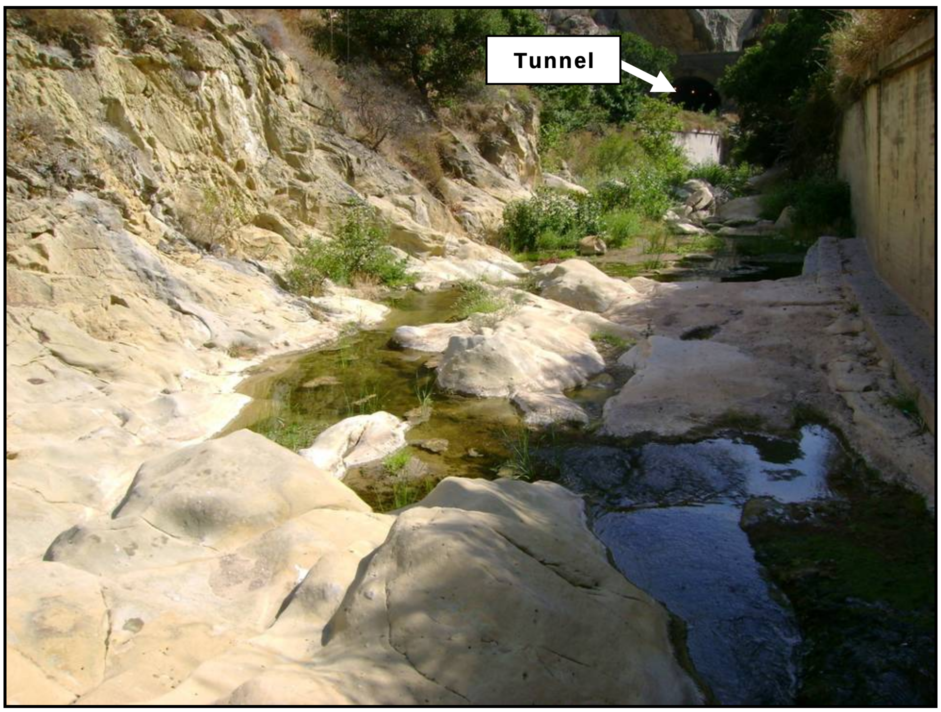


Figure 4.13 – Looking downstream at bedrock chute (BR_CHUTE), with tunnel of northbound Highway 101 in background. Note the bedrock banks on left and vertical concrete retaining wall forming right bank.

Figure 4.14 – Looking upstream at boulder jam (BLDR_JAM), located at upstream end of bedrock chute. The right boulder is secured to concrete retaining wall with rebar. There is a small channel around the jam on the left side of photo that adult steelhead can likely ascend during moderate to high flows. Lack of a leap pool at the base of the side channel makes it a barrier at low flows.

Figure 4.15 – GA 7 is skewed at a 45-degree angle with the centerline of the channel. It is likely that this structure was built to protect a now- abandoned pipe that is visible in parts of the structure.

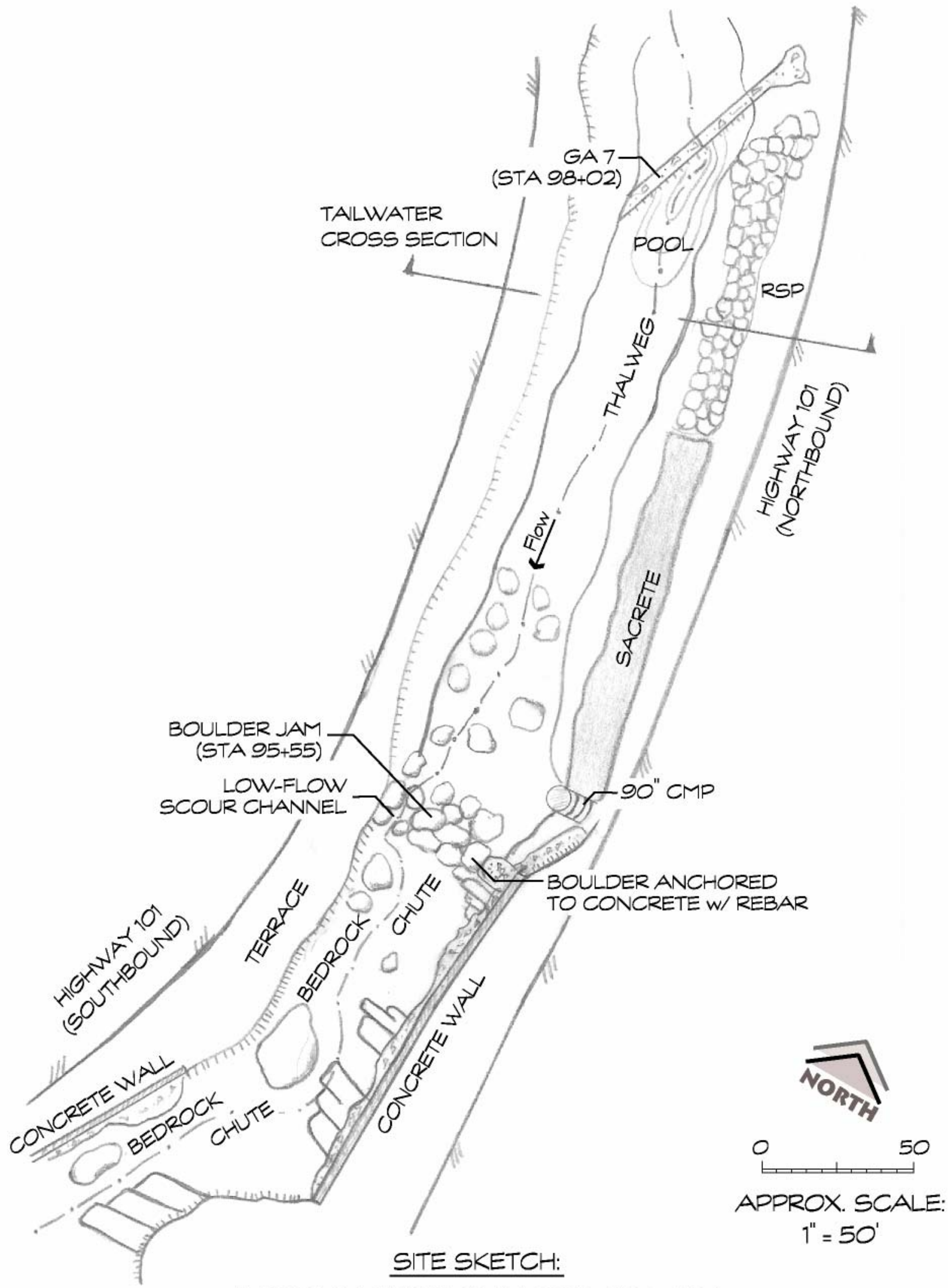


Figure 4.16 – Plan map drawing of the channel reach containing GA7

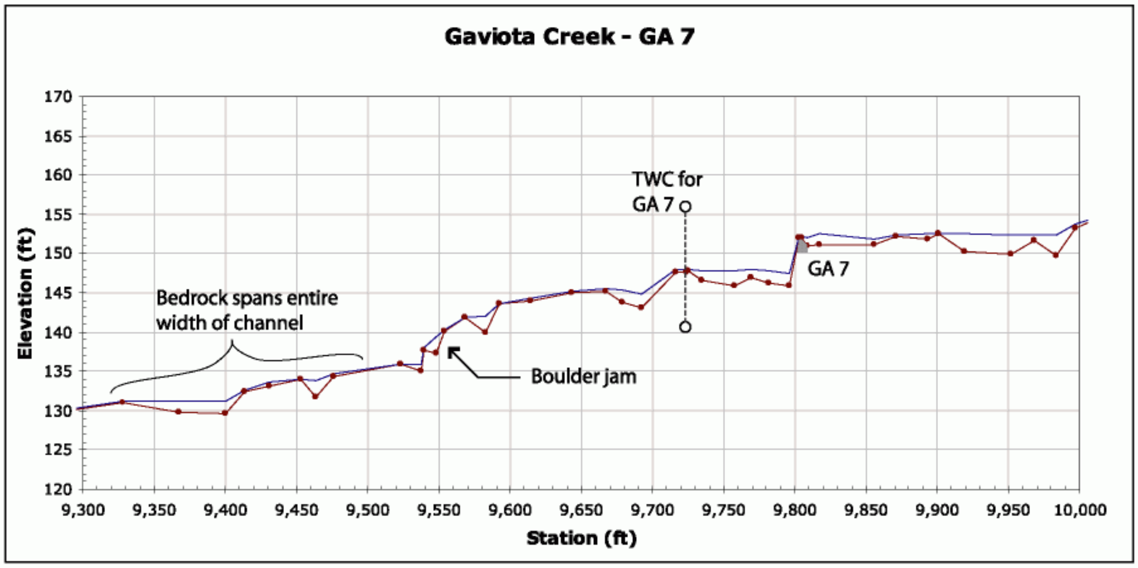


Figure 4.17 – Longitudinal profile showing location of the bedrock chute, boulder jam (BLDR JAM), and grade control GA7.

Table 4.3 - Water surface drop for fish passage flows at the GA7 from FishXing model results.

		Water Surface Drop				
		Flow (Exceedance)				
Station	**Feature**	0 cfs	8.1 cfs (10%)	19 cfs (5%)	50 cfs (2%)	115 cfs (1%)
98+02	GA 7	4.1	3.9	3.7	3.5	3.2

4.4 Grade Controls GA8 through GA13

The most upstream group of grade control structures in the study reach is GA8 through GA13. Located approximately 2,500 feet upstream of the Highway 101 bridge and tunnel, they are grouped in series along a 700 feet reach of channel. Grade controls GA 8-13 are concrete construction and located in series anchored on the right bank into a sacrete revetment wall that runs along the southbound highway embankment. The left bank along this reach is an incised high terrace of native material with occasional large boulder exposures.

The channel immediately downstream of GA8 is characterized by a boulder field with cascades stepping up to the grade control. The boulder cascades appear to be a depositional feature caused by a channel constriction created by a 25ft high concrete wall on the left bank and exposed bedrock and large boulders on the right bank. Exposed bedrock is visible in the channel and along both banks.

GA 8 (Sta 111+76) constructed from concrete and anchored into large mid channel boulder. GA8 appears to be a concrete apron poured over an existing boulder cluster. It is less than 1 ft thick, is undercut approximately 4 ft and appears to be failing. The downstream pool is controlled by boulders and has a residual depth of 1.4 feet. Fines and small gravels are stored behind GA8 and cattails are abundant in the long shallow pool between GA8 and GA9.

GA 9 (Sta 112+50) and **GA 10** (Sta 113+71) are concrete weirs that span the channel. GA 9 is 10 feet wide and GA10 is 3 feet wide. They are both 30 feet long across the channel. A 4 ft x 4 ft concrete box culvert stamped 1931 enters the channel on the right bank between GA9 and GA10. Both of these structures do not appear to have much undercut on the downstream side. Both are anchored on the right bank to the sacrete revetment and on the left bank to native material. GA10 is failing along the left bank by flanking around the concrete structure and eroding the bank. The channel upstream is a low gradient depositional section with sand and small gravels, and abundant cattails. The residual pool depth below GA9 and GA10 are 3.8 feet and 2.5 feet, respectively.

GA 11 (Sta 114+56) Constructed of concrete and anchored into the sacrete revetment on the right bank and a boulder cluster that is keyed into exposed bedrock on the left bank. GA11 spans 21 feet across the channel and is 3 feet wide. The pool below GA11 is relatively deep, with a residual pool depth of 4.2 feet.

GA 12 (Sta 115+76) is anchored to the sacrete revetment on the right bank and to a large exposed boulder on the left bank. There is a well-defined tailwater pool created by the drop over GA12. The pool has a residual depth of 3.9 feet. The downstream channel between GA11 and GA12 is low gradient and populated by large boulders. The channel upstream of GA12 is a bedrock chute that completely spans the channel. It is roughly 60 feet long, and forms the tailwater control for GA13.

GA 13 (Sta 117+46) located at the upper most end of the study reach. GA 13 is a concrete slab that is 1-2 ft thick and undercut approximately 5 ft. It is anchored to the sacrete wall and a large exposed boulder. There is ample evidence of scour from high flows. The residual drop is approximately 3 feet and plunges into a large tailwater pool that has a residual depth of 3.7 feet. The pool elevation is controlled by the bedrock chute immediately downstream.

4.4.1 GA 8-13 Fish Passage Hydraulics

Assessing fish passage conditions over GA8, GA9, GA10, GA11, GA12, and GA13 involve determining the water surface drops over each structure at various fish passage flows. A HEC-RAS model was developed for this reach and model input included surveyed cross sections, the channel slope below the tailwater control (0.047 ft/ft) and an estimate of hydraulic roughness. Mannings roughness (n) of 0.045 was assumed for the reach since the channel is characterized by boulders, willow mats and cattail clusters.

Model results predict the water surface drop over each grade control weir at typical adult steelhead passage flows and at the no-flow condition (Table 4.4). With the exception of the GA8 and GA13, the drop heights over each of the grade control structures are controlled by the next downstream structure (Figure 4.24 and Figure 4.25). During fish passage flows (8.1 cfs to 115 cfs) GA8, GA10, GA12 and GA13 create a drop ranging from of 2.0 ft to 4.7 ft. The notable exception is GA9, which is completely backwatered at all fish passage flows, and GA 11, which has a drop of less than 1 ft.

CDFG and NOAA requirements for water surface drops over grade control structures is 1 foot maximum for adult steelhead and 0.5 feet for resident trout and juvenile salmonids. GA8, GA10, GA12, and GA13 have drop heights greater than 1 foot at all flows. GA8 and GA13 have the largest drops and are categorized as RED (impeding passage for all fish) under the CDFG assessment protocol.

Table 4.4 - Water surface drop for fish passage flows at the GA8, GA9, GA10, GA11, GA12 and GA13 from HEC-RAS model results.

		Water Surface Drop				
		Flow (Exceedance)				
Station	**Feature**	0 cfs	8.1 cfs (10%)	19 cfs (5%)	50 cfs (2%)	115 cfs (1%)
111+76	GA 8	3.9	4.3	4.1	3.9	3.6
112+50	GA 9	0.3	0.0	0.0	0.0	0.0
113+71	GA 10	1.5	2.1	2.2	2.2	2.1
114+56	GA 11	1.3	0.8	0.7	0.6	0.5
115+76	GA 12	2.1	2.1	2.1	2.2	2.2
117+46	GA 13	5.0	4.7	4.7	4.2	3.7

Figure 4.18 – GA8 appears to be a concrete apron less than 1 foot thick, poured over an existing boulder cluster. It is undercut approximately 4 ft and failing around the large mid channel boulder.

Figure 4.19 – GA9 has the smallest residual drop and backwatered during fish passage flows.

Figure 4.20 –GA10 is failing along the river-left bank from flanking that has eroded the native material along the steep right bank.

Figure 4.21 – GA11 and GA12 are keyed to sacrete and large boulders.

Figure 4.22 - GA13 is keyed into the sacrete wall and large boulders and exposed bedrock. There is ample evidence of scour along the undercut wall and GA13 is undercut approximately 5 ft. The pool elevation is controlled by a bedrock chute the spans the entire width of the downstream channel.

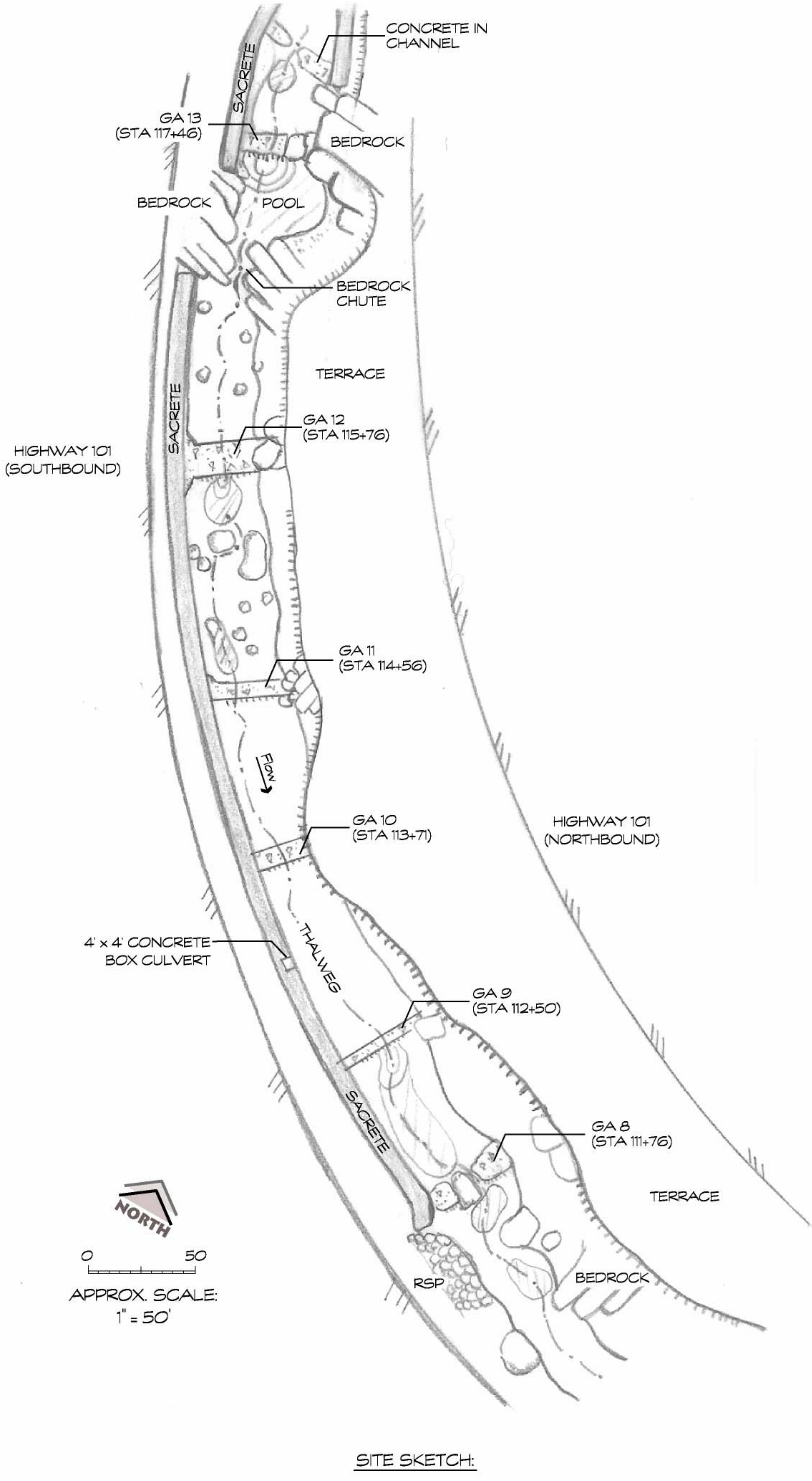


Figure 4.23 – Plan map drawing of the channel reach containing GA 8-13

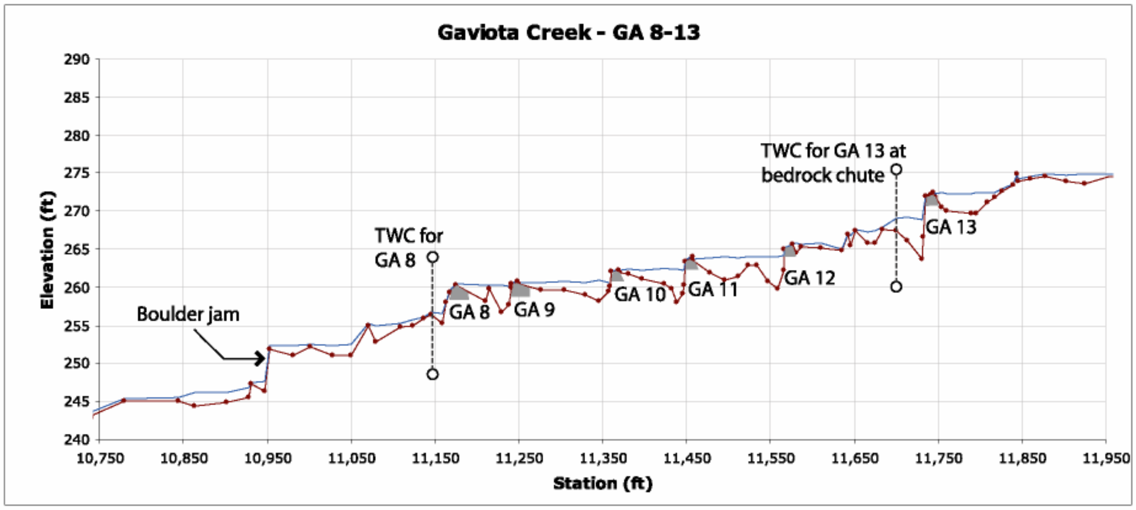


Figure 4.24 – Longitudinal profile showing location of the GA 8 through GA 13. *(Note: elevations shown are based on arbitrary datum)*

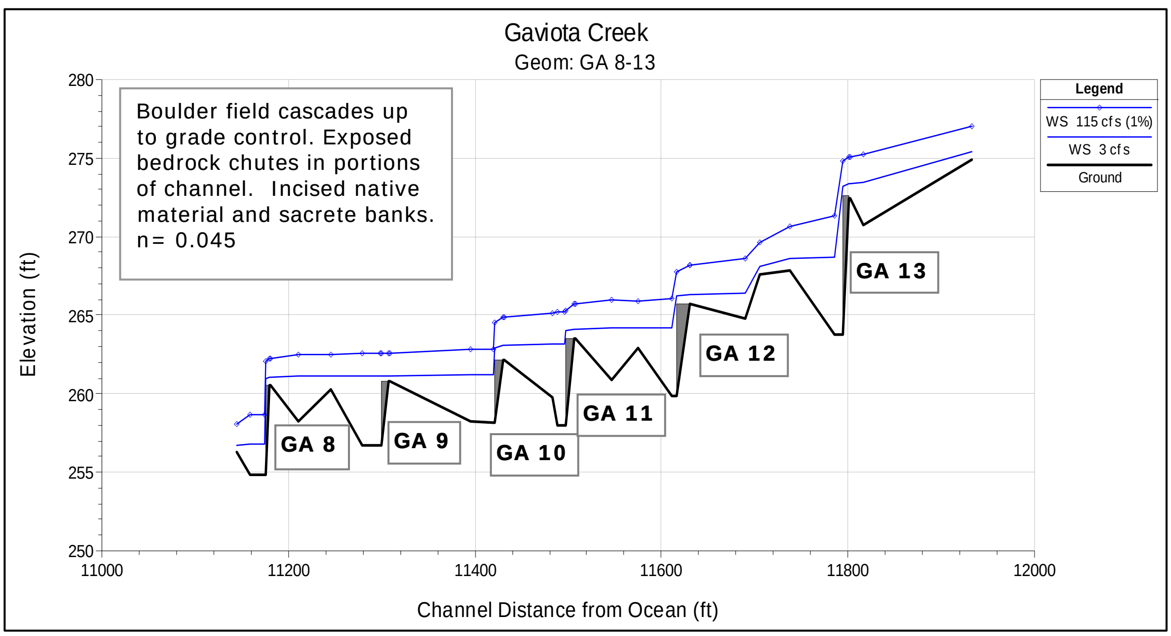


Figure 4.25 – HEC-RAS results showing water surface profiles for the constructed GA8, GA9, GA10, GA11, GA12 and GA13 at 3 cfs and 115cfs. *(Note: elevations in model are based on arbitrary datum)*

4.5 Fish Passage Summary

As discussed in Chapter 3, CDFG first phase filter categorizes a structure as RED if the drop is greater than 2 feet and GRAY if less than 2 feet. CDFG and NOAA design criteria define a drop of 6 inches or less as being suitable for both adult and juvenile salmonids. Therefore, we defined a drop of 6 inches or less as GREEN.

The residual drop is the difference between the weir crest and the tailwater control elevations, also referred to as the no-flow drop height. The residual drop over each grade control structure is presented in Table 4.5 in order of severity. Note that the largest drop is generally associated with the most downstream grade control structure within each group.

Table 4.5 – Summary of drop height as applied to fish passage and ordered by severity of barrier.

Grade Control	No-Flow Drop Height	CDFG Filter Category
GA4	5.2 feet	RED
GA13	5.0 feet	RED
GA2	4.2 feet	RED
GA7	4.1 feet	RED
GA8	3.9 feet	RED
GA5	3.5 feet	RED
GA3	2.9 feet	RED
GA6	2.3 feet	RED
GA12	2.1 feet	RED
BLDR WEIR	1.7 feet	GRAY
GA10	1.5 feet	GRAY
GA11	1.3 feet	GRAY
GA9	0.3 feet	GREEN

5 Geomorphic Assessment

Gaviota Creek flows from north to south, cutting through the Traverse Range of the Santa Ynez Mountains in southwestern Santa Barbara County. Gaviota Creek is unique, since none of the other streams draining the Santa Ynez Mountains from Point Conception to the Ventura River cuts through the Traverse Range. As the creek flows towards the ocean it enters Gaviota Canyon, which becomes increasingly narrow until reaching the "pass"; a location where the canyon is less than 30 feet wide, confined by nearly vertical bedrock cliffs (Figure 5.1). The exposed bedrock throughout the canyon is predominately sedimentary and the horizontal strata have been tilted nearly vertical. The bedrock and large colluvium within the channel is mostly composed sandstone and mudstone. There are also numerous sulfur hot springs surfacing along the canyon walls

The channel is geologically incising, apparently accelerated by alterations made to the channel's alignment, length, and streambank composition as a result of the highway. This incision process and the presence of constructed grade control structures to prevent further incision and bank erosion has lead to numerous steelhead migration barriers through Gaviota Canyon. Therefore, the focus of this geomorphic assessment is on the causes of channel incision and role of the grade control structures in maintaining the existing channel grade.

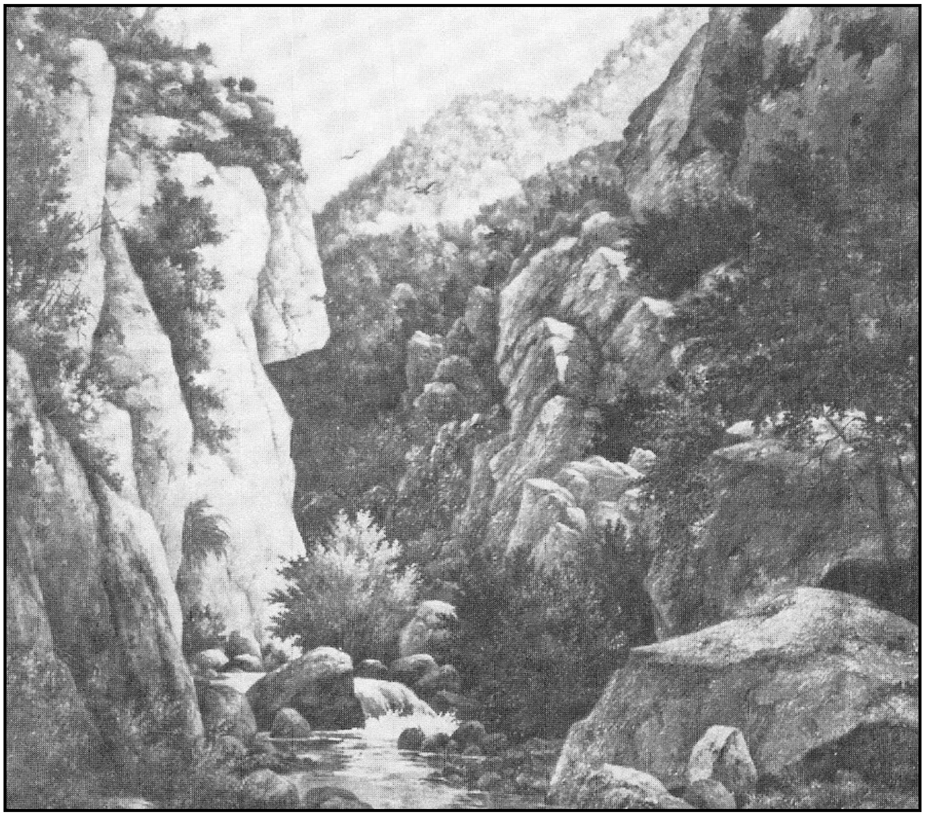
5.1 History of the Highway and Resulting Changes to the Channel

Even prior to the first road being constructed, bedrock and large colluvium along the stream's bed and banks constricted the channel. As described by Chesnut (1993), wagons could not go through the pass until 1854, when the cliffs were chiseled to make a wide enough roadway. The first County road through Gaviota Canyon was constructed in 1861. Construction involved the use of dynamite to widen the road at the pass and placing a wooden bridge over the creek near the location of the current bridge. The road was too narrow for wagons to pass one another in numerous locations.

The Division of State Highways took ownership of the road in 1915. In 1931 the section of highway through the canyon was reconstructed to accommodate increased traffic. Initially, it was estimated that the highway would need to cross Gaviota Creek nineteen times within the three-mile section running through the canyon. To avoid this, the channel was straightened in places and numerous concrete retaining walls were constructed.

5.1.1 Lower Gaviota Creek Channel Realignment

In 1934 a road straightening project between Gaviota and La Honda involved removal of a large meander in lower Gaviota Creek and rerouted the channel along the road embankment, as evident in the 1943 air photo (Figure 5.2). Subsequently, the channel alignment was further altered. In total, changes in channel alignment shortened the channel length by as much as 1,600 feet.



(a)

(b)

Figure 5.1 – Looking upstream at the "pass" in Gaviota Canyon, **(a)** illustrated during an early expedition prior to the first road (from Chesnut, 1993) and **(b)** under present conditions, with the southbound 101 bridge crossing the creek. Note the overhanging bedrock formation in the upper left in both images.

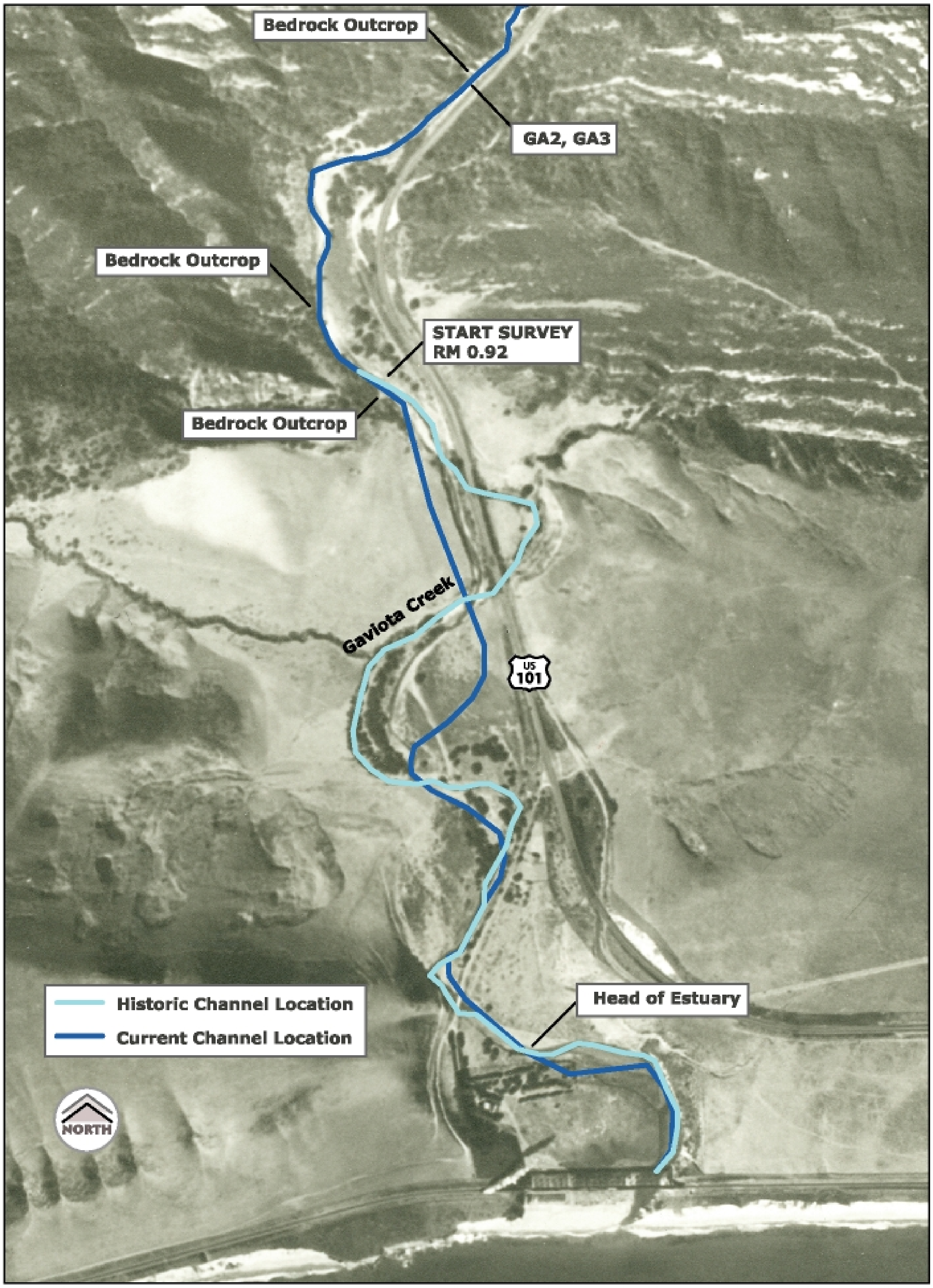


Figure 5.2 – Aerial photograph from 1943 showing current and historic alignment of Gaviota Creek between the ocean and the first set of grade control structures (GA2 and GA3). Current alignment is roughly 1,600 feet shorter than the historic alignment.

Shortening the channel length would initially result in a steepening of the overall grade. An expected channel response within this previously unconfined reach would be headward incision of the channel bed, decreasing the slope back to its historic grade within the realigned reach. Although the realigned reach was not surveyed as part of this project, we estimate it has an average channel slope of roughly 0.5%. This was based on:

1. Current channel length from the upstream end of the realignment to the estuary,

2. The surveyed elevation at the upstream end of the realigned channel (where this projects survey began), and

3. Assuming the channel bed is near mean sea level at the upstream end of the estuary.

Based on a loss of 1,600 feet of channel length and a channel slope of 0.5%, the upstream channel may have experienced up to 8 feet of incision. Incision of the upstream channel bed appears to be partially controlled by exposed bedrock in two distinct locations (Figure 5.5) and possibly by the lower two grade control structures (GA2 and GA3).

5.2 Channel Morphology

The surveyed channel reach begins 2,200 feet downstream of the first grade control structure (GA2) and extends through the confined sections of Gaviota Canyon to the second southbound 101 bridge crossing, for a total distance of 7,700 feet (Figure 5.3). From GA2 to the second bridge, the channel maintains a steep grade and the channel bed and banks are controlled by a combination of large colluvium, boulder jams, bedrock outcroppings, concrete grade control structures, hardened road embankments, and concrete retaining walls. To assist in defining the existing geomorphic channel characteristics and describing the channel interactions associated with the existing grade control structures, we have categorized the surveyed channel into three reaches: Lower, Middle, and Upper.

5.2.1 Lower Channel Reach

The lower surveyed channel reach begins at the upstream end of the realigned channel (Sta. 48+50) and continues to the base of the boulder weir (BLDR_WEIR) just downstream of grade control structure GA_4 (Sta. 78+00). The reach is 2,950 feet in length and has an average channel slope of 1.3%. A Wolman pebble count was conducted within the reach, just downstream of GA_2, to help classify the surface substrate (Figure 5.4). The substrate is alluvial and the predominate material is gravel (54%), followed by cobble (27%). The reach also contains some large boulders (>3 feet diameter) and sand (Table 5.1).

This lower channel reach lacks rhythmic bedforms and is characterized by long stretches of relatively featureless bed. Using the Montgomery and Buffington classification system (1997), the morphology of the lower reach can best be described as a plane-bed alluvial channel.

Throughout the entire reach the right bank of the stream is confined by the hill slope to the west. In several distinct locations bedrock outcroppings protrude into the channel, controlling the grade and forcing pools to form immediately downstream.

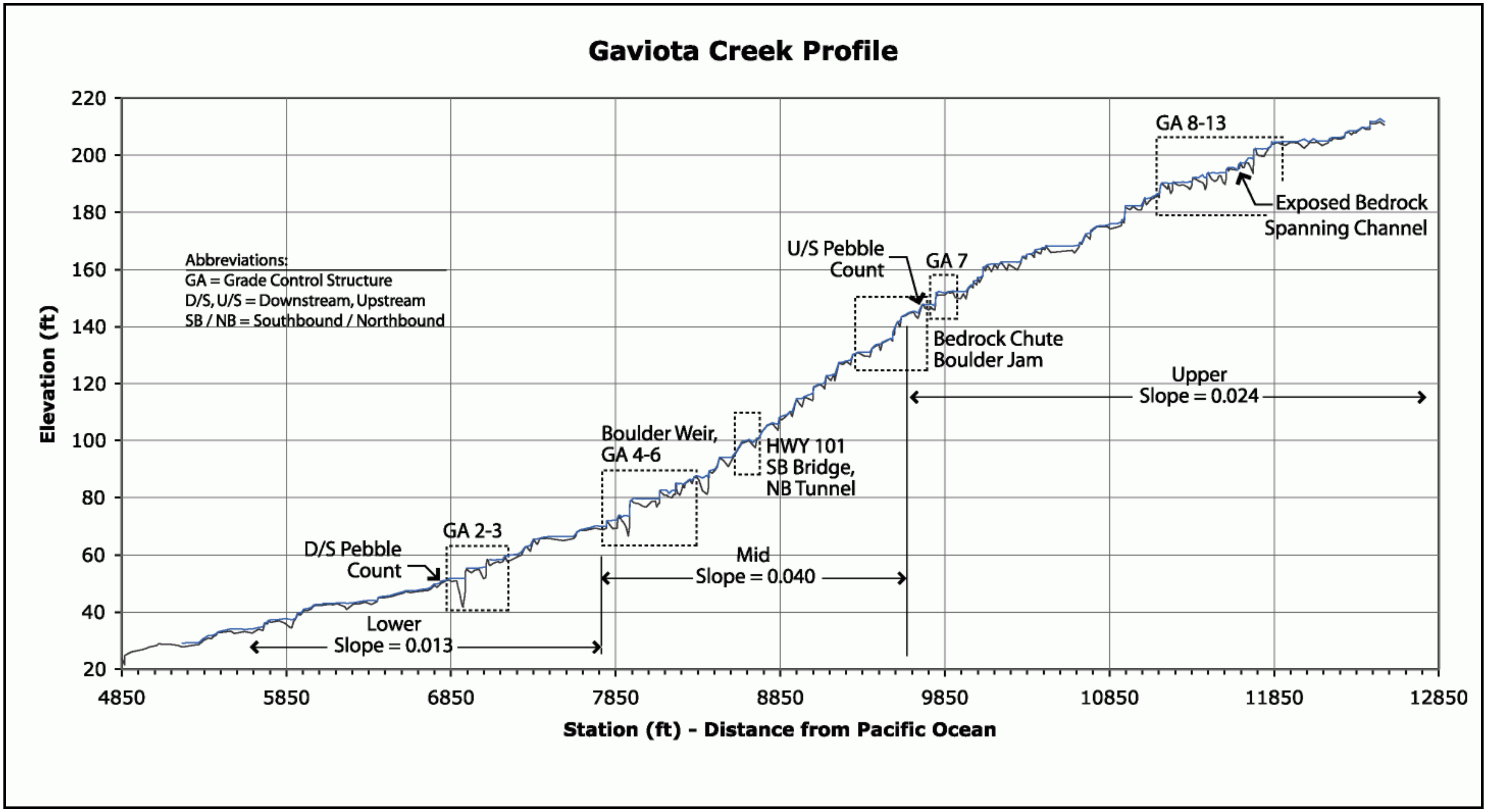


Figure 5.3 – Longitudinal Profile of Gaviota Creek Study Reach. 1.45 miles were surveyed from river mile 0.92 (from the ocean) to river mile 2.37.

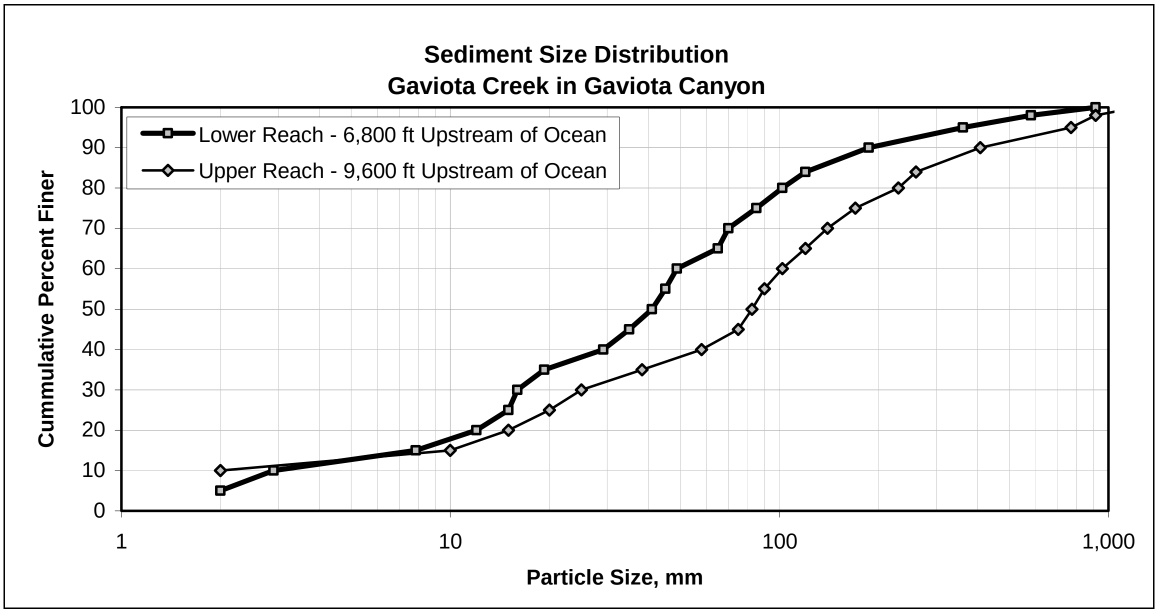


Figure 5.4 – Size distribution of substrate within Gaviota Creek, measured using a Wolman style pebble count (n = 100). The sample locations were approximately 100 feet downstream of GA2 (Lower Reach) and immediately upstream of the boulder jam (Upper Reach)

Table 5.1 – Frequency of substrate by class from Wolman pebble count.

Size Class	Max Size (mm)	Frequency Lower Reach	Frequency Upper Reach
Sand, Silt, Clay	2	10	11
Gravel	64	54	30
Cobble	256	27	42
Boulder	4056	9	17

Figure 5.5 – The lower reach is predominately a plane-bed stream (left) with bedrock outcroppings (right) along the right bank forcing the formation of pools.

Within the lower 2,000 feet of the reach the left (east) bank is relatively unconfined with a large active point bar separating the channel from the highway. The bar consists of large cobbles and contains a high-flow scour channel. Beginning at the first grade control the channel becomes highly confined by the valley wall along the right bank and hardened highway embankment along the left bank. Likely the historic stream alignment was to the east, where the highway is currently located.

Influence of Grade Control Structures within Reach

The downstream end of the lower channel reach was undoubtedly affected by the channel realignment that occurred in the 1930's. The shortening of the downstream channel by as much as 1,600 feet may have resulted in up to 8 feet of channel incision. Bedrock outcrops within the reach likely help to control the grade and reduced the upstream extend of incision. However, it is likely that the drop over the first two grade control structures (GA2 and GA3) is partially a result of channel incision occurring due to the downstream realignment combined with constriction of the channel from the road embankment.

The residual drop over GA2 is 4.2 feet, created by a combination of headward incision and localized scour from plunging flow over the weir. The scour pool is more than 100 feet long and is over 10 feet deep. The length of the scour pool, which consists of a flat rather than sloping water surface, is responsible for as much as 1.3 feet of the drop height over GA2.

5.2.2 Middle Channel Reach

The middle reach begins below the constructed boulder weir (BLD_WEIR) at Sta. 78+00 and ends immediately downstream of the boulder jam (BLDR_JAM) at Sta. 95+25. The average channel slope through this reach is 4.0% and the channel is highly constricted by both the canyon walls and the highway embankments. The channel reach includes boulder cascades, boulder step-pools, and a bedrock chute (Figure 5.6).

Lower Section (from Boulder Weir to GA6)

At the beginning of the middle reach there is a series of four grade controls: the boulder weir, GA4, GA5 and GA6. Throughout this section of channel the left bank is composed of sacrete along the sloping road embankment. From the boulder weir upstream to GA5 the right bank is composed of a nearly vertical 10 to 15 feet tall bank along a large alluvial that appears to be highly erosive. From GA5 to upstream of GA6 the right bank is composed of bedrock. The active channel width through this section is relatively consistent, at 35 feet. Within this roughly 550 feet section of channel the bed is completely controlled by the grade control structures, with long pools formed between each one. The bed composition within the pools range from sand and silt to boulder size substrate.

Mid Section (from GA6 to 101 bridge at Gaviota Pass)

Upstream of GA6, from Sta. 82+60 to Sta. 85+60, the channel morphology becomes dominated by large colluvial boulders (up to 18 feet diameter) within the channel. The right bank is vertical bedrock and the left bank is a combination of colluvial large boulders and sacrete armoring the road embankment. The stream consists of boulder steps and two large pools. This 300 feet long section maintains an average slope of 3.0% and an active channel width of 35 feet. From historic photographs of the Gaviota Pass, it appears this reach has not changed significantly since the construction of the highway.

Figure 5.6 – Middle reach, from downstream to upstream, consists of (a) four grade controls with long pools in-between, followed by sections of large boulder step-pools and cascades (b and c), and a constricted bedrock channel (d).

Upper Section (101 bridge at Gaviota Pass to Bedrock Chute)

Immediately downstream of the southbound Highway 101 bridge at the Gaviota Pass the channel morphology is a steep boulder cascade with an average active channel width of about 40 feet. Throughout this 535 feet long section (Sta. 85+60 to 90+95) the average channel slope is 4.6%. The bridge does not appear to further constrict the channel width, which is naturally constricted by the bedrock and boulders. Once upstream of the bridge the left and right banks are constricted by vertical concrete retaining walls that rest on bedrock. Channel width average 40 feet and the bed morphology is a combination of cascades and boulder forced step pools.

Bedrock Chute to Boulder Jam

From Sta. 90+95 to Sta. 95+40 the bed of the channel consists of relatively flat bedrock. Although the right bank continues to be defined by a vertical concrete retaining wall, the left bank becomes bedrock and the channel width narrows slightly. The average slope through this bedrock section is 3.8%. The end of this section is distinguished by a large boulder jam and change in the morphology of the channel bed and banks.

Influence of Grade Control Structures within Middle Reach

As evidenced by the thickness and undercutting of the grade controls, GA4 through GA6 were likely originally constructed at, or slightly above the grade of the streambed. As with the other groups of grade control structures, all of the drop in grade through this channel section occurs at the grade controls. Although grade is controlled by boulder cascades and steps within the channel immediately upstream of GA4 through GA6, the grade control structures have scoured the channel below each drop, preventing the formation of boulder steps or cascades between the grade controls. Within the shallow pools between each grade control there are numerous boulders that could help maintain the channel grade if the grade control structures were removed. However, removal of these grade controls may result in localized failure of the sacrete armored highway embankment if action was not taken to stabilize them.

5.2.3 Upper Channel Reach

The upper reach begins at the boulder jam (BLDR_JAM) at Sta. 95+25 and ends at the bridge crossing on southbound Highway 101, at Sta. 122+85 near the end of the surveyed longitudinal profile. The reach length is 2,760 feet and the average channel slope is 2.4%. Northbound Highway 101 lane is adjacent to the left (east) bank and southbound traffic travels adjacent to the right bank. In addition to the boulder jam, there are 7 concrete grade control structures within the reach.

The reach has two distinct sections: from the boulder jam to GA8 and from GA8 to the Highway 101 bridge. Throughout the entire reach the channel is highly incised and constricted by bedrock outcrops, hardened highway embankments, and vertical retaining walls. The channel includes boulder cascades, bedrock dominated step-pools, and long glides. (Figure 5.7).

Lower Section (from Boulder Jam to GA8)

The transition from the middle to upper reach is distinguished by a change from a bedrock to an alluvial channel bed, which occurs at a large boulder jam at Sta. 95+25. The boulder jam retains alluvial material, creating a 6 feet rise in the channel bed. From the boulder jam to GA8 at Sta. 111+60 the channel morphology consists of an alluvial bed with a repeating sequence of boulder steps and cascades followed by long glides, or shallow pools. This 1,635 feet section of channel maintains an average slope of 2.7% and an average active channel width of 30 feet.

This section of channel is straight and the banks are confined by the highway embankments. For roughly 800 feet, from the boulder jam to Sta. 103+30, the left (east) bank consists of the highway embankment. The embankment slopes at approximately 1H:1V and is armored with sacrete and rip rap. Between Sta. 104+50 and 110+00 the right (west) bank consist of a 540 feet long by 25 feet tall vertical concrete retaining wall. The remaining 160 feet of the channel section has rip rap armoring the right bank.

Figure 5.7 - Upper reach, from downstream to upstream, consists of (a) boulder steps and boulder cascades followed by long glides, highly confined banks due to the proximity of the highway (b and c), followed by a section of channel bed controlled by bedrock (d) and concrete grade control structures.

To help characterize substrate within this lower section of the Upper Reach, a Wolman pebble count was conducted upstream of the bolder jam. Sampled substrate was 42% cobble, followed by gravel and then boulders (Table 5.1).

<u>Upper Section (from GA8 to Highway 101 Bridge)</u>

The upper section begins at grade control GA8 at Sta. 111+60 and continues to the Highway 101 bridge crossing at Sta. 122+85. This 1,125 feet section of channel maintains an average slope of 1.9% and is distinguished by six concrete grade control structures and several bedrock exposures. With the exception of one short section a bedrock, the right (west) bank consists completely of a

1H:1V sloping sacrete armored road embankment. The left bank is primarily exposed bedrock from GA8 through GA13. At Sta. 118+60 to the Highway 101 bridge the left bank consist of a straight 400 feet long section of sloping sacrete embankment.

For GA9 through GA12 the drop height is controlled by the next downstream grade control. The result is long pools between each grade control. Within the pools are some large boulders mixed with smaller substrate.

Influence of Grade Control Structures within Reach

Boulder Jam

The boulder jam, which is partially held in place by the concrete retaining wall along the left bank and rebar dowelled into the left boulder, is the most substantial grade control feature surveyed as part of this study. It may possibly prevent the upstream channel from scouring to bedrock, as is the case downstream of the boulder jam. If the jam breaks apart, there is potential for substantial incision of the upstream channel bed. There is a well-defined channel around the side of the jam that appears suitable for adult steelhead passage at moderate to high flows. Modification should be considered to improve low-flow passage conditions by creating a pool at the base of the side channel.

Grade Control GA7

GA7 has an 80 ft long pool and a 4 ft drop. When accounting for the overall slope within this section of channel, the length of the pool accounts for roughly 2 feet of the total drop height. If this grade control was removed there appears to be ample boulders within the channel immediately upstream that would prevent upstream channel incision. Furthermore, it appears that this structure was originally constructed to protect a now abandoned pipeline crossing, and was not intended as a grade control structure.

Grade Control GA8

GA8 consists of concrete poured around an existing boulder step, and bedrock was found to be spanning the channel 40 feet upstream. Although some localized problems with the stability of the sacrete embankment may occur if GA8 was returned to a natural boulder step, headward erosion and incision does not appear to be a concern.

Grade Controls GA9 through GA12

At the bottom of the pool below GA12 there is bedrock spanning the channel bed, as well as being just downstream of GA9. There is also a bedrock chute between GA12 and GA13. Due to the presence of bedrock throughout much of the reach, removal of GA9 through GA12 would likely only result in relatively minor changes in the channel bed elevation. Removal of GA12 would result in the channel incising down to bedrock between Sta. 115+67 and 116+35. This would likely increase the length of the bedrock reach from about 50 feet to 120 feet and cause some localized stability problems with the sacrete along the right bank.

Grade Control GA13

GA13 is located at a bedrock constriction in the channel and appears to be maintaining the upstream channel grade, which is less steep than downstream. Removal of this grade control would likely cause substantial upstream incision and threaten the stability of the sacrete embankments located along both sides of the creek.

5.3 General Observations

This section gives a larger scale perspective of the entire 6,700 feet of surveyed channel and the geomorphic processes that are occurring.

5.3.1 Rate of Colluvial Inputs within Canyon

From the first grade control GA2 to the end of the survey the vast majority of the channel banks are hardened with retaining walls, sacrete, or rip rap. As a result of this bank hardening, there is no signs of bank erosion or recent inputs of colluvial material from the adjacent canyon walls, terraces, or tributaries. Additionally, one of the only sizable tributary to Gaviota Canyon, upstream of the pass, enters the channel through a 90 inch culvert just upstream of the boulder jam. Recently a large "trash rack" above the culvert inlet was added that now traps all large alluvial material. The other large tributary is at the Northbound rest area. It plugged with sediment and debris during recent floods, preventing the larger bedload from routing into Gaviota Creek. Additionally large colluvium that comes down the hillsides from landslides is frequently removed and transported offsite by CalTrans, preventing it from entering the main channel. Upstream of the survey, as the channel leaves the canyon, the hill slopes become more gentle sloping and there is little in the way of large colluvium in the channel.

Since recent colluvial inputs are minimal, it is likely that the vast majority of colluvium within the channel entered the channel prior to the construction of the highway and the rate of colluvial input has declines substantially (although upstream sediment supply of fine grain material is high). The possible decrease in rate of colluvial inputs combined with factors, such as channel constriction and realignment, has likely accelerated the incision rate within the canyon and may be partially responsible for the bedrock chute below the boulder jam. Over time the loss of colluvial inputs may cause more of the channel to incise to bedrock, potentially threatening the stability of the existing highway embankments and retaining walls and further impact upstream steelhead passage.

5.3.2 Channel Realignment

Channel degradation within the lower reach, from just upstream of GA3 to GA6 appears to be the result of relocating and straightening of the channel. Given the width of the canyon it is possible that the channel was historically located further to the east and was not as straight. Maps and documents showing the historic location of the channel prior to the construction of the highway would be useful in determining the channel reaches that have been relocated and the length of channel that has been lost due to channel straightening and relocation.

6 Recommendations

6.1 Potential Solutions for Improving Fish Passage

The six most challenging grade control structures for upstream passage of adult steelhead are:

Grade Control Structure	No-Flow Drop Height
GA4	5.2 feet
GA13	5.0 feet
GA2	4.2 feet
GA7	4.1 feet
GA8	3.9 feet
GA5	3.5 feet

The remaining six concrete grade control structures have drops ranging between 2.9 feet and less than 0.5 feet. Improving passage conditions at these six structures is key to improving fish passage through Gaviota Canyon. However, since the structures are located in groups (except for GA7) it is most practical to develop recommendations that address passage for each group.

Development of preliminary recommendations for improving passage was approached by considering each of the grade control groups.

6.1.1 GA2 and GA3

As described in Chapter 5, a large proportion of the drop over each of these grade controls is related to the length of the downstream scour pool. The length of the pools below GA2 and GA3 are 100 feet and 124 feet, respectively. The remaining grade maintained by these structures is likely attributed to the channel incision as a result of large scale channel realignment that shortened the channel length by as much as 1,600 feet.

Site Scale Approach

(1) *Leaving Grade Controls In-Place*
A series of boulder grade control weirs could be used to buildup the downstream channel below GA2 and from GA2 to GA3. To ensure the structural integrity of the boulder weirs, a roughened channel approach (Bates 2003) should be used that armors the bed and banks in between each weir with a mix of imported rock. Drops between weirs should be kept to roughly 6 inches to provide passage for juvenile and resident trout and to effectively dissipate energy. Since the upstream channel maintains an average slope of 4%, it would be reasonable that the weirs be spaced such that the constructed slope is approximately 4%. This would make the reach similar geomorphically and hydraulically to the upstream natural channel. The length of the roughened channels would not need to be any longer than the existing downstream scour pools.

(2) ***Replace Existing Grade Controls with Constructed Boulder Step-Pool Reach***
An alternative approach would be to remove the existing grade controls, GA2 and GA3, and construct new grade control in the form of boulder step-pools. The regraded channel section could begin at the existing downstream end of GA2's scour pool and end near Sta. 71+50 (Figure 6.1), where the channel beings to move away from the highway embankment. Similar to the previous option, the boulder steps should have drops of 6 inches or less and the design should follow typical roughened channel construction techniques. This reach would have an average channel slope of only 2.2%, which would provide an average spacing of 22 feet between boulder steps. Since the slope would only be 2.2%, the stability and fish passage through the regrade channel could be better than the previous option that would require a 4% slope. The stability of the sacrete revetment along the highway embankment could likely be maintained since the channel thalweg (flow-line) would be close to its current elevation.

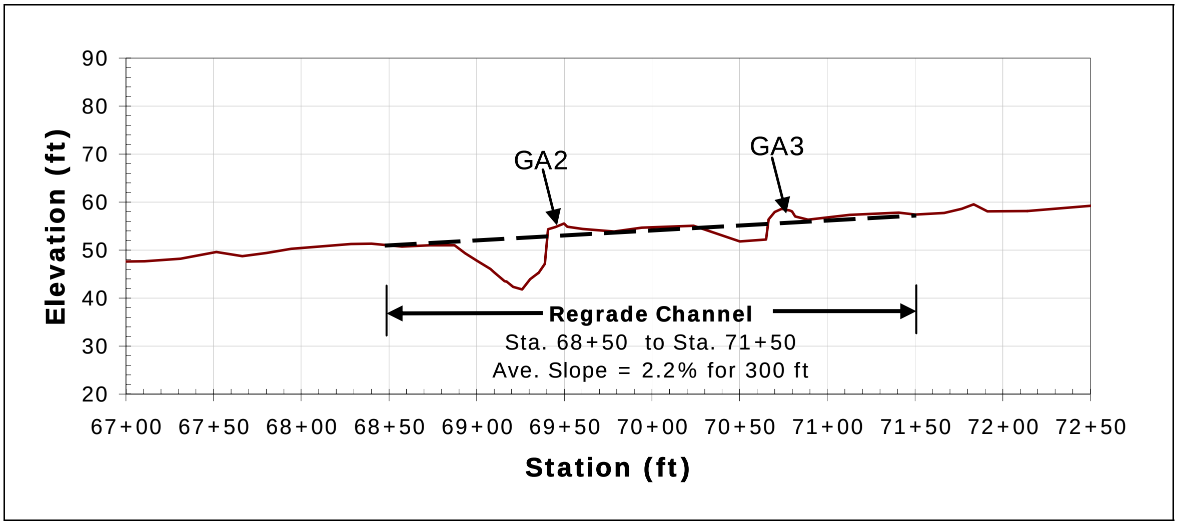


Figure 6.1 – A potential fish passage solution is removal of GA2 and GA3 combined with regrading the channel and constructing stable boulder step-pool morphology between 68+50 and 71+50.

Large Scale Approach

Adding length to the downstream channel, where the historic meander was eliminated is a large scale alternative (Figure 5.2). This lower reach of channel has been placed in a ditch along the toe of the highway embankment. To increase the channel length, habitat complexity and riparian canopy, Gaviota Creek could be moved to the west, where a large low alluvial terrace exists. This location would allow for increasing the channel sinuosity and length and would move the channel away from the highway embankment.

6.1.2 GA4 through GA6

Improving steelhead passage at this group of grade control structures may be the most challenging of all. The two boulder weirs that were constructed downstream of GA4 to improve fish passage (one weir failed shortly after construction) appear to have decreased the drop by roughly 2 feet. However, GA4 still maintains the largest drop (5.2 feet) of all 13 grade control structures. The nearly 15 feet tall vertical alluvial right (west) bank appears highly erosive, making it difficult to add additional grade control downstream of GA4 without pulling back the bank to a more gradual slope.

The channel was undoubtedly straightened to some degree between GA3 and GA6. This loss of channel length, and possibly moving the channel into smaller and less consolidated material, may explain the large grade difference from below GA4 to GA6.

Site Scale Approach

ReplaceGA4 and GA5 with boulder step-pools and Modify GA6

Given the difficulty in attempting to steepen the channel grade downstream of GA4, as evident by the previous attempt to install two boulder weirs, an alternative approach would be to remove GA4 and GA5 and regrade the 250 feet long section at roughly a 3.6% slope. For grade control, a roughened rock channel shaped as a step-pool morphology could be constructed. Although this type of grade control requires a large volume of rock of varying sizes, it tends to be much more stable than individual boulder weirs. Since regrading the channel would lower the thalweg (flow-line) in some locations (Figure 6.2), the structural integrity of the existing sacrete revetment along the highway embankment would need to be evaluated and structural modifications would likely be required.

GA6 appears to be a natural constriction point in the channel, with bedrock along the right bank and either bedrock or a very large boulder along the left bank (Figure 4.9). Fish passage could be improved by removing and reshaping the concrete in GA6 to make for a more natural type of step. Making the drop more complex would help eliminate the sheeting flow over the weir and make it hydraulically resemble the numerous boulder and bedrock steps that are immediately upstream.

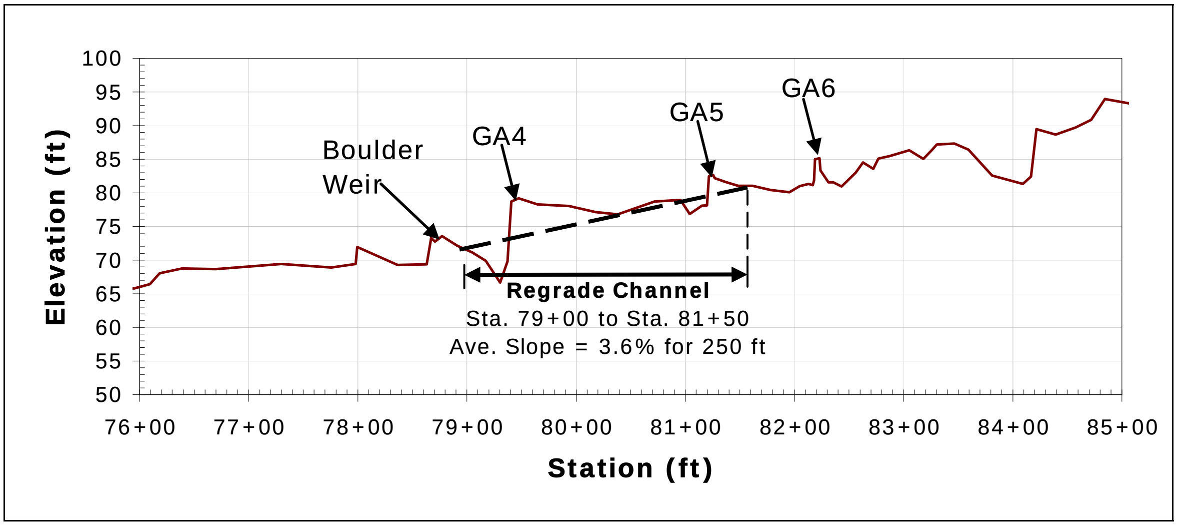


Figure 6.2 - A potential fish passage solution is removal of GA4 and GA5 combined with regrading the channel and constructing stable boulder step-pool morphology between 79+00 and 81+50. This would also require modification of GA6 along with possible structural reinforcement and scour protection for highway embankment.

Large Scale Approach

The channel was undoubtedly straightened through this reach. Increasing the length of the channel through this reach would provide more distance to make-up grade. Between about Sta. 76+00 and 81+00, just downstream of GA5, there is a relatively flat alluvial terrace to the west of the existing channel (Figure 6.3). One alternative to explore is moving the channel to the west and away from the highway. This option could add over 100 feet of length to the channel and provide effective fish passage while eliminating problems associated with the stability of the sacrete revetment and confinement of the channel. Within the constructed channel more natural-type grade controlling features could be included. It would also provide an opportunity to enhance the aquatic and riparian habitat of the stream. The new channel would need to reconnect to the existing channel downstream of GA5 due to a bedrock outcropping and end of the terrace. The grade of the new channel could be sufficiently raised to eliminate the barrier at GA5, and possibly at GA6.

Figure 6.3 – The channel could be relocated away from the highway into the alluvial terrace to the west of GA4.

6.1.3 Bedrock Chute and Boulder Jam

As described in the fish passage section of Chapter 4, no modification to the bedrock chute is recommended at this time. However, modification to the boulder jam should be explored to improve passage through the side channel along the right (west) bank. This modification should focus on creating pools of sufficient depth for steelhead to be able to leap over the drops that occur in the side channel at low and moderate flows. Additionally, annual monitoring of the boulder jam should occur to track its conditions. If the boulder jam becomes mobile, the upstream channel may become unstable, threatening the highway embankment, and possibly fish passage. If this occurs, any repair projects should consider fish passage.

6.1.4 GA7

GA7 appears originally constructed as scour protection for a pipeline crossing that is now abandoned. Based on the longitudinal profile, GA7 appears to be influencing the upstream channel grade for only 100 feet or less. In this 100 feet section the road embankment along the left (east) bank is armored with rip rap (RSP). It is our recommendation that GA7 be removed and the upstream channel allowed to regrade itself. Prior to removal, an engineering investigation should be conducted to see what modifications, if any, to the RSP would be required to ensure protection of the highway embankment.

6.1.5 GA8 through GA13

Between GA8 and GA13 the highway embankment for the southbound lanes forms the streams right bank. Throughout this section the right bank, sloping at 1H:1V or steeper, consists of sacrete revetment. The left bank is mostly bedrock. GA8 consists of concrete poured around an existing boulder step, and bedrock was found to be spanning the channel 40 feet upstream. At the bottom of the pool below GA12 there is bedrock spanning the channel bed. Also, a 40 feet long bedrock chute spans the channel between GA12 and GA13.

Site Scale Approaches

Construct Concrete Fishway through Bedrock Section
Given the confinement of this reach by numerous bedrock exposures and outcropping along the left bank and channel bottom and the highway embankment along the right bank, one potential approach is to remove the existing grade controls and construct a pool-and-weir type fishway. This would be a series of concrete weirs strategically placed to utilize the bedrock where possible. They would span the channel, similar to the existing grade control structures, and be keyed into the bedrock bank on left and the sacrete revetment on right. Following typical fishway design standards, the weir shape would be designed for fish passage and would be sufficient in height to form pools that are at least two feet deep. Drop from weir to weir should not exceed 6 inches and pools would be sized sufficiently large to avoid a turbulence barrier.

Removal of GA8 through GA13
An alternative approach would be to remove the existing grade controls GA8 through GA13, which would provide the best fish passage conditions. Due to the presence of bedrock throughout much of the reach, the resulting channel incision would likely be relatively minor in most locations. This approach would require extensive field mapping of bedrock and a structural assessment of the existing sacrete revetment along the highway embankment. It may also include strengthening or reconstructing some of the existing revetments.

6.2 Develop an Action Plan

We recommend that an action plan be developed to address each group of barriers. Barriers should be addressed from downstream to upstream, where feasible. Generally, groups of grade controls should be addressed together rather than one grade control at a time.

Developing any of the recommended options will require CalTrans to conduct an investigation of the structural integrity of the sacrete revetments adjacent to each grade control structure. Therefore, the appropriate next step in addressing these barriers may be to conduct a structural investigation of these sacrete revetments throughout the entire Gaviota Canyon. If there is a maintenance plan already in existence for performing repairs on any of these sections, this may also serve as an opportunity to include features that improve fish passage.

Many of the potential solutions for improving fish passage can also serve as an opportunity to improve the condition and safety of the highway and its drainage features.

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APPENDIX A

Fish passage assessment of two Highway 101 Culverts

Upper Gaviota Creek (GA_20)
Las Canovas Creek (GA_CA_1)

Steelhead Passage Assessment of Highway 101 Stream Crossings on Upper Gaviota and Las Canovas Creek

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NATURAL RESOURCE ASSESSMENT AND RESTORATION SERVICES

March 15, 2007

Fish Passage Assessment of Highway 101 Culverts on Upper Gaviota Creek and Las Canovas Creek

Table of Contents:

1) Overview

This report summarizes the assessment of existing fish passage conditions for two CalTrans maintained stream crossing on Highway 101 within the Gaviota Creek watershed of Southern Santa Barbara County. The crossings are Highway 101 at Upper Gaviota Creek (Barrier ID: GA_20) and Highway 101 at Las Canovas Creek (Barrier ID GA_CA_1). **Figure 1** shows the location of the two stream crossings. These road-stream crossings were identified as impassable in a recent steelhead habitat and passage assessment report (Stoecker, 2002). The earlier assessment was for the entire southern Santa Barbara County and passage was assessed based primarily on professional judgment.

The intent of the current assessment is to quantify the passage conditions at the two culverts by following the Assessment Protocol (Taylor and Love, 2003). This work was funded through California Department of Fish and Game's California Coastal Salmon Recovery Program. It was performed in conjunction with a fish passage and geomorphic assessment for 12 grade control structures in Lower Gaviota Creek, in Santa Barbara County along Highway 101.

In the previous assessment by Stoecker, these two crossings were identified as complete barriers (Severity = 1). The Highway 101 culvert on Upper Gaviota Creek was given the highest priority within the watershed, and if passage was reestablished at this crossing steelhead would regain access to over 1.9 miles of "high" quality salmonid habitat. The Highway 101 culvert on Las Canovas Creek was given the second highest priority within the watershed, and if passage was reestablished at this crossing steelhead would regain access to as much as 0.46 miles of "high" to "moderate-high" quality salmonid habitat.

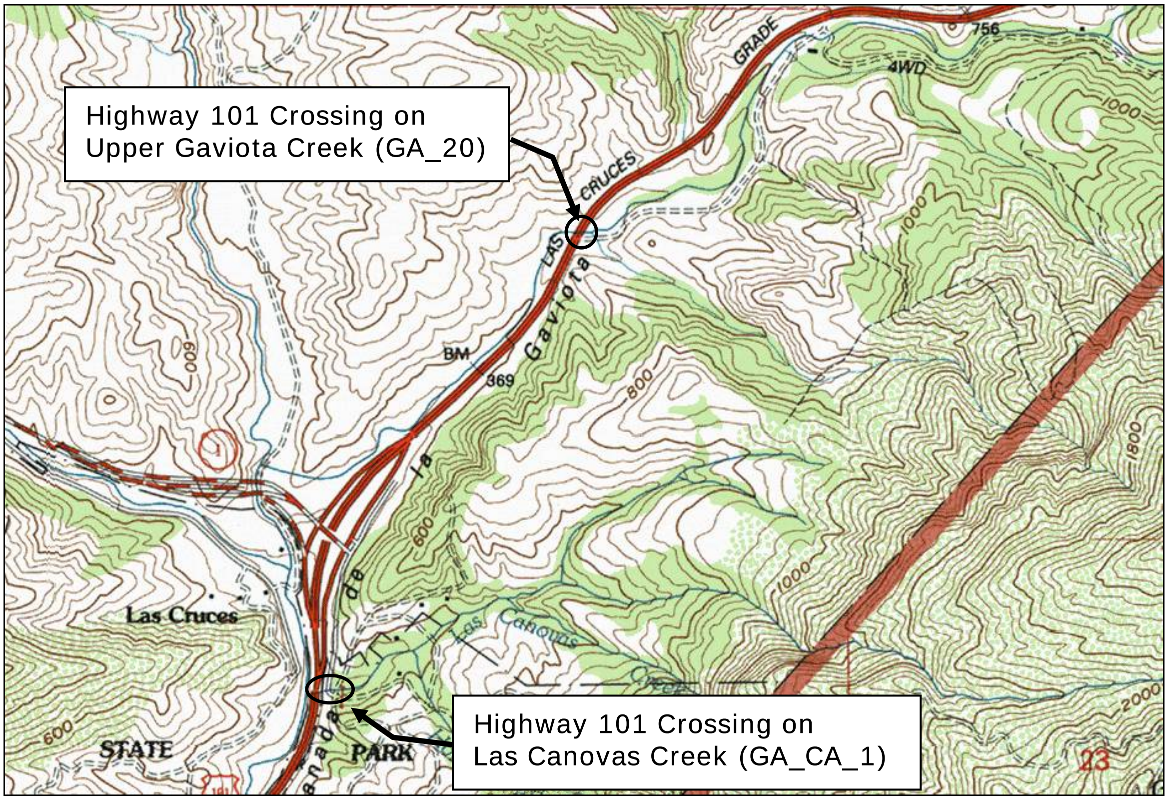


Figure 1 – Location of the two assessed Highway 101 stream crossings (GA_20 and GA_CA_1) shown on the USGS 7.5 minute Solvang quadrangle.

2) Activities

The Upper Gaviota Stream Crossing and the Las Canovas Creek stream crossing was surveyed on October 15th 2006. Both are owned and maintained by CalTrans, however the land owner upstream and downstream of the Upper Gaviota Creek crossing was not contacted for access, preventing a quantitative assessment of the adjacent stream channel. However, from survey data collected within the CalTrans Right-of-Way we were able to assess the hydraulic conditions in the culvert as relating to fish passage.

The survey followed the California Department of Fish and Game (CDFG) fish passage assessment protocol (Taylor and Love, 2003). Tasks included taking standard measurements of the culvert, surveying a longitudinal profile through each culvert, surveying a channel cross section at the tailwater control below each crossing, and measuring active channel widths upstream of each crossing within accessible areas. Since the tailwater control for the outlet pool at the Upper Gaviota crossing was beyond the CalTrans right-of-way, the tailwater cross section was surveyed using the prismless feature of the survey equipment.

The data from the field survey of the two sites was entered into spreadsheets for analysis. Culvert slopes and outlet drops were calculated and plots were made of the longitudinal profiles. Using the CDFG protocol for analyzing passage conditions, we calculated the fish migration flow range for adult steelhead, adult rainbow trout, and juvenile trout. Then, using

CDFG prescribed swimming and leaping abilities and minimum water depth requirements, we analyzed fish passage conditions through each culvert using FishXing 3.0.

4) Hydrology and Fish Passage Flows

Peak Flow Estimates

As part of the CDFG fish passage inventory protocol, the capacity of the crossing is assessed to determine its ability to accommodate peak flood flows. Magnitudes of peak flows associated with varying recurrence intervals were estimated using a probabilistic analysis of 20 years of annual peak flow records from Gaviota Creek at Gaviota (USGS Gage No. 11120550). The peak flows were then scaled by contributing drainage area for each of the stream crossings. **Table 1** shows the estimated flows associated with the 2 to 100 year recurrence intervals.

Table 1 - Peak flow estimates for stream crossings on Gaviota and Las Canovas Creek at Highway 101 for various recurrence intervals.

		Highway 101 at Las Canovas Creek	Highway 101 at Upper Gaviota Creek
Drainage Area	=	1.39 mi^2	3.32 mi^2
2-year Flow	=	77 cfs	185 cfs
5-year Flow	=	210 cfs	502 cfs
10-year Flow	=	342 cfs	818 cfs
25-year Flow	=	539 cfs	1,288 cfs
50-year Flow	=	716 cfs	1,710 cfs
100-year Flow	=	913 cfs	2,181 cfs

Calculated using probabilistic analysis of peak flow record from USGS Gaviota Creek at Gaviota, adjusted by drainage area. Analysis followed USGS Bulletin 17B procedures (USGS 1982).

Fish Passage Flows

Analyzing fish passage conditions requires defining a range of flows for which passage should be provided. Generally, passage is not required at extremely low or high flows, when fish are not expected to be moving. Methods for determining the lower and upper passage flows are defined by NOAA Fisheries (2001) and CDFG (2002) for adult steelhead, adult resident rainbow trout, and juvenile trout. Between the lower and upper passage flows hydraulic conditions at the stream crossing should be adequate for the target species and lifestage. A stream crossing that provides adequate passage conditions at all flows between the lower and upper fish passage flow is considered to be "100% passable" for that species and lifestage. The majority of culverts are not 100% passable, but fall into the partial or complete barrier categories. Many block adult steelhead at some flows and juvenile salmonids at all flows.

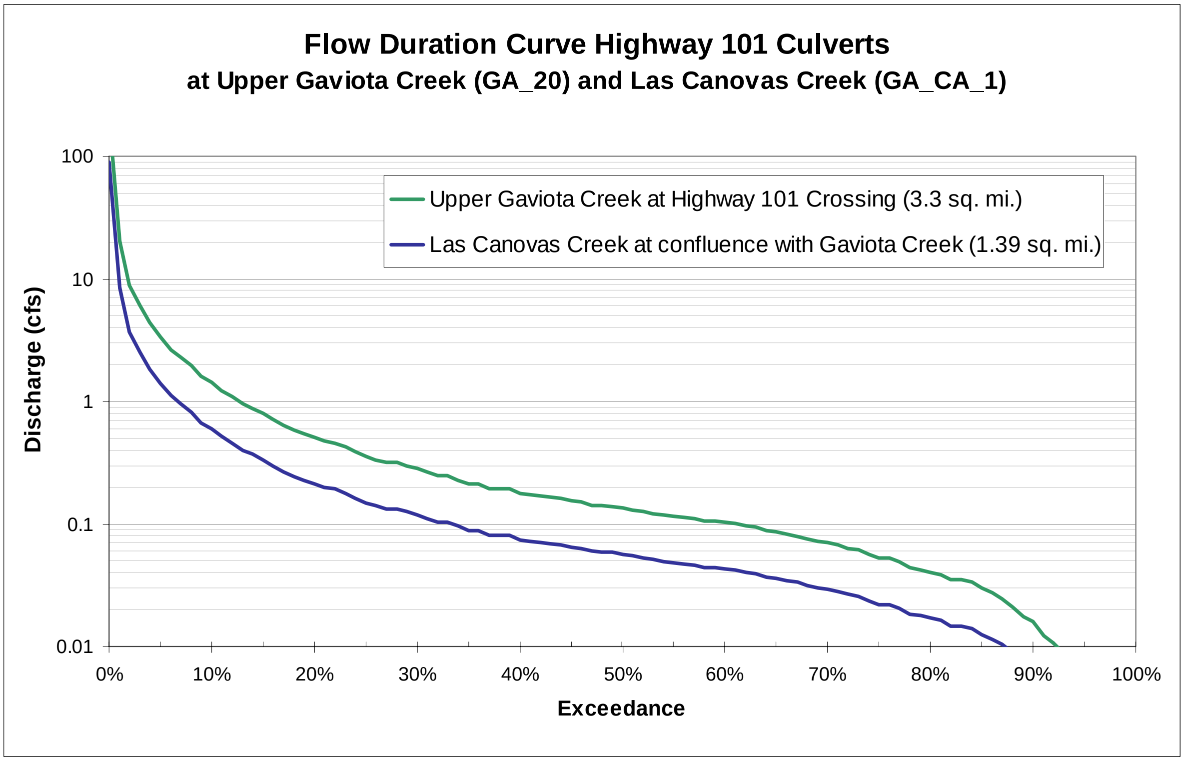


Figure 2 - Flow duration curve for the assessed stream crossings on Upper Gaviota and Las Canovas Creek, constructed from Gaviota Creek at Gaviota daily average streamflow records.

Table 2 - Fish Passage Flow Criteria as defined by NOAA Fisheries and CDFG.

Species and Lifestage	Lower Passage Flow	Upper Passage Flow
Adult Steelhead	50% exceedance flow or 3 cfs (whichever is greater)	1% exceedance flow
Adult Rainbow Trout	90% exceedance flow or 2 cfs (whichever is greater)	5% exceedance flow
Juvenile Trout	95% exceedance flow or 1 cfs (whichever is greater)	10% exceedance flow

Table 3 - Fish passage flows for Highway 101 culverts on Upper Gaviota and Las Canovas Creeks.

	Fish Passage Flows					
	Adult Steelhead		Adult Resident Rainbow Trout		Juvenile Salmonids	
Location	Lower	Upper	Lower	Upper	Lower	Upper
Highway 101 at Las Canovas Creek(GA_CA_1)	3 cfs	8.5 cfs	2 cfs	2 cfs	1 cfs	1 cfs
Highway 101 at Upper Gaviota Creek(GA_20)	3 cfs	20.3 cfs	2	3.4 cfs	1 cfs	1.4 cfs

The lower and upper passage flows are defined in terms of exceedance flows (**Table 2**). Exceedance flows, which are obtained from flow duration curves (FDC's), express the average amount of time within a year that flows are above a certain threshold. For example, flows within the stream are greater than the 25% exceedance flow on average one quarter of the time during the course of a year.

Since no stream flow gage is maintained at the culverts, exceedance flows were obtained from the USGS stream gage Gaviota Creek at Gaviota and then adjusted to the drainage area of the two assessed stream crossings (**Figure 2**). Using the FDC and the fish passage design flow criteria from NOAA and CDFG (**Table 2**), we estimated lower and upper fish passage flows for steelhead, adult resident rainbow trout, and juvenile trout (**Table 3**).

However, it is important to note that using the 1% exceedance flow to estimate a reasonable high passage flow for adult steelhead was based largely on the hydrology of Northern California. Many have argued that steelhead in Southern California streams migrate at substantially higher flows, and causing migrational delay at a culvert has far larger consequences for Southern Steelhead in regards to successful migration, spawning, and offspring viability due to the infrequent nature of suitable migration flows. Although this assessment uses the fish passage flows listed in **Table 3**, design of a fish passage facility at these sites should include reexamining the fish passage design flows in context to the hydrology of Gaviota Creek and its tributaries and the biological implications of a selected design flow.

5) Fish Passage Assessment Criteria

The CDFG fish passage assessment protocol prescribes minimum required water depths and maximum swimming and leaping speeds for assessing fish passage (**Table 4**). Swimming speeds are divided into two categories; prolonged speeds, which can be maintained for long periods of time, and burst speeds, which are equivalent to sprinting and can only be maintained for a few seconds. Leap speed is the speed a fish can leap out of the water as it leaps towards a perched culvert outlet. To meet fish passage criteria (1) the fish must be able leap or swim into the culvert, (2) water depths must be adequate throughout the culvert, and (3) the fish must be able to swim through the entire culvert without becoming exhausted by the water velocities.

Table 4 - CDFG prescribed water depth and swimming criteria for assessing fish passage at stream crossings using the FishXing software.

Fish Species and Lifestage	Minimum Water Depth	Prolonged Swimming		Burst Swimming		Maximum Leap Speed
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	
Adult Steelhead	0.8 ft	6.0 ft/sec	30 min	10.0 ft/sec	5.0 sec	15.0 ft/sec
Adult Rainbow Trout	0.5 ft	4.0 ft/sec	30 min	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile Trout	0.3 ft	1.5 ft/sec	30 min	3.0 ft/sec	5.0 sec	4.0 ft/sec

The swim speeds and minimum water depths prescribed by CDFG are relatively conservative, and meant to represent the needs and abilities of the weaker swimming individual fish. Many individual fish are able to swim faster and swim through shallower flows than indicated in Table 4. Therefore, it is not uncommon for some fish to pass through stream crossings that fail to meet these passage criteria.

For the two crossings, fish passage for all three life stages of steelhead/rainbow trout were assessed between the lower and upper fish passage flows using the CDFG criteria.

6) Findings

Las Canovas Creek at Highway 101 (GA_CA_1)

The Las Canovas crossing is a 325 foot long, 10 feet wide x 10 feet tall reinforced concrete box (RCB) culvert with multiple slopes and 3 horizontal turns. The slope and lengths starting from the culvert outlet to the inlet are:

Culvert Section	Length	Slope
1	158 ft	2.3%
2	44 ft	9.8%
3	62 ft	6.0%
4	61 ft	2.1%

Outlet and Tailwater Conditions

The outlet is located at the confluence of Las Canovas Creek with Gaviota Creek (**Figure 3**). The outlet is perched 2.2 ft above the channel bed control in Gaviota Creek, forcing fish to leap into the culvert outlet at lower flows.. There is an accumulation of boulders and gravels inside the lower 75 feet of the culvert, suggesting significant backwatering from Gaviota Creek during high flows. A living alter tree and associated root mass on the culvert apron appears to help retain the deposited sediment in the culvert.

The tailwater control below the culvert outlet is a riffle crest located in Gaviota Creek approximately 60 ft downstream of the outlet. To predict backwater conditions in the culvert a tailwater cross section and channel profile was surveyed in Gaviota Creek below the outlet. For assessment purposes, the flow in Gaviota Creek was assumed to correspond proportionally (by drainage area) to the flow in Las Canovas Creek. For example, we assumed that Gaviota Creek at the culvert outlet would flow at the 1% exceedance flow at the same time as Las Canovas Creek.

During the survey one 11 inch rainbow trout and four pond turtles were observed in Gaviota Creek about 300 feet upstream of the culvert outlet. Three rainbow trout, 5 to 7 inches in length, were observed in the lower portion of the culvert

Inlet Conditions
During the field visit, we found a large diameter Sycamore tree had fallen across the inlet of the culvert (**Figure 4**). There was a substantial amount of large bedload aggraded at the culvert inlet, which is often associated with backwater effects resulting from undersized or debris plugged culverts. The upstream channel is steep and characterized by boulder steps. The average actively scoured channel width is 21.8 feet while the width of the culvert opening is 10 feet, constricting the active channel by 45%.

Assessment Results
Using the CDFG coarse screen, the culvert is categorized as RED, because its slope is much greater than 2% and the residual outlet drop is greater than 2 feet. Further hydraulic assessment of the crossing using FishXing 3.0 found that it did not satisfy passage criteria for all species and lifestages at any flow (**Table 5)**. While acceptable velocities were found for adult steelhead below 7 cfs, the water depth in the culvert is insufficient, at less than 0.1 feet. Detailed results of the fish passage analysis and a water surface profile through the culvert are provided at the end of this report.
Using standard Federal Highways Chart 8, the capacity of the crossing is estimated to be 930 cfs when the headwater (water at the inlet) is at the top of the culvert, this corresponds to the estimated 100-year peak flow.

Table 5 – Fish passage conditions at Las Canovas stream crossing. Results are for Section 2 of the culvert, which has the steepest slope and is most limiting to passage conditions.

Fish Species and Age Class	**Fish Passage Design Flows**	**Insufficient Depth below**	**Excessive Velocity above**	**Percent Passable** between lower and upper passage design flows
Adult Steelhead	3 cfs – 8.5 cfs	78.4 cfs	7.07 cfs	**0%**
Adult Rainbow Trout	2 cfs – 2 cfs	37.11 cfs	2.42 cfs	**0%**
Juvenile Trout	1 cfs – 1 cfs	16.23 cfs	0.54 cfs	**0%**

Figure 3 – Outlet of Las Canovas Creek culvert, at the confluence with Gaviota Creek. Looking downstream towards tailwater control in Gaviota Creek.

Figure 4 - Looking upstream through the inlet of the Highway 101 Las Canovas Creek culvert. The crossing is a 10 ft x 10 ft box culvert, with 3 turns and four distinct breaks in slope. There is substantial aggradation of boulders and cobbles at the inlet.

Upper Gaviota Creek at Highway 101

The Upper Gaviota Creek crossing is a 194 feet long, 10 feet wide x 10 feet tall reinforced concrete box (RCB) culvert with two slopes and one horizontal turns. The slope and lengths starting from the culvert outlet to the inlet are:

Culvert Section	Length	Slope
1	112 ft	9.2%
2	82 ft	3.3%

Outlet and Tailwater Conditions

The outlet flows directly into a large tailwater pool (**Figure 5**). There is a 1.24 feet residual drop at the outlet and the tailwater control consists of small boulders accumulated across the channel (**Figure 6**). During the field visit, numerous rainbow trout were observed in the outlet pool, some as large as 5 to 7 inch in length.

Due to a restricted access by the landowner, the tailwater control cross section was determined from site sketches and reflective survey methods.

Assessment Results

Using the CDFG coarse screen, the culvert is categorized as RED, because its slope is much greater than 2%. Further hydraulic assessment of the crossing using FishXing 3.0 found that it did not satisfy passage criteria for all species and lifestages at all flows (**Table 6**). While acceptable velocities were found for adult steelhead and resident trout below 7.0 and 3.0 cfs respectively, the resulting depth was insufficient throughout the culvert. Detailed results of the fish passage analysis and a water surface profile through the culvert are provided at the end of this report.

Using standard Federal Highways Chart 8, the capacity of the crossing was estimated to be 930 cfs when the headwater (water at the inlet) is at the top of the culvert, this corresponds to just above the estimated 10-year return flow of 818 cfs. During the estimated 100-year return flow of 2,181 cfs the ratio of headwater depth to the height of the culvert (HW/D) is 2.4. The height of the road prism was not measured as part of this survey, so it is unknown if this headwater depth would result in overtopping of the road. However, it is certain that it would inundate a portion of a private ranch road that runs along the creek upstream of the culvert.

Table 6 – Fish passage conditions at Upper Gaviota stream crossing. Results are for the most downstream section, which is steepest, and most limiting to passage conditions.

Fish Species and Age Class	Fish Passage Design Flows	Insufficient Depth below	Excessive Velocity above	**Percent Passable** between lower and upper passage design flows
Adult Steelhead	3 cfs – 20.3cfs	151.0 cfs	7.0 cfs	**0%**
Adult Rainbow Trout	2 cfs – 3.4 cfs	74.0 cfs	3.0 cfs	**0%**
Juvenile Trout	1 cfs – 1.4 cfs	33.0 cfs	0.0 cfs	**0%**

Figure 5 – Outlet of Upper Gaviota Creek culvert.

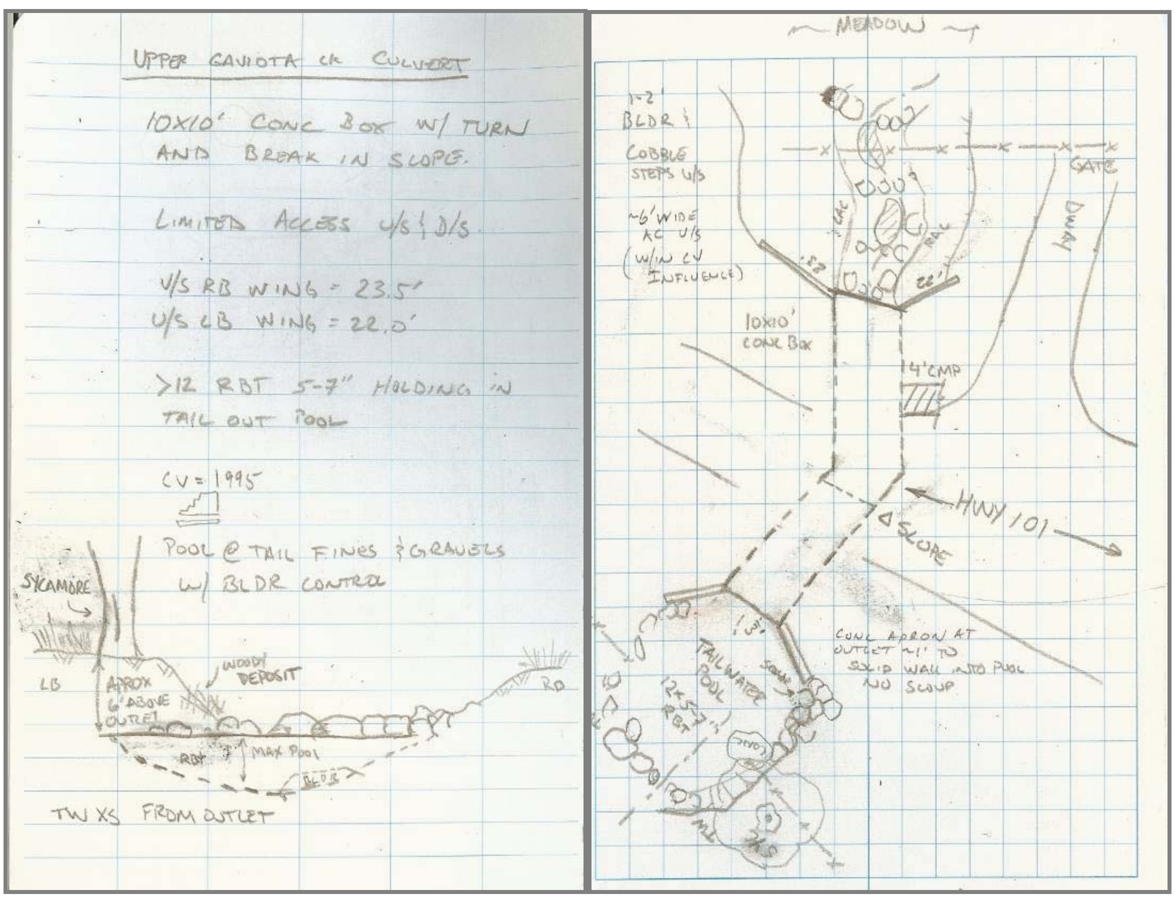


Figure 6 – Site sketches for Upper Gaviota Creek showing tailwater control cross section and plan map of crossing. Survey data was limited to the highway right-of-way.

7) Summary

Both Upper Gaviota Creek at Highway 101 and Las Canovas Creek at Highway 101 are placed into the RED category according the CDFG assessment protocols. Additional fish passage analysis using the FishXing Version 3 software and CDFG recommended fish swimming and leaping speeds identified the crossing as failing to provide adequate passage conditions for all life stages of salmonids, including adult steelhead, at all flows. Passage conditions are poor due to excessive water velocities and insufficient depth caused by steep slopes and a flat smooth bottom. Based on experience with previous fish passage assessments, it is unlikely that any fish are able to pass through either of these culverts under any conditions.

8) Recommendations

Both culverts have a large amount of fill material and multiple lanes of traffic over them. Replacement of either crossing would be a multi-million dollar investment and require many years of planning, making replacement not a viable short-term alternative. Any future large-scale modifications to the culverts or adjacent highway should consider removal of these culvers and installation of a "stream simulation" type crossing.

The extremely steep slopes within both of these culverts makes retrofitting them to provide steelhead passage difficult. Baffles are frequently added to culverts to slow water velocities, increase water depths and improve fish passage. However, baffles fail to work effectively at slopes greater than 3.5% (Bates 2003). The slopes in these two culverts are far too steep for baffles, with each having a culvert section that has a slope exceeding 9%.

Pool-and-Weir Fishway Alternative

The most viable alternative is to construct a pool-and-weir type fishway within the culvert barrel. This could consist of a series of weirs, with 6-inch drops between weirs to provide passage for all age classes of trout. The pools formed by the weirs would require a minimum depth of 2 feet and would need to be sufficient in size to dissipate the energy associated with each drop. Otherwise, excessive turbulence may become a barrier.

Both of these culverts are currently inlet controlled due to their slope, meaning that the inlet shape and size controls its capacity rather than the hydraulics within the culvert barrel. As with other culvert retrofit projects, it may be possible to maintain inlet control conditions during peak flows at both of these culverts while providing a pool-and-weir fishway within them. To avoid further reduction in culvert capacity, the floor of the culvert near the inlet may need to be cut and reformed at a lower elevation. Additionally, the upper most weir can be placed well downstream of the culvert inlet, to avoid reducing the cross-sectional area of the inlet.

CalTrans District 1 recently completed a similar type culvert retrofit on Luffenholz Creek on Highway 101 in Humboldt County. This retrofit involved constructing concrete weirs within an existing concrete box culvert to improve salmon and steelhead passage (Sebastian Cohen, Per. Communication).

9) Conclusions

There are currently various age classes of rainbow trout at the outlets of both of these culverts. Additionally Stoecker observed an adult steelhead within the pool below the Upper Gaviota Creek culvert. Eliminating the migration barrier at the Highway 101 culvert at Upper Gaviota Creek and Las Canovas Creek would immediately provide anadromous steelhead and resident rainbow trout thousands of feet of high quality habitat and should be considered a high priority within the efforts to restore and maintain a viable steelhead population within the Gaviota Creek Watershed.

10) References

Bates. 2003. *Design of Road Culverts for Fish Passage.* (http://wdfw.wa.gov/hab/engineer/habeng.htm#upstrm).

California Dept. of Fish and Game (CDFG). 2002. *Culvert criteria for fish passage..*.

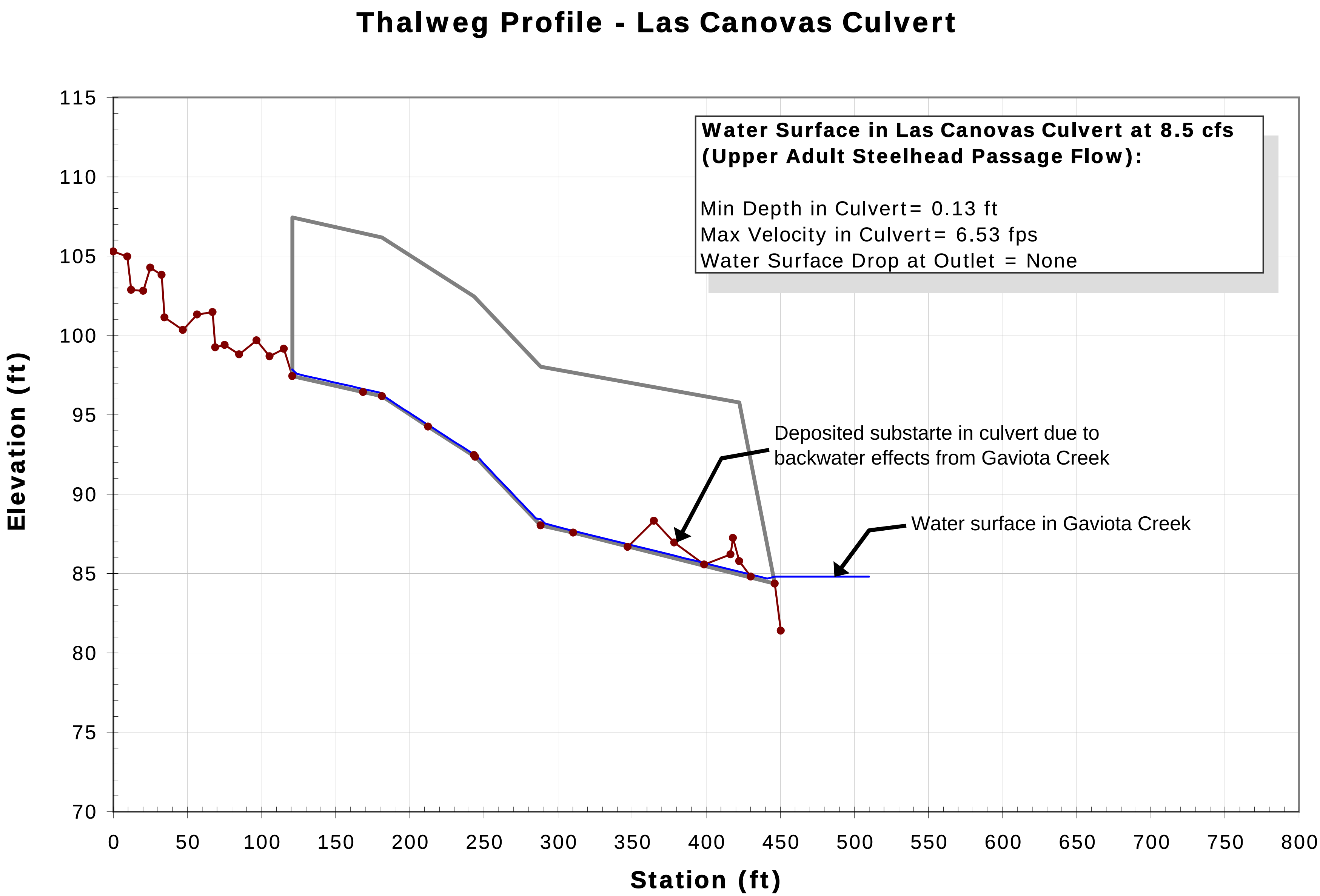
Cohen, Sebastian. 2005. Personal Communication. Engineering, CalTrans District 1, Eureka CA.

NOAA Fisheries. 2001. *Guidelines for salmonid passage at stream crossings.* NMFS SW Region. 14 pages

Taylor, Ross and Michael Love. 2003. Part IX – Fish passage evaluation at stream crossings. In California Salmonid Stream Habitat Restoration Manual. CA Dept of Fish and Game. 64 pages.

USGS. 1982. Guidelines for determining flood flow frequency. Bulletin #17B of the Hydrology Subcommittee. Interagency Advisory Committee on Water Data, US Dept. of Interior, Geological Survey, Virginia.

Stoecker, Matt. 2002. Steelhead Assessment and Recovery Opportunities in Southern Santa Barbara County. Conception Coast Project. Santa Barbara, CA. 439 pages.


Thalweg Profile - Las Canovas Culvert
Water Surface in Las Canovas Culvert at 8.5 cfs
(Upper Adult Steelhead Passage Flow):
Min Depth in Culvert= 0.13 ft
Max Velocity in Culvert= 6.53 fps
Water Surface Drop at Outlet = None
Deposited substarte in culvert due to
backwater effects from Gaviota Creek
Water surface in Gaviota Creek
Elevation (ft)
Station (ft)
115
110
105
100
95
90
85
80
75
70
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800

STREAM CROSSING SUMMARY SHEET

Site: Las Canovas Creek
Road: State Highway 101

General Information

Survey Date:	10/14/06	7.5 Minute Quad Name:	Solvang
Survey Team:	Love, Llanos, Stoecker	Latitude:	34° 30' 16.81"N
Stream Name:	Las Canovas Creek	Longitude:	120° 13' 36.15"W
Land Ownership:	State of California	Tributary to:	Gaviota Creek

Culvert Information

Shape: Box
Material: Concrete
Roughness (n): 0.018
Inlet Type: Wingwall 30-70°
Outlet Type: Projecting concrete apron
Diameter: 10 ft
Bankfull Width:

Culvert Section 1 of 4
Length: 158 ft
Constant Slope: 2.3%
Residual Outlet Depth: -1.8 ft
Retrofit: No

Culvert Section 2 of 4
Length: 44 ft
Constant Slope: 9.8%
Retrofit: No

Culvert Section 3 of 4
Length: 62 ft
Constant Slope: 6.0%
Retrofit: No

Hydrology

Drainage Area: 1.39 mi^2
Estimated 100-yr Flow*: 913 cfs

Culvert Capacity based on FHWA Chart 8
ENTRANCE TYPE: Wingwall 30-70°

Crossing Peak Flow Capacity
Top of Inlet (HW/D = 1.0) = 930 cfs

Mean Reach Slope: 4.53%

Culvert Section 4 of 4
Length: 61 ft
Constant Slope: 2.1%
Retrofit: No
Residual Inlet Depth: -15.3 ft

*Value derived from average of Log-Pearson Type III using local stream gage records, normalized by Drainage area

Fish Passage Conditions

Fish Passage Criteria From CA Salmonid Stream Habitat Restoration Manual Chapter IX- DFG

Species or Lifestages	Minimum Water Depth	Prolonged Swimming Mode		Burst Swimming Mode		
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	Maximum Leap Speed
Adult Anadromous Salmonids	0.8 feet	6.0 ft/sec	30 minutes	10.0 ft/sec	5.0 sec	15.0 ft/sec
Resident Trout and Juvenile Steelhead >6"	0.5 feet	4.0 ft/sec	30 minutes	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile Salmonids <6"	0.3 feet	1.5 ft/sec	30 minutes	3.0 ft/sec	5.0 sec	4.0 ft/sec

Fish Passage Design Flows

Design Flow Window Limits	Adult Anadromous Salmonids	Resident Trout and Juvenile Steelhead >6"	Juvenile Salmonids <6"
Lower Passage Flow (Qlp)	3.0 cfs	2.0 cfs	1.0 cfs
Upper Passage Flow (Qhp)	8.5 cfs	2.0 cfs	1.0 cfs

STREAM CROSSING SUMMARY SHEET

Site: Las Canovas Creek
Road: State Highway 101

Existing Conditions at Fish Passage Design Flows

Existing Conditions for Culvert

Fish Passage Flow Window	Qlp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	3.0	0.07	4.53	0.68
Adult Rainbow Trout	2.0	0.05	3.68	0.84
Juvenile Salmonids	1.0	0.04	2.79	1.08

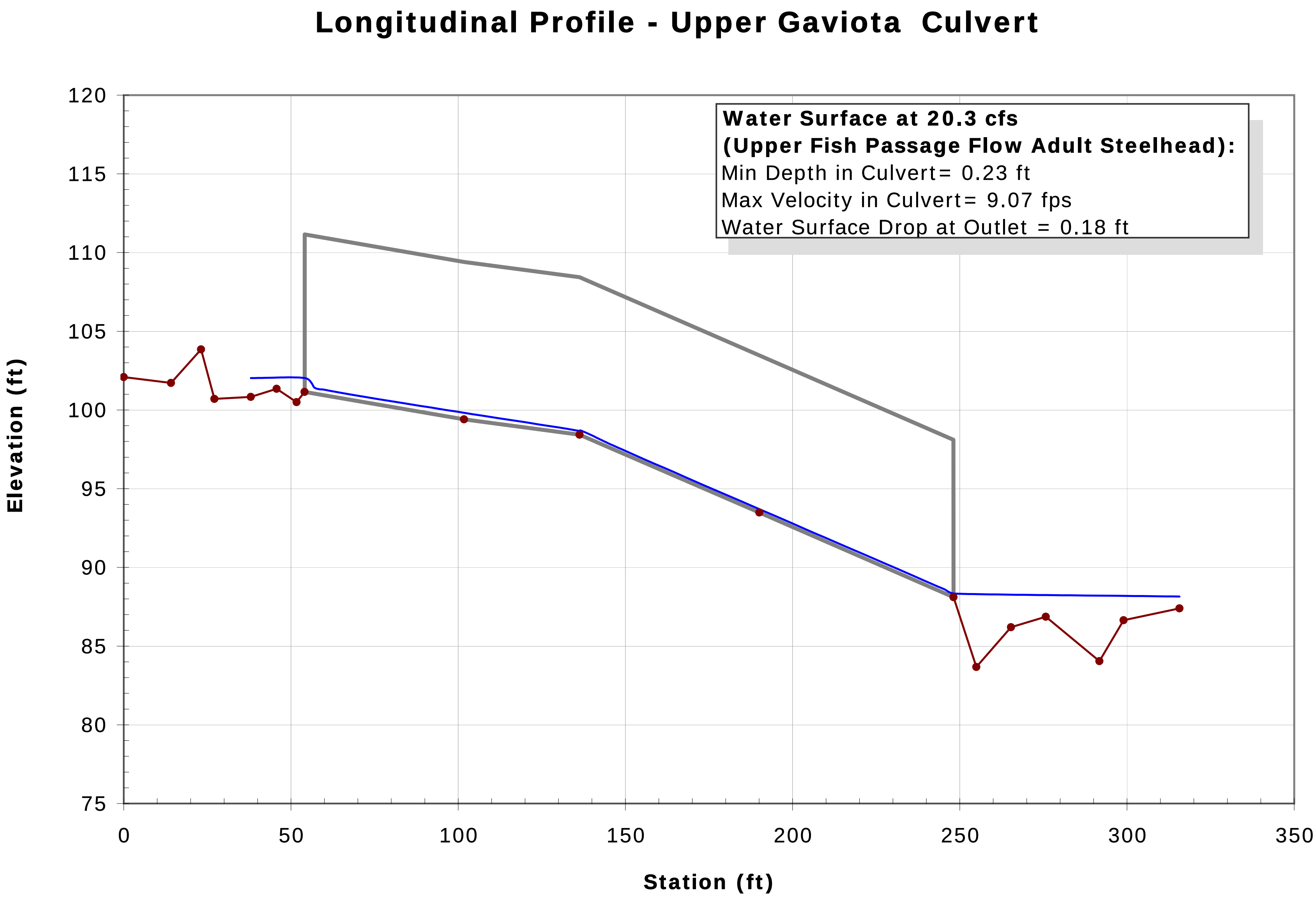
Fish Species and Age Class	Qhp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	8.5	0.13	6.53	0.00
Adult Rainbow Trout	2.0	0.08	4.46	0.84
Juvenile Salmonids	1.0	0.04	2.79	1.08

Flows Meeting Fish Passage Criteria

Fishxing Results for Culvert

Fish Species and Age Class	Insufficient Depth below	Excessive Velocity above	Excessive Outlet Drop below	Flows Passable between Lower and Upper Fish Passage Flows
Adult Steelhead	78.4 cfs	7.1 cfs	-	0%
Adult Rainbow Trout	37.1 cfs	2.4 cfs	2.0 cfs	0%
Juvenile Salmonids	16.2 cfs	0.5 cfs	5.6 cfs	0%

The Las Canovas culvert is a barrier to Adult Steelhead, Adult Resident Trout and Juvenile Salmonids at all flows. While there is a small window of acceptable velocity for Adult Steelhead and Trout, the depth is insufficient for an excessive length.


Longitudinal Profile - Upper Gaviota Culvert
Water Surface at 20.3 cfs
(Upper Fish Passage Flow Adult Steelhead):
Min Depth in Culvert= 0.23 ft
Max Velocity in Culvert= 9.07 fps
Water Surface Drop at Outlet = 0.18 ft
Elevation (ft)
120
115
110
105
100
95
90
85
80
75
0
50
100
150
200
250
300
350
Station (ft)

STREAM CROSSING SUMMARY SHEET

Site: Upper Gaviota Creek
Road: State Highway 101

General Information

Survey Date:	10/14/06	7.5 Minute Quad Name:	Solvang
Survey Team:	Love, Llanos, Stoecker	Latitude:	34^{o} 31' 3.06"N
Stream Name:	Upper Gaviota Creek	Longitude:	120^{o} 13' 3.24"W
Land Ownership:	State of California	Tributary to:	Gaviota Creek

Culvert Information

Shape:	Box
Material:	Concrete
Roughness (n):	0.018
Inlet Type:	Wingwall 30-70^{o}
Outlet Type:	Wingwall 30-70o
Diameter:	10 ft
Bankfull Width:	
Culvert Section 1 of 2	
Length:	112 ft
Constant Slope:	9.2%
Residual Inlet Depth:	N/A ft
Residual Outlet Depth:	-0.9 ft
Retrofit:	No
Culvert Section 2 of 2	
Length:	82 ft
Constant Slope:	3.3%
Residual Inlet Depth:	-13.8 ft
Residual Outlet Depth:	N/A ft
Retrofit:	No

Hydrology

Drainage Area:	3.32 mi^{2}
Estimated 100-yr Flow*:	2,181 cfs

Culvert Capacity based on FHWA Chart 8

ENTRANCE TYPE: Wingwall 30-70^{o}

Crossing Peak Flow Capacity

Top of Inlet (HW/D = 1.0) =	913 cfs
Top of Road (HW/D = 1.1) =	cfs

Mean Reach Slope: 6.11%

*Value derived from average of Log-Pearson Type III using local stream gage records, normalized by Drainage area

Fish Passage Conditions

Fish Passage Criteria From CA Salmonid Stream Habitat Restoration Manual Chapter IX- DFG

Species or Lifestages	Minimum Water Depth	Prolonged Swimming Mode		Burst Swimming Mode		
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	Maximum Leap Speed
Adult Anadromous Salmonids	0.8 feet	6.0 ft/sec	30 minutes	10.0 ft/sec	5.0 sec	15.0 ft/sec
Resident Trout and Juvenile Steelhead >6"	0.5 feet	4.0 ft/sec	30 minutes	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile Salmonids <6"	0.3 feet	1.5 ft/sec	30 minutes	3.0 ft/sec	5.0 sec	4.0 ft/sec

Fish Passage Design Flows

Design Flow Window Limits	Adult Anadromous Salmonids	Resident Trout and Juvenile Steelhead >6"	Juvenile Salmonids <6"
Lower Passage Flow (Qlp)	3.0 cfs	2.0 cfs	1.0 cfs
Upper Passage Flow (Qhp)	20.3 cfs	3.4 cfs	1.4 cfs

STREAM CROSSING SUMMARY SHEET

Site: Upper Gaviota Creek
Road: State Highway 101

Existing Conditions at Fish Passage Design Flows

Existing Conditions for Culvert Section 1 of 2

Fish Passage Flow Window	Qlp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	3.0	0.07	4.23	0.51
Adult Rainbow Trout	2.0	0.06	3.61	0.55
Juvenile Salmonids	1.0	0.04	2.74	0.60

Fish Species and Age Class	Qhp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	20.3	0.23	9.07	0.18
Adult Rainbow Trout	3.4	0.08	4.46	0.50
Juvenile Salmonids	1.4	0.04	3.13	0.58

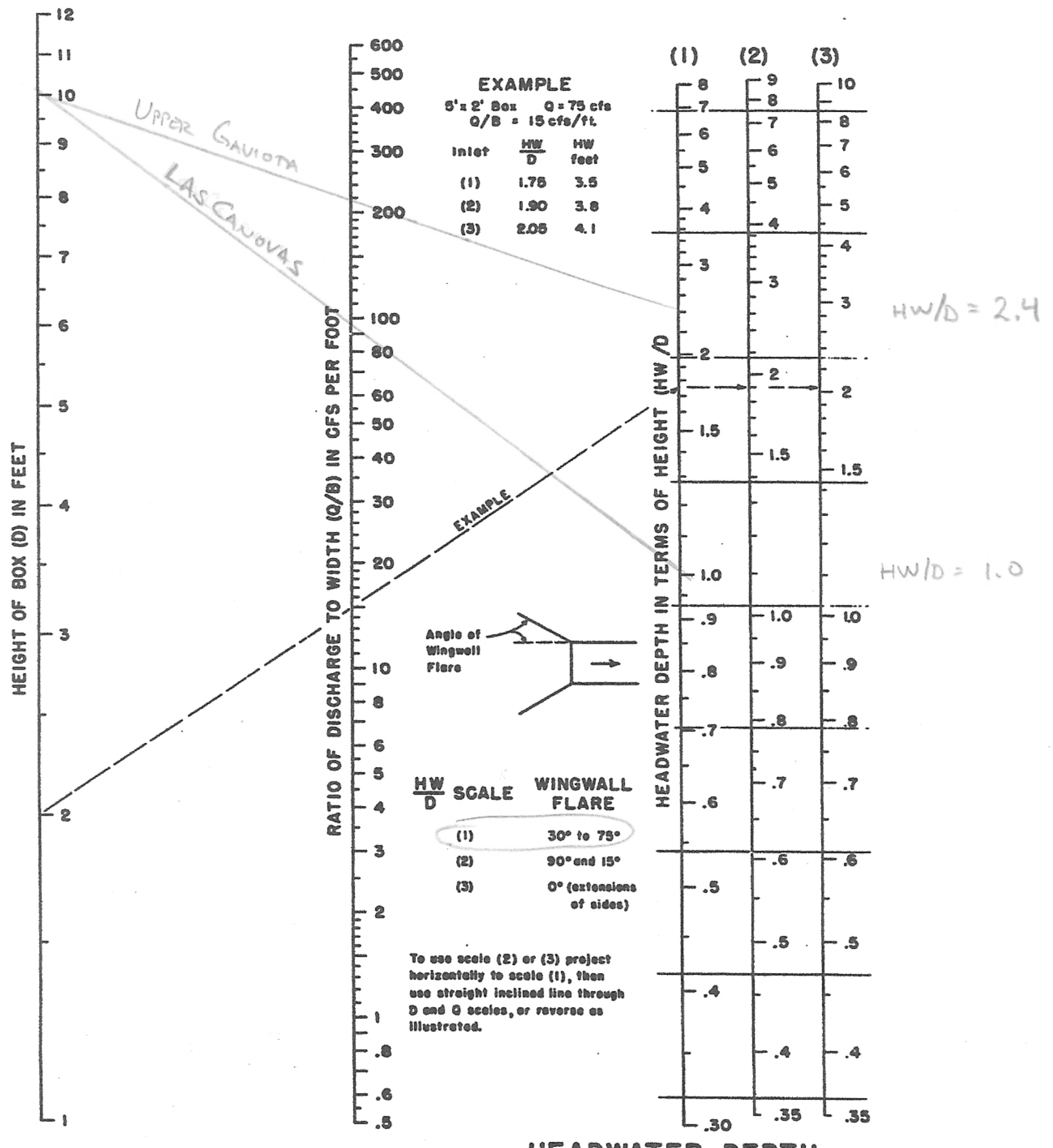
Flows Meeting Fish Passage Criteria

Fishxing Results for Culvert Section 1 of 2

Fish Species and Age Class	Insufficient Depth below	Excessive Velocity above	Excessive Outlet Drop below	Flows Passable between Lower and Upper Fish Passage Flows
Adult Steelhead	151.0 cfs	7.0 cfs	0.0 cfs	0%
Adult Rainbow Trout	74.0 cfs	3.0 cfs	0.0 cfs	0%
Juvenile Salmonids	33.0 cfs	0.0 cfs	15.0 cfs	0%

The Upper Gaviota culvert is a barrier to Adult Steelhead, Adult Resident Trout and Juvenile Salmonids at all flows. While there is a small window of acceptable velocity for Adult Steelhead and Trout, the depth is insufficient for an excessive length.

CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Las Canovas Q/B = 91.3 cfs/ft

Upper Gaviota Q/B = 218.1 cfs/ft

STREAM CROSSING SUMMARY SHEET

Site: Las Canovas Creek
Road: State Highway 101

Existing Conditions at Fish Passage Design Flows

Existing Conditions for Culvert

Fish Passage Flow Window	Qlp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	3.0	0.07	4.53	0.68
Adult Rainbow Trout	2.0	0.05	3.68	0.84
Juvenile Salmonids	1.0	0.04	2.79	1.08

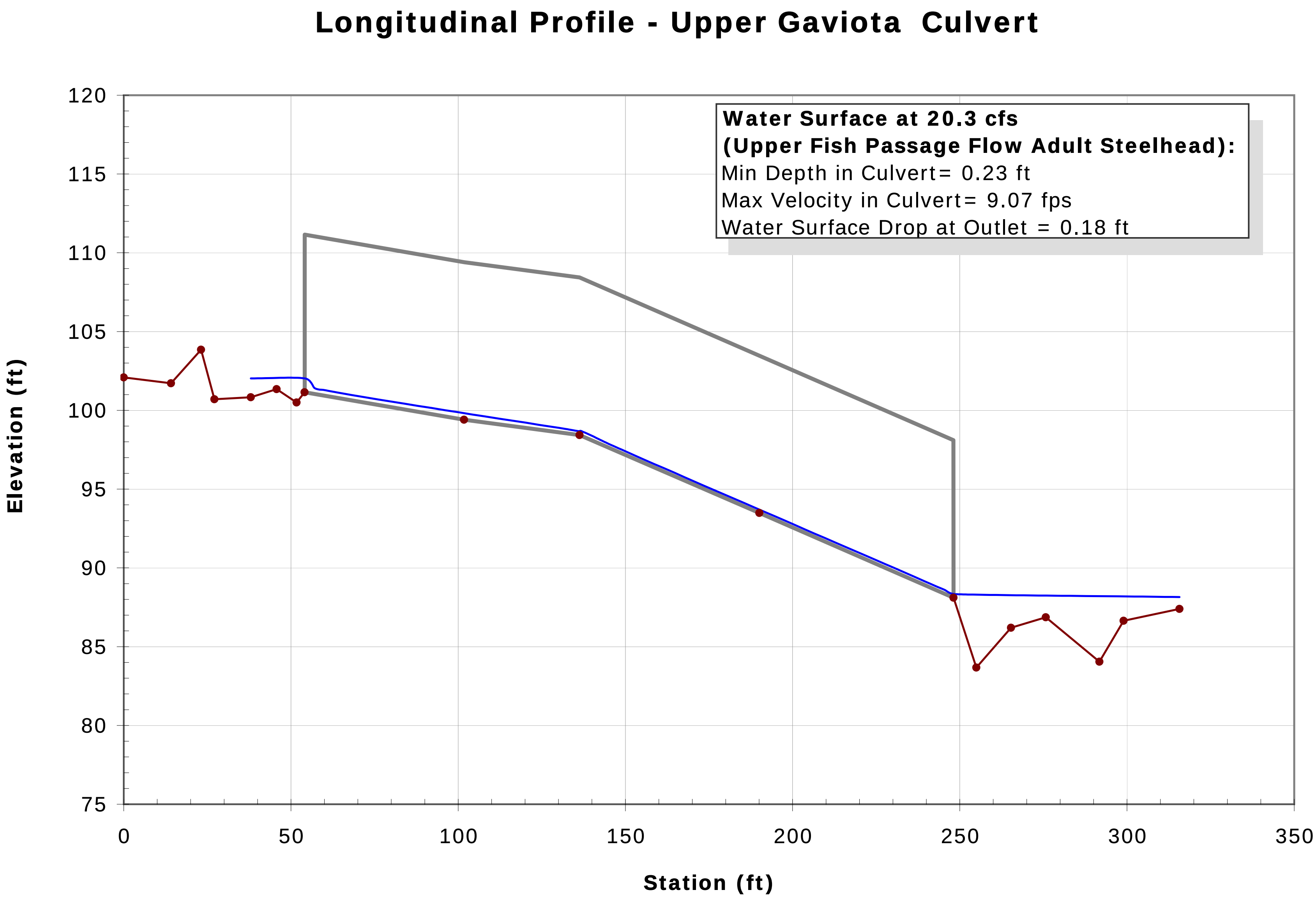
Fish Species and Age Class	Qhp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	8.5	0.13	6.53	0.00
Adult Rainbow Trout	2.0	0.08	4.46	0.84
Juvenile Salmonids	1.0	0.04	2.79	1.08

Flows Meeting Fish Passage Criteria

Fishxing Results for Culvert

Fish Species and Age Class	Insufficient Depth below	Excessive Velocity above	Excessive Outlet Drop below	Flows Passable between Lower and Upper Fish Passage Flows
Adult Steelhead	78.4 cfs	7.1 cfs	-	0%
Adult Rainbow Trout	37.1 cfs	2.4 cfs	2.0 cfs	0%
Juvenile Salmonids	16.2 cfs	0.5 cfs	5.6 cfs	0%

The Las Canovas culvert is a barrier to Adult Steelhead, Adult Resident Trout and Juvenile Salmonids at all flows. While there is a small window of acceptable velocity for Adult Steelhead and Trout, the depth is insufficient for an excessive length.



Longitudinal Profile - Upper Gaviota Culvert
Water Surface at 20.3 cfs
(Upper Fish Passage Flow Adult Steelhead):
Min Depth in Culvert= 0.23 ft
Max Velocity in Culvert= 9.07 fps
Water Surface Drop at Outlet = 0.18 ft
Elevation (ft)
120
115
110
105
100
95
90
85
80
75
0
50
100
150
200
250
300
350
Station (ft)

STREAM CROSSING SUMMARY SHEET

Site: Upper Gaviota Creek
Road: State Highway 101

General Information

Survey Date:	10/14/06
Survey Team:	Love, Llanos, Stoecker
Stream Name:	Upper Gaviota Creek
Land Ownership:	State of California
7.5 Minute Quad Name:	Solvang
Latitude:	34^{o} 31' 3.06"N
Longitude:	120^{o} 13' 3.24"W
Tributary to:	Gaviota Creek

Culvert Information

Shape:	Box
Material:	Concrete
Roughness (n):	0.018
Inlet Type:	Wingwall 30-70^{o}
Outlet Type:	Wingwall 30-70o
Diameter:	10 ft
Bankfull Width:	

Culvert Section 1 of 2

Length:	112 ft
Constant Slope:	9.2%
Residual Inlet Depth:	N/A ft
Residual Outlet Depth:	-0.9 ft
Retrofit:	No

Culvert Section 2 of 2

Length:	82 ft
Constant Slope:	3.3%
Residual Inlet Depth:	-13.8 ft
Residual Outlet Depth:	N/A ft
Retrofit:	No

Hydrology

Drainage Area:	3.32 mi^2
Estimated 100-yr Flow*:	2,181 cfs

Culvert Capacity based on FHWA Chart 8

ENTRANCE TYPE: Wingwall 30-70^{o}

Crossing Peak Flow Capacity

Top of Inlet (HW/D = 1.0) =	913 cfs
Top of Road (HW/D = 1.1) =	cfs

Mean Reach Slope: 6.11%

*Value derived from average of Log-Pearson Type III using local stream gage records, normalized by Drainage area

Fish Passage Conditions

Fish Passage Criteria From CA Salmonid Stream Habitat Restoration Manual Chapter IX- DFG

Species or Lifestages	Minimum Water Depth	Prolonged Swimming Mode		Burst Swimming Mode		
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	Maximum Leap Speed
Adult Anadromous Salmonids	0.8 feet	6.0 ft/sec	30 minutes	10.0 ft/sec	5.0 sec	15.0 ft/sec
Resident Trout and Juvenile Steelhead >6"	0.5 feet	4.0 ft/sec	30 minutes	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile Salmonids <6"	0.3 feet	1.5 ft/sec	30 minutes	3.0 ft/sec	5.0 sec	4.0 ft/sec

Fish Passage Design Flows

Design Flow Window Limits	Adult Anadromous Salmonids	Resident Trout and Juvenile Steelhead >6"	Juvenile Salmonids <6"
Lower Passage Flow (Qlp)	3.0 cfs	2.0 cfs	1.0 cfs
Upper Passage Flow (Qhp)	20.3 cfs	3.4 cfs	1.4 cfs

STREAM CROSSING SUMMARY SHEET

Site: Upper Gaviota Creek
Road: State Highway 101

Existing Conditions at Fish Passage Design Flows

Existing Conditions for Culvert Section 1 of 2

Fish Passage Flow Window	Qlp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	3.0	0.07	4.23	0.51
Adult Rainbow Trout	2.0	0.06	3.61	0.55
Juvenile Salmonids	1.0	0.04	2.74	0.60

Fish Species and Age Class	Qhp (cfs)	Mid Barrel Water Depth (ft)	Mid Barrel Velocity (ft/s)	Outlet Drop (ft)
Adult Steelhead	20.3	0.23	9.07	0.18
Adult Rainbow Trout	3.4	0.08	4.46	0.50
Juvenile Salmonids	1.4	0.04	3.13	0.58

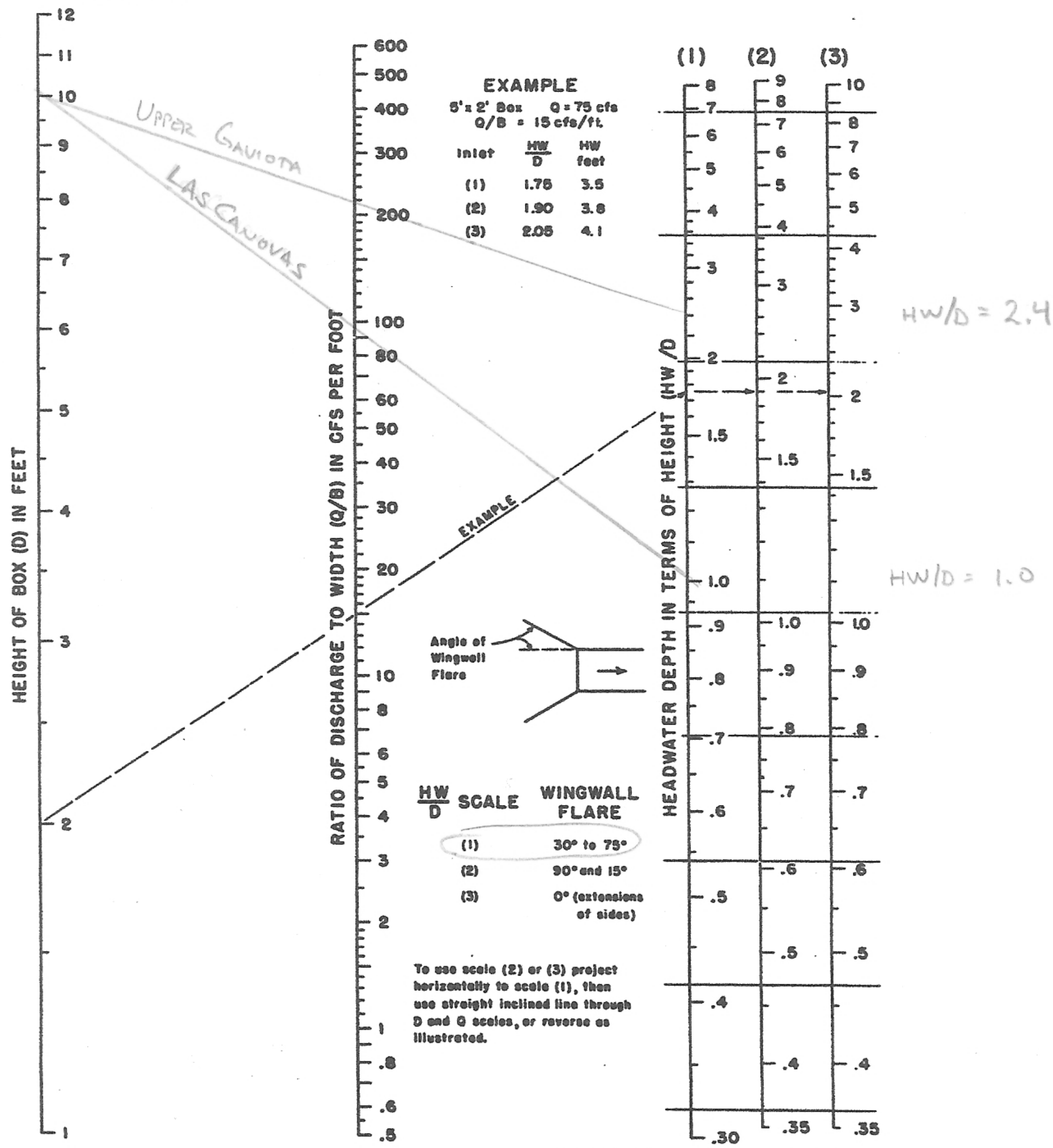
Flows Meeting Fish Passage Criteria

Fishxing Results for Culvert Section 1 of 2

Fish Species and Age Class	Insufficient Depth below	Excessive Velocity above	Excessive Outlet Drop below	Flows Passable between Lower and Upper Fish Passage Flows
Adult Steelhead	151.0 cfs	7.0 cfs	0.0 cfs	0%
Adult Rainbow Trout	74.0 cfs	3.0 cfs	0.0 cfs	0%
Juvenile Salmonids	33.0 cfs	0.0 cfs	15.0 cfs	0%

The Upper Gaviota culvert is a barrier to Adult Steelhead, Adult Resident Trout and Juvenile Salmonids at all flows. While there is a small window of acceptable velocity for Adult Steelhead and Trout, the depth is insufficient for an excessive length.

CHART 8



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Las Canovas Q/B = 91.3 cfs/ft

Upper Gaviota Q/B = 218.1 cfs/ft

APPENDIX B

Hydrologic Calculations

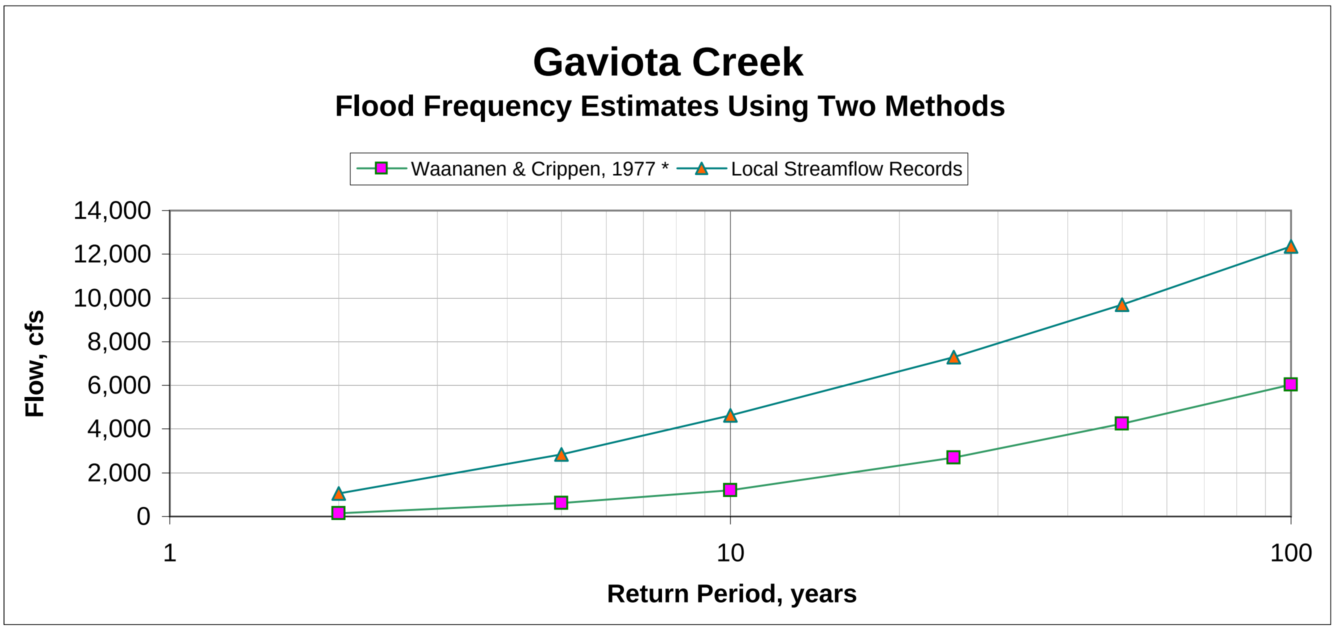
Gaviota Creek

Summary of Peak Flow Calculations

USGS Gage at Gaviota Creek

Drainage Area (mi^2) = **18.8**
Mean Annual Precip. (in/yr) = **20.0**

Method	Q-2yr (cfs)	Q-5yr (cfs)	Q-10yr (cfs)	Q-25yr (cfs)	Q-50yr (cfs)	Q-100yr (cfs)
Waananen & Crippen, 1977 *	148	605	1,210	2,681	4,244	6,033
Local Streamflow Records	1,048	2,843	4,632	7,291	9,684	12,348



* Estimates using regional regression equations developed for the South Coast Region of California by the USGS (Waananen and Crippen, 1977):

South Coast Region (SC)

$Q_2 = 0.14 * A^{0.72} * p^{1.62}$
$Q_5 = 0.40 * A^{0.77} * p^{1.69}$
$Q_{10} = 0.63 * A^{0.79} * p^{1.75}$
$Q_{25} = 1.10 * A^{0.81} * p^{1.81}$
$Q_{50} = 1.50 * A^{0.82} * p^{1.85}$
$Q_{100} = 1.95 * A^{0.83} * p^{1.87}$

A = drainage area (mi2),
p = mean annual precipitation (in/yr),

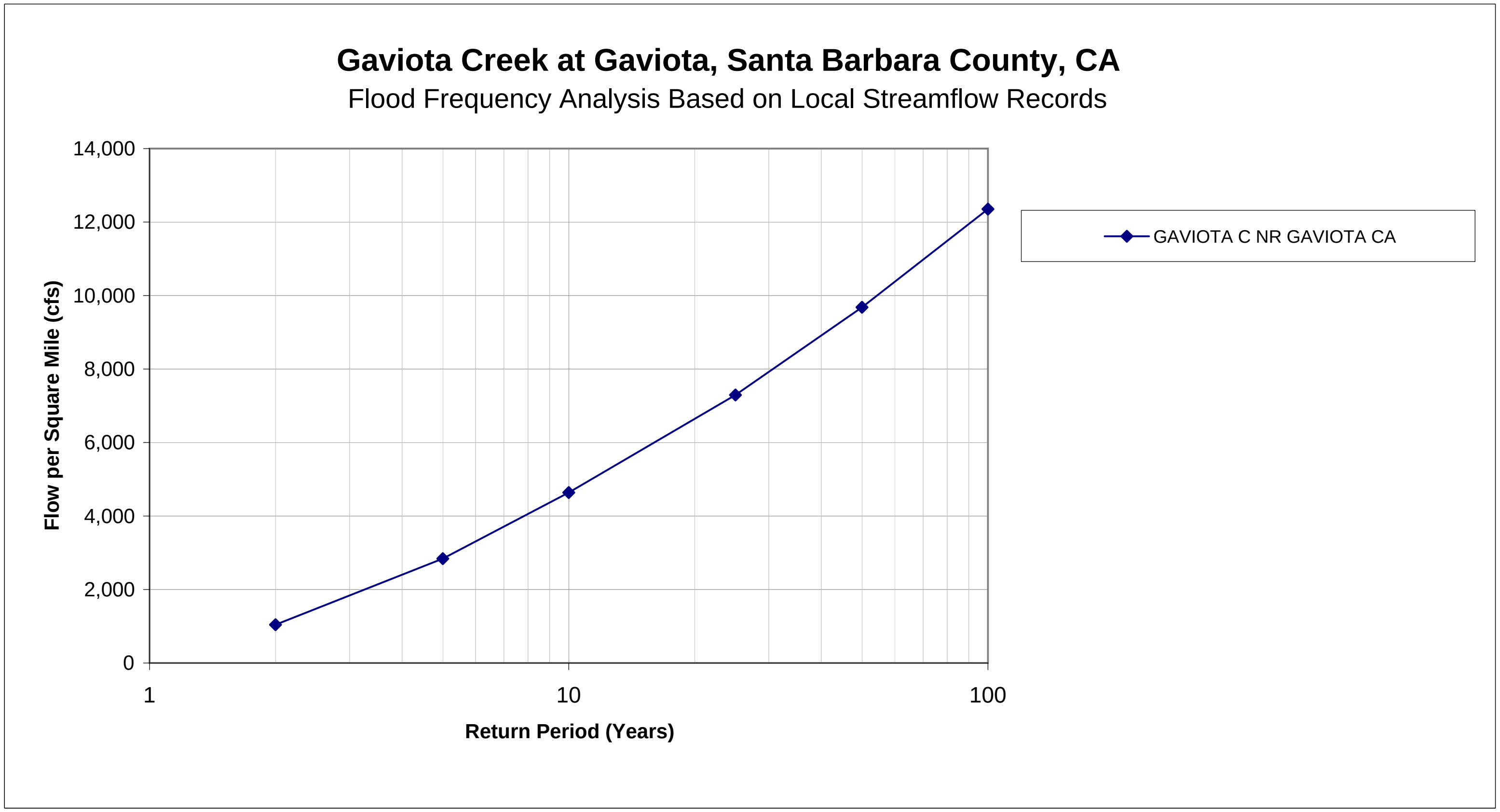
Mean annual precipitation was obtained from Parameter-elevation Regressions on Independent Slopes Model (PRISM). Data set provided by Oregon Climate Service (OCS) mapping program.

Gaviota Creek at Gaviota, Santa Barbara County, CA

Flood Frequency Analysis Based on Local Streamflow Records

Peak flows associated with the 2-yr, 25-yr, 50-yr, and 100-yr recurrence intervals were estimated using a Log-Pearson type III distribution as described in Bulletin 17B (Guidelines for Determining Flood Flow Frequency, USGS, 1982).

Site Name	Location		Drainage Area (mi^2)	Record Length (yrs)	Recurrence Interval of Peak Flows					
					2-yr (cfs)	5-yr (cfs)	10-yr (cfs/mi^2)	25-yr (cfs/mi^2)	50-yr (cfs/mi^2)	100-yr (cfs/mi^2)
GAVIOTA C NR GAVIOTA CA	34°29'16"	120°13'34"	18.8	20	1,048	2,843	4,632	7,291	9,684	12,348



Flood Frequency based on Annual Maximum Series

GAVIOTA C NR GAVIOTA CA

Station # 11120550

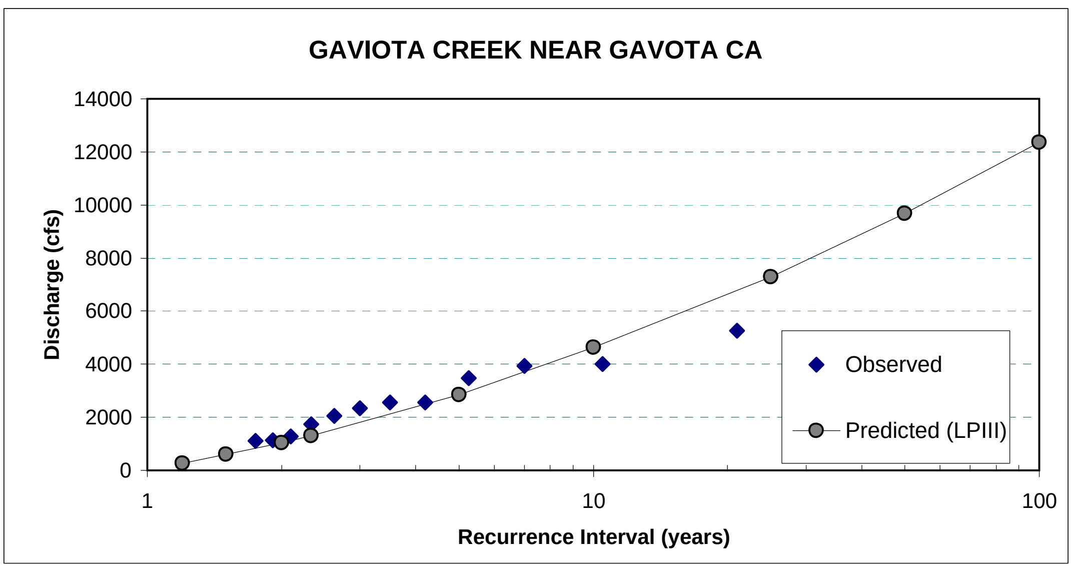
Drainage Area sq. mi 18.80

Location: 34°29'16" 120°13'34" NAD27

WY	Date of Peak	Discharge (cfs)
1967	1/24/1967	4000
1968	3/13/1968	94
1969	2/24/1969	2340
1970	3/4/1970	161
1971	12/21/1970	318
1972	12/27/1971	458
1973	1/18/1973	3940
1974	1/7/1974	1110
1975	12/3/1974	2050
1976	2/10/1976	1730
1977	1/6/1977	96
1978	3/4/1978	3470
1979	3/27/1979	1290
1980	2/19/1980	2560
1981	3/1/1981	1140
1982	4/1/1982	227
1983	1/28/1983	5270
1984	12/25/1983	439
1985	12/19/1984	776
1986	2/14/1986	2560

RANK	Recurrence Interval (years)	Dischage (cfs)	Discharge (cms)	log-discharge (cfs)
1	21.00	5270	149	3.72
2	10.50	4000	113	3.60
3	7.00	3940	112	3.60
4	5.25	3470	98	3.54
5	4.20	2560	72	3.41
6	3.50	2560	72	3.41
7	3.00	2340	66	3.37
8	2.63	2050	58	3.31
9	2.33	1730	49	3.24
10	2.10	1290	37	3.11
11	1.91	1140	32	3.06
12	1.75	1110	31	3.05
13	1.62	776	22	2.89
14	1.50	458	13	2.66
15	1.40	439	12	2.64
16	1.31	318	9	2.50
17	1.24	227	6	2.36
18	1.17	161	5	2.21
19	1.11	96	3	1.98
20	1.05	94	3	1.97

Number of Years, n =	20		
Skewness =	0.86	0.86	-0.55
Mean=	1701	48	2.98
Std Dev=	1532	43	0.55



Peaks Flow Frequency

From USGS Data

Station # 11120550

Generalized Skew=	**-0.30**	A=	-0.28596
Station Skewness (log Q)=	-0.55	B=	0.79686
Station Mean (log Q)=	2.98	MSE (station skew) =	0.29797
Station Std Dev (log Q)=	0.55		
Weighted Skewness (G_W)=	**-0.43**		

Log Pearson Type III Distribution

Return Period (years)	Exceedence Probability	Log-Pearson K	Predicicted Discharge (cfs)
1.2	0.833	-0.98230	274
1.5	0.667	-0.37400	595
2.0	0.500	0.07082	1,048
2.33	0.429	0.24434	1,306
5.0	0.200	0.85546	2,843
10	0.100	1.23915	4,632
25	0.040	1.59573	7,291
50	0.020	1.81887	9,684
100	0.010	2.00984	12,348

Values From K-Table for Linear interpolation

Weighted Skewnes	-0.50	-0.40	-0.43
P	K	K	K
0.9	-1.32309	-1.31671	-1.31838
0.8	-0.80829	-0.81638	-0.81427
0.7	-0.45812	-0.47228	-0.46858
0.6	-0.17261	-0.18916	-0.18484
0.500	0.08302	0.06651	0.07082
0.429	0.25558	0.24037	0.24434
0.200	0.85653	0.85508	0.85546
0.100	1.26180	1.23114	1.23915
0.040	1.56740	1.60574	1.59573
0.020	1.77716	1.83361	1.81887
0.010	1.95472	2.02933	2.00984

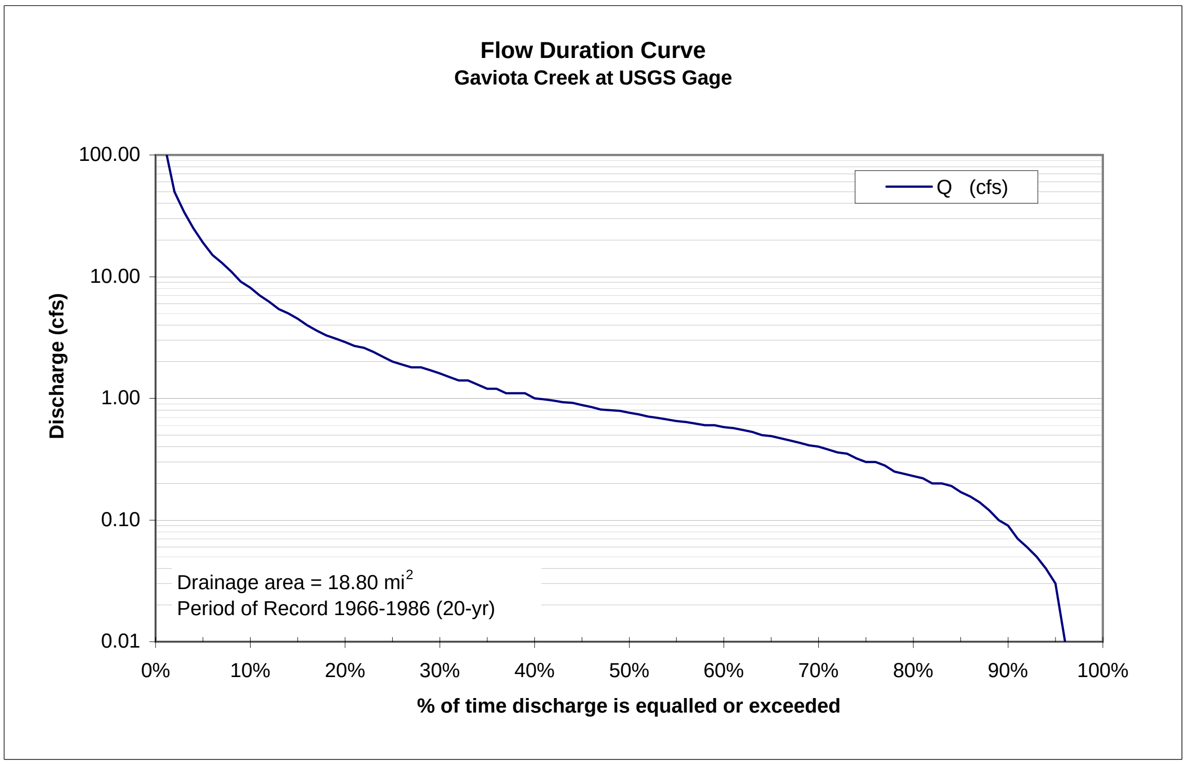
Gaviota Creek

Flow Duration Table and Curve

USGS Flow Gage Summary	
Station Number	11120550
Stream Name	Gaviota Creek
Latitude (ddmmss)	34°29'16"
Longitude (ddmmss)	120°13'34"
Record Length (years)	20
Coverage (WY)	1966-86
Drainage Area (sq. mi)	18.80
MAP (in/yr)	19
Ave Annual Runoff (in)	9.9
Qave (cfs)	13.7

Exceedance*	Q (cfs)
1%	114.96
5%	19.00
10%	8.10
50%	0.76
90%	0.09
95%	0.03

* % of time discharge is equaled or exceeded



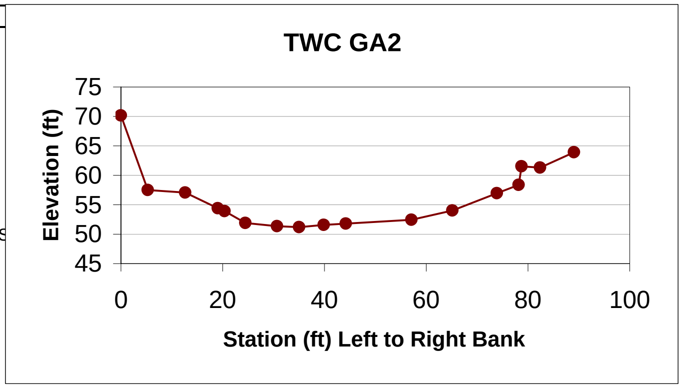
APPENDIX C

Channel Cross Sections

Cross Sections for Grade Controls **Gaviota Creek**
LB > RB Looking upstream

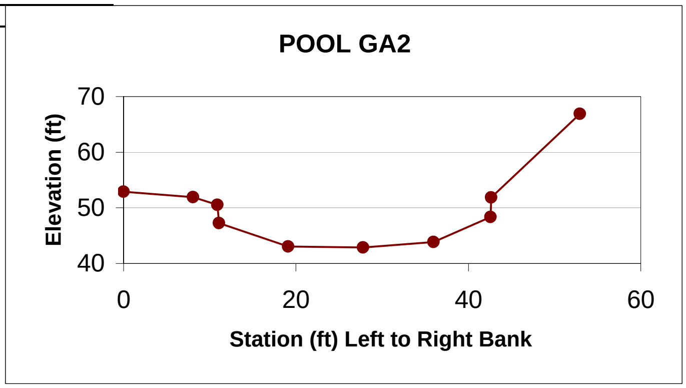
TWC GA 2

Pt	Sta	Elev	Desc
286	0.00	70.19	TOP TR
285	5.29	57.49	?
283	12.62	57.08	HIGH TR
282	19.06	54.39	TOP TR IN THICK WILLOW
281	20.36	53.93	LAC
280	24.45	51.89	LEW
279	30.71	51.39	
278	35.02	51.17	
277	39.87	51.58	
276	44.20	51.81	REW GRAVEL COBBLE, SOME BLDRS
275	57.14	52.47	
274	65.15	54.01	
273	73.89	56.93	TOE SAC
272	78.15	58.35	TOP SAC
271	78.73	61.52	
270	82.42	61.30	
269	89.04	63.90	TOE RB CONC WALL



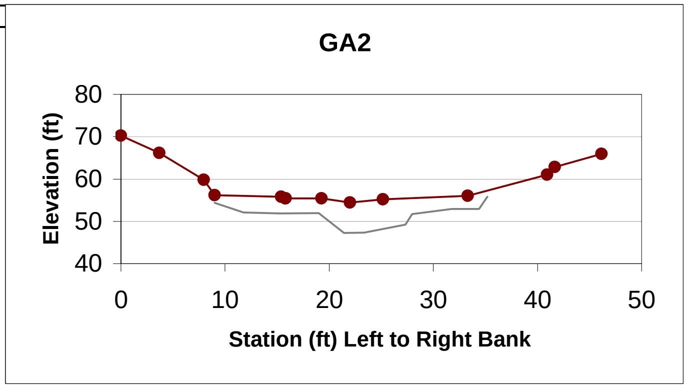
Pool at GA2

Pt	Sta	Elev	Desc
359	0.00	52.92	LAC BDRX
343	8.07	51.89	LEW
344	10.87	50.55	POOL LB TO RB
345	11.08	47.28	
346	19.10	43.08	
347	27.79	42.88	
348	35.97	43.84	
349	42.57	48.33	BLDR DROP OFF
350	42.66	51.88	REW
351	52.95	66.91	RB RSP



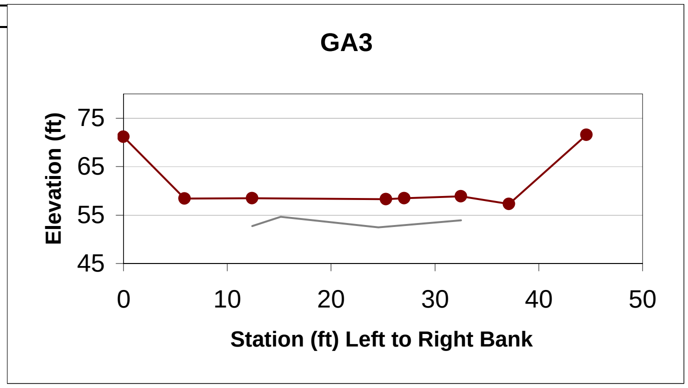
GA2

Pt	Sta	Elev	Desc
297	0.00	70.23	CONC WEIR
296	3.69	66.17	TOP RB
295	7.97	59.81	GS RB
294	8.99	56.16	GS RB
298	15.40	55.82	CONC WEIR
299	15.79	55.45	CONC WEIR
300	15.84	55.44	CONC WEIR
301	19.27	55.41	CONC WEIR
302	22.01	54.47	CONC WEIR
303	25.17	55.16	CONC WEIR
304	33.31	56.05	CONC WEIR
305	40.93	61.04	GS SAC
306	41.67	62.85	GS SAC
307	46.16	65.94	GS
324	8.99	54.40	BEDROCK
323	11.78	52.10	TOE BEDRX
322	15.29	51.85	COBBLE ON BDRX
321	19.00	51.97	BDRX
320	21.42	47.22	POOL
319	23.35	47.36	SPILLWAY
318	27.31	49.20	POOL
317	27.98	51.74	CONC RUBBLE
316	31.77	52.91	CONC RUBBLE
315	34.39	52.97	TOE BELOW WEIR
314	35.17	55.84	DS WEIR IN POOL LB



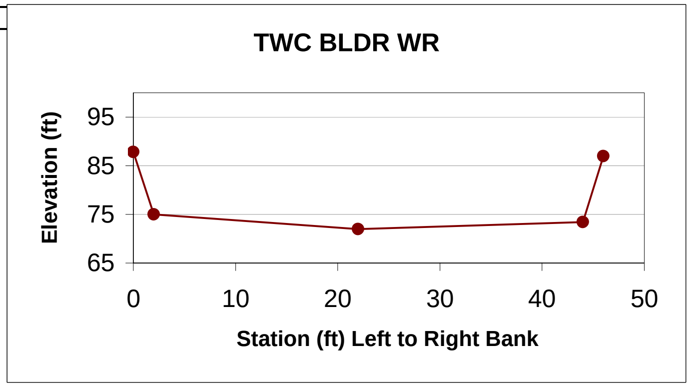
GA3

Pt	Sta	Elev	Desc
394	0.00	71.16	BDRX
393	5.90	58.43	TOE AT BDRX
392	12.39	58.48	CONC
390	25.29	58.24	SPILLWAY
389	27.06	58.47	LEW
388	32.51	58.89	TOE RSP
391	37.14	57.31	REW
386	44.61	71.57	GC2 RB TO LB TOE RSP
396	12.39	52.70	GS D/S OF GC2
397	15.13	54.64	GS D/S OF GC2
398	24.55	52.49	GS D/S OF GC2
399	32.51	53.93	GS D/S OF GC2



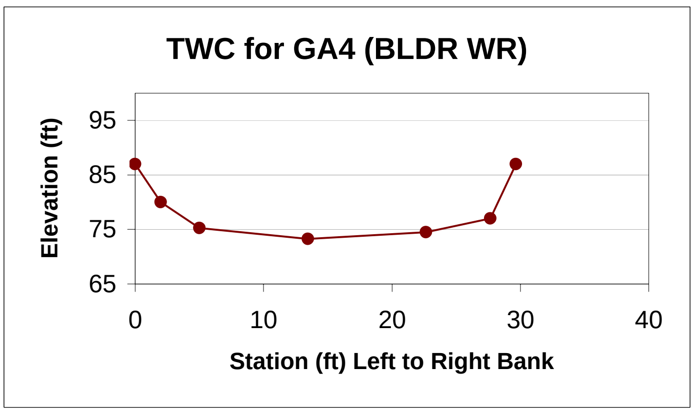
TWC BLDR WR

Pt	Sta	Elev	Desc
0	0.00	87.80	RD
0	2.00	75.00	BLDR
0	22.00	71.96	Conc
0	44.00	73.40	Conc
0	46.00	87.00	TR



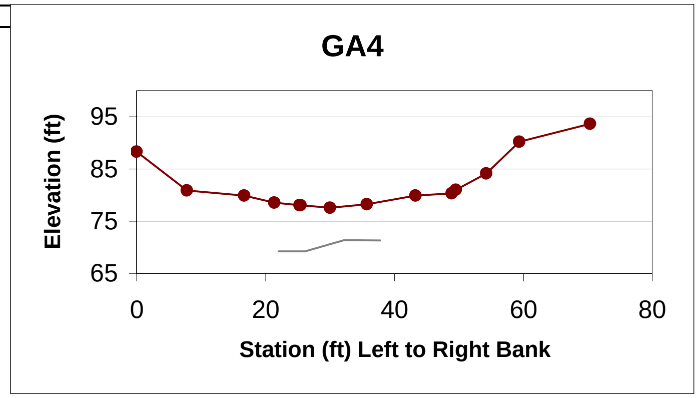
TWC for GA4 (BLDR WR)

Pt	Sta	Elev	Desc
0	0.00	87.00	TR
0	2.00	80.00	RB BLDR
453	5.00	75.26	TOP RB BOULDER WEIR
452	13.47	73.27	TH TOP BOULDER WEIR W/4-5 TON BLDR
456	22.66	74.51	LEFT
0	27.66	77.00	LEFT
0	29.66	87.00	RD



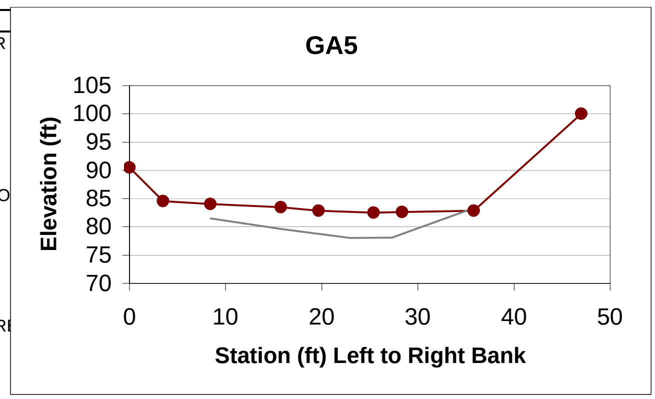
GA4

Pt	Sta	Elev	Desc
479	0.00	88.30	DS SIDE GA 4 TOP LB
480	7.80	80.91	LB CONC
481	16.68	79.91	CONC
482	21.35	78.56	BLDR
483	25.27	78.05	CONC DAM TOP
484	25.45	78.04	CONC
485	30.03	77.58	SPILLWAY
486	35.74	78.24	CONC
487	43.26	79.90	CONC
488	48.91	80.32	END CONC, TOE SAC
489	49.55	80.99	SAC
490	54.27	84.13	SAC
491	59.36	90.21	TOP SAC
492	70.37	93.60	EOP
494	22.00	69.22	POOL
495	26.14	69.23	POOL
496	32.21	71.40	POOL
497	37.83	71.32	POOL



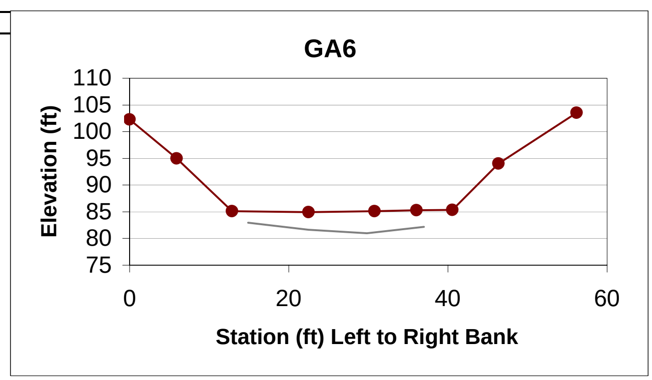
GA5

Pt	Sta	Elev	Desc
536	0.00	90.52	TOP BLDR RB LR, TOP IS 4' OVER
535	3.50	84.58	BLDR LB
533	8.44	84.04	BLDR
532	15.74	83.45	CONC AT BLDR KEY
531	19.69	82.87	CONC
530	25.40	82.54	CONC
529	28.36	82.64	CONC
528	35.83	82.86	DS GC4 LB TOE SAC, USE PREVIO
	47	100	EOP Faked
541	8.44	81.52	RB TOE
540	15.78	79.66	
539	22.94	78.06	
538	27.30	78.10	
537	35.05	82.83	DS TOE XS GC4 IN POOL LB TO RI



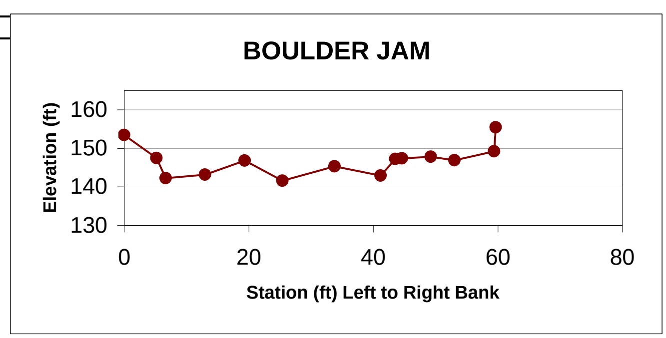
GA6

Pt	Sta	Elev	Desc
590	0.00	102.30	DS LIP GC5 LB ON SLOPE
591	5.93	94.97	TOP XPOSED BDRX
592	12.88	85.11	RB GC6
593	22.50	84.92	TH
594	30.80	85.08	BLDR EDGE CONC
596	36.07	85.29	TOP BLDR IN CONC
597	40.58	85.34	TOE GC5
598	46.34	94.00	TOP SAC
599	56.19	103.56	TOP EOP
600	14.88	82.93	LB TOE IN POOL
601	22.44	81.67	TH TOE
602	29.82	80.95	TOE DS GC5 POOL
603	37.00	82.19	TOE INTERSECTION WITH SAC



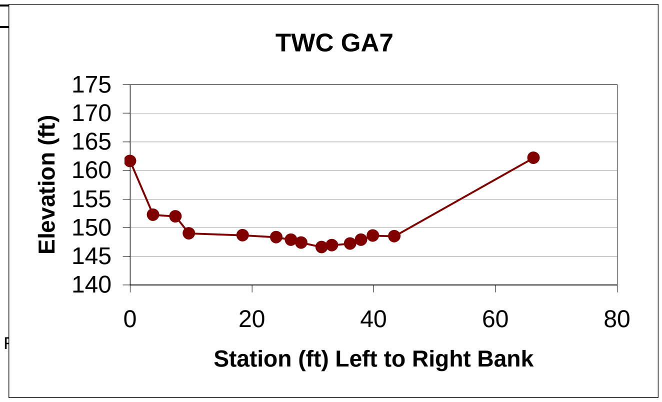
BLDR JAM

Pt	Sta	Elev	Desc
729	0.00	153.51	BLDR TOP LB
728	5.17	147.53	BLDR
727	6.66	142.27	BLDR
726	12.98	143.23	NOTCH LOW POINT IN JAM
725	19.36	146.80	TOP BLDR
724	25.43	141.63	?
723	33.80	145.38	?
722	41.16	142.91	
721	43.53	147.26	
720	44.61	147.45	TOP BLDR
719	49.26	147.85	TOP HIGHEST BLDR (8')
718	53.05	146.88	CONC HITS BLDR
717	59.40	149.23	TOE WALL
715	59.64	155.47	TOP VERT RB CONC WALL



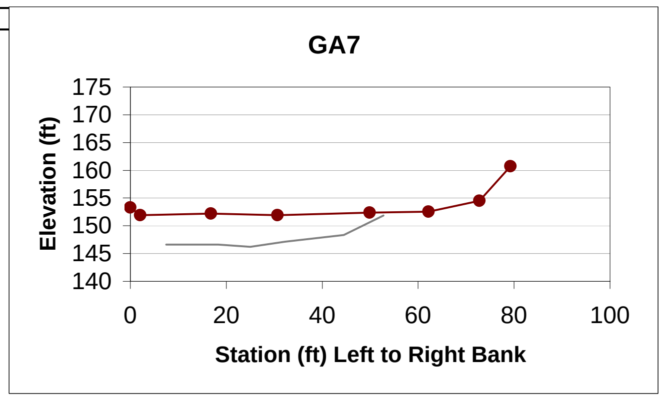
TWC GA7

Pt	Sta	Elev	Desc
769	0.00	161.63	ALMOST TOB
768	3.76	152.27	BLDR TOE BANK
767	7.49	151.97	BLDR
766	9.66	148.98	LAC WILLOW
765	18.51	148.66	WILLOW
764	24.02	148.32	BLDR
763	26.41	147.90	LEW BLDR
762	28.13	147.37	BLDR
761	31.51	146.58	GRAVEL TH
760	33.18	146.94	GRAVEL
759	36.15	147.24	GRAVEL
758	37.97	147.88	REW
757	39.90	148.61	GRAVEL
756	43.41	148.51	RAC SAND
755	66.29	162.21	TW GC6 LB RSP 8' OVER AND UP TO



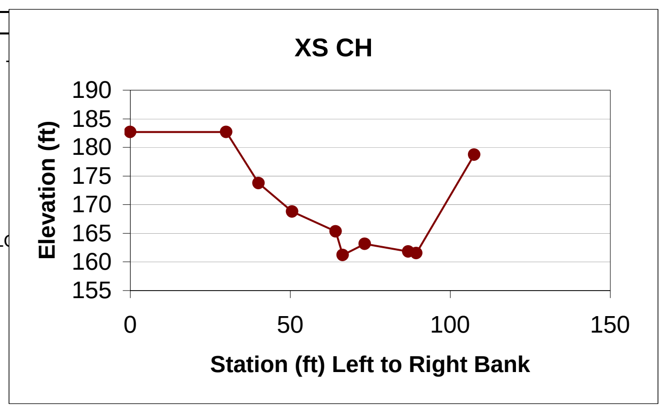
GA7

Pt	Sta	Elev	Desc
778	0.00	153.31	CONC LT WR
777	2.05	151.91	
776	16.84	152.19	CONC
775	30.68	151.94	DS EDGE GC6
774	49.92	152.40	CONC PK NAIL
773	62.18	152.56	CORNER CONC
772	72.76	154.50	
771	79.28	160.71	RB GC6
782	7.50	146.60	DS GC 6
783	18.33	146.63	DS GC 6
784	24.99	146.21	SPILLWAY TH D=1.5'
785	32.24	147.13	
786	37.50	147.64	1' TO LEFT TO TWO 9" IRON PIPES
787	44.47	148.36	GS GC
788	52.80	151.88	GS GC



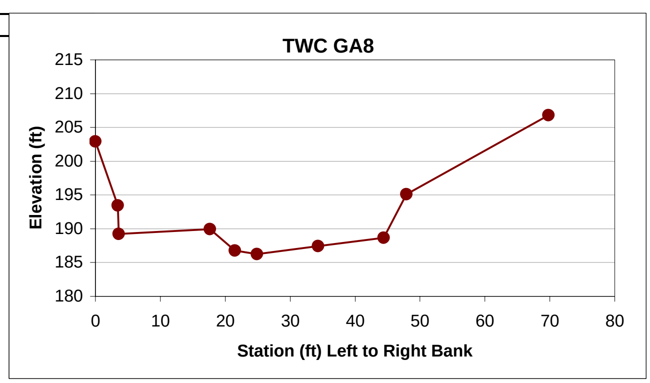
XS CH

Pt	Sta	Elev	Desc
	0	182.67	to EOP
830	30.00	182.67	TOP FILL SLOPE GOES LEVEL FOR 30'
829	40.10	173.73	TOE FILL SLOPE
828	50.61	168.79	LAC
827	64.16	165.32	TOP ROOT
826	66.37	161.18	TOE LARGE ALDER
825	73.34	163.17	GRAVEL BAR
824	86.86	161.79	TH
823	89.41	161.55	TOE SAC
822	107.51	178.74	TOP SAC FILL SLOPE RD 5' AT 1:1 SLO



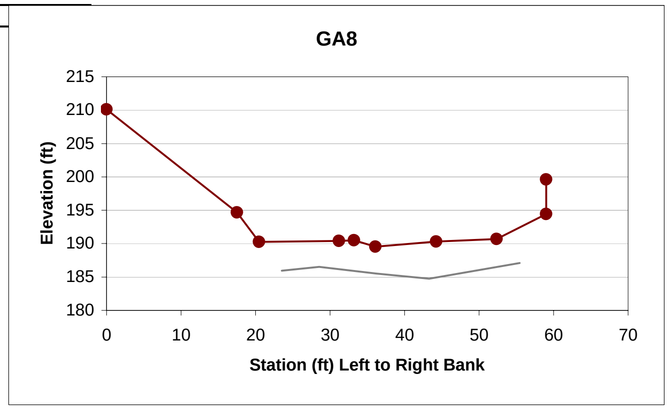
TWC for GA8

Pt	Sta	Elev	Desc
902	0.00	202.93	LB BDRX 6' UP TO ROAD
901	3.47	193.44	US END RSP
900	3.58	189.24	LAC
899	17.65	189.94	TOP BLDR
898	21.50	186.77	BLDR TOE
897	24.91	186.27	TH D=0.5
896	34.32	187.43	CH
894	44.42	188.66	RAC
893	47.91	195.10	RB BLDR
892	69.78	206.79	TWC FOR GC7 RB NID SLOPE BLDR



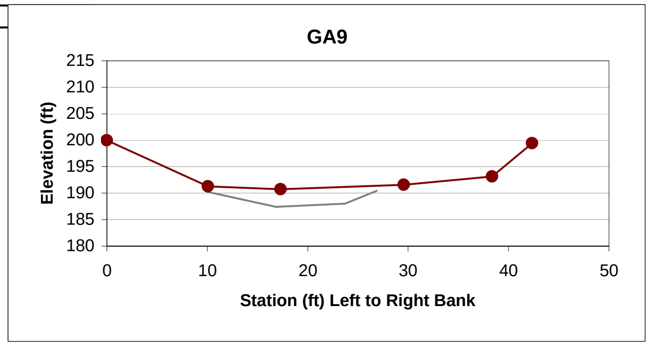
GA8

Pt	Sta	Elev	Desc
903	0.00	210.09	US SIDE OF GC7 TOP ROAD FILL EOP
904	17.50	194.66	TOP SAC
905	20.48	190.27	TOE SAC US EDGE GC
906	31.20	190.41	RT SIDE BLDR IN WR
907	33.20	190.51	CNTR BLDR STICKS UP 2.5 '
908	36.10	189.55	
909	44.27	190.31	TH D=2.5
910	52.38	190.70	LT GC
911	59.02	194.43	LAC
912	59.03	199.61	LB UP TO RD 30' AT 1:1 SLOPE
920	23.50	185.94	DS GC7 IN POOL RB
921	28.55	186.54	DS GC7 IN POOL
922	36.23	185.53	DS GC7 IN POOL
923	43.28	184.76	DS GC7 IN POOL
924	55.43	187.11	RAC DS OF GC7 IN POOL



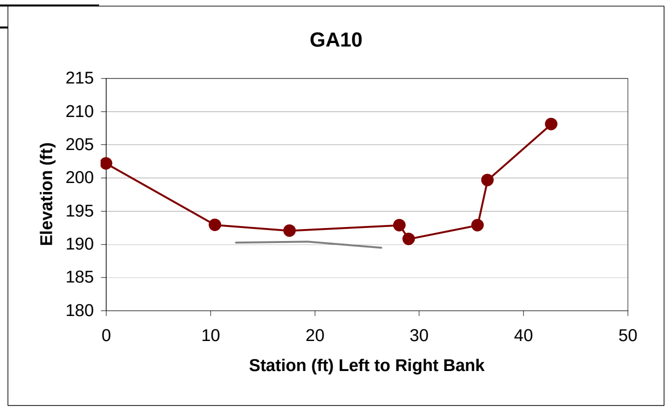
GA9

Pt	Sta	Elev	Desc
940	0.00	200.00	LB TOP SAC RD 10' UP 1:1 SLOPE
941	10.06	191.31	LT EDGE GC8 US
942	17.31	190.76	TH
943	29.59	191.58	RT GC8
944	38.36	193.14	RAC
946	42.34	199.44	LB SLOPING HILL
950	10.00	190.24	TOE SAC RT SIDE
949	16.83	187.41	DS EDGE GC8
948	23.71	188.03	DS EDGE GC8
947	26.87	190.42	DS LT EDGE GC8



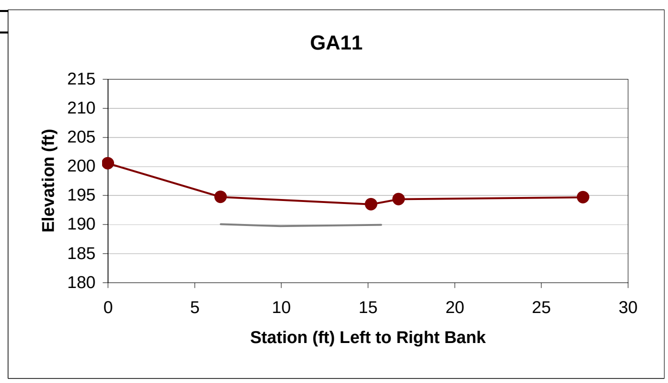
GA10

Pt	Sta	Elev	Desc
964	0.00	202.16	LB TOP SAC
965	10.43	192.92	TOE SAC EDGE GC
966	17.59	192.05	CL FL GC
967	28.13	192.90	EDGE CONC GC LB
968	29.01	190.79	DROP EGDE CONC
969	35.59	192.88	RAC
970	36.56	199.67	ROCK WALL RB
971	42.65	208.09	ROCK WALL LB 12' TO TOP
974	12.43	190.28	GS TOE SAC
973	19.30	190.39	GS DS GC CL TH
972	26.37	189.48	GS DS GC LB TO RB



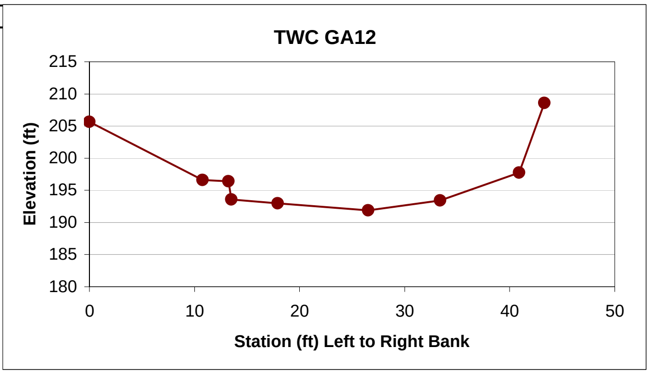
GA11

Pt	Sta	Elev	Desc
1012	0.00	200.52	DS END GC SAC LB
1014	6.50	194.75	TOE SAC LAC
1015	15.18	193.49	CL GC
1016	16.78	194.36	GC
1017	27.41	194.72	RT EDGE CONC
1021	6.50	190.08	TOE DS GC
1020	9.94	189.73	2.5 DS GC
1019	15.77	189.96	TH



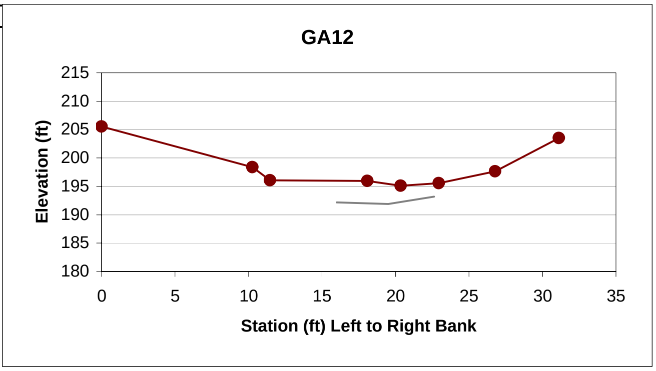
TWC GA12

Pt	Sta	Elev	Desc
1022	0.00	205.66	LB TOP SAC
1024	10.76	196.62	TOE SAC
1025	13.23	196.39	TOP FOOTING
1026	13.51	193.55	TOE RAC
1027	17.92	192.95	TH D=1'
1028	26.54	191.90	CH
1029	33.39	193.45	CH
1030	40.90	197.74	RAC
1031	43.32	208.58	RB VERT CLIFF



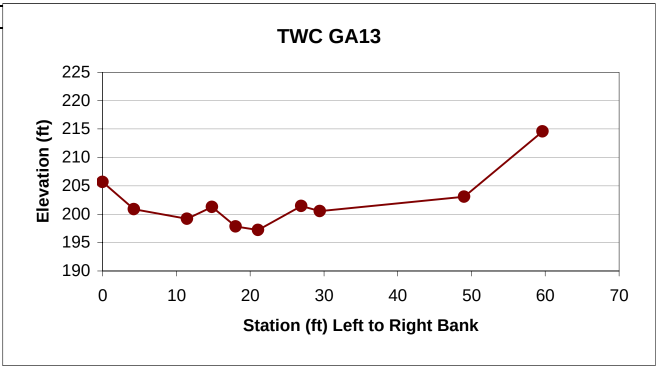
GA12

Pt	Sta	Elev	Desc
1032	0.00	205.55	TOP SAC LB
1034	10.26	198.40	TOE SAC
1035	11.46	196.09	LT EDGE WR
1036	18.09	195.94	GC
1037	20.36	195.11	SPILLWAY TH
1038	22.94	195.56	GC RIGHT EDGE
1039	26.79	197.65	TOP BLDR
1040	31.11	203.48	ON SLOPE
1043	16.00	192.18	DS GC LT
1042	19.51	191.89	DS GC CENTER
1041	22.61	193.18	DS GC RT



TWC GA13

Pt	Sta	Elev	Desc
1083	0.00	205.69	BDRX GOES UP 12' AT 1:1 SLOPE TO
1084	4.24	200.89	BDRX
1085	11.45	199.18	BDRX
1086	14.82	201.28	BDRX
1087	18.02	197.83	BDRX
1088	21.06	197.21	TWC
1089	26.92	201.43	BDRX
1090	29.45	200.57	GRAVEL BAR
1091	49.03	203.07	TOE LB
1092	59.63	214.59	ON SLOPE



GA13

Pt	Sta	Elev	Desc
1068	0.00	216.32	LB BDRX SLOPE
1069	5.34	210.43	BDRX
1070	15.34	206.15	BDRX
1071	20.96	202.57	LT WR
1074	42.02	202.56	RT DS EDGE, TOE SAC
1075	50.09	200.77	TOP SAC
	60.00	210.00	fake
1080	21.00	194.18	DS RT EDGE OF GC AND TOE SAC
1079	25.23	194.38	DS GC
1078	29.69	194.00	DS GC
1077	34.72	195.69	DS GC
1076	39.28	196.72	LT DS GC