ADULT STEELHEAD PASSAGE FLOW ANALYSIS FOR THE SANTA YNEZ RIVER

Prepared for:

SANTA YNEZ RIVER CONSENSUS COMMITTEE
Santa Barbara, California

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SANTA YNEZ RIVER TECHNICAL ADVISORY COMMITTEE
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Cachuma Member Unit Exhibit No. 226(c)

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1.0
INTRODUCTION

Upstream migration is a critical event in the steelhead lifecycle. Steelhead, like the other anadromous salmonids, are born in freshwater and live there for generally one or two years before migrating to sea. While at sea they grow to sexual maturity and then return to the stream in which they were born to spawn. If passage from the ocean to their spawning grounds is prevented, the steelhead cannot complete its lifecycle and spawn the next generation. When this happens the fish may spawn in another stream or wait for another year to spawn. Fortunately, the lifecycle of steelhead is much more flexible than it is for other salmonids. Unlike salmon that die after spawning, steelhead are capable of spawning several times (in different years) under the right conditions (Shapovalov and Taft 1954).

In the Santa Ynez River, access to the river can be affected by the sand bar which forms at the river's mouth in most years, or by shallow riffles in more upstream areas. Like most southern California coastal rivers, the mouth of the Santa Ynez River can be closed off each year by the formation of a sandbar across its mouth. The sandbar is formed by long-shore drift of sand created by the California current, and by wave and tidal action. During some portions of the year, the bar may be breached when flow from the river fills the lagoon, overtopping the barrier causing it to breach. These flows do not occur in all years, however. Upstream passage barriers may consist of a variety of physical features that may partially or completely block passage for adult steelhead. These barriers might consist of drops or falls which are too high for fish to leap, of areas where the flow is too shallow to allow fish to swim past. This report focuses on the relationship of mainstem flow and passage opportunities in the Santa Ynez River from the upper portion of the lagoon to Bradbury Dam.

1.1 PREVIOUS STUDIES

Potential passage impediments have been investigated by several previous studies. Habitat surveys that identified potential passage barriers were conducted in the portion of the river between Lompoc and Buellton by DWR and Thomas R. Payne in 1991 (unpublished data, T. R. Payne and Associates) and between Buellton and Bradbury Dam by ENTRIX, Inc. in 1994 (ENTRIX 1995). Neither of these surveys found any velocity barriers in the mainstem river, but areas with insufficient depth for upstream migration were observed. These barriers were usually related to shallow riffles or gravel bars, and not to permanent hydrological features (i.e., bedrock sills, weirs, etc.). A second potential passage problem identified was the numerous beaver dams observed in the Lompoc area. In wet years, steelhead can generally get around, over, or through beaver dams and steelhead are common in rivers and streams where beaver are numerous. In dry years, the presence of beaver dams may inhibit upstream migrations by steelhead.

Some previous work on evaluating the amount of water needed in the mainstem river to provide passage was evaluated in the environmental assessment for the Cachuma Contract Renewal (Woodward-Clyde Consultants, 1995). This evaluation relied on data collected from Buellton and upstream areas for the habitat assessment using the Instream Flow Incremental Method. Transects placed in riffle habitats were used to determine physical conditions (depth, velocity, and top width of the channel) present at various flow levels. Riffles were selected for evaluation because they represent the shallowest habitat type and thus would most likely represent the low flow passage barriers that were identified during habitat mapping. Those riffles in the segment below Refugio Road were evaluated because the river was wider in this area than above Refugio Road, and hence would be shallower and would represent the most critical passage areas. A modification of the upstream passage criteria for salmon and steelhead developed by Thompson (1972) was used to determine when conditions were appropriate for passage. In this modification, the 10 and 25 percent width suggested for passage are allied to the wetted width of the channel, rather than the length of the transect from headpin to headpin. These studies indicated that a minimum flow of 25 cfs was required to allow adult steelhead to migrate upstream.

2.0
METHODS

2.1 TRANSECT PLACEMENT

In 1995, as part of the Long-term Study Plan (Job 2) the SYRTAC conducted additional studies specifically designed to address the passage issue (SYRTAC 1996). Ms. Kris Vyverberg, a geomorphologist for the California Department of Fish and Game, conducted geomorphic surveys of the river to identify areas where critical passage riffles were likely to be relatively persistent. After these areas were identified, 10 transects were located in identified critical riffles located between Lompoc and the area just upstream of Refugio Road. One of these transects (Alisal 2) could not be calibrated and was dropped from the analysis. Two additional transects were placed in the Alisal reach in 1997 to supplement the analysis. These transects were selected by Mr. Larry Wise, a fisheries biologist with ENTRIX, Inc. Each transect was marked with rebar or fence posts to allow for easy relocation during data collection.

2.2 SITE DESCRIPTIONS

Transects were placed in four areas of the Santa Ynez River where access to the river could be obtained from local land-owners: River Park in Lompoc, Cargasachi Ranch, Alisal Bridge near Buellton, and the Upper Refugio Area near Solvang. Brief descriptions of these areas are provided below.

The River Park Area was located in Lompoc between Floradale Bridge and Hwy 246. The channel form in this transect area is characterized by poorly defined braided channels (multiple thread channel) in an overly wide and shallow reach (150 to 350 feet wide by several inches to several feet deep) with a sand-sized substrate.

The Cargasachi Ranch Area is located between Hwy 246 and Santa Rosa Creek about 24 miles downstream of Bradbury Dam. Sediment tends to deposit in this area and substrate is mainly composed of highly embedded gravel. The active channel ranges from 50 to 200 ft wide and is characterized by bar complexes with flatwater areas being less abundant. Streamflow is generally in a single thread, although some braiding takes place at the downstream end of the reach. Habitat is dominated by long, shallow, runs, glides and riffles.

The Alisal Bridge Area is located near Buellton between Hwy 101 and Alisal Road (at Solvang). The channel form in this transect area is characterized by a coarse generally imbedded or cemented gravel substrate and an active typically single thread channel periodically split into two or more channels by large channel-spanning transverse or mid-channel gravel bars. The active channel varies from 80 to 200 feet in width and meanders across a broad flood plain 500 to 800 feet wide.

The Upper Refugio Area is located near the town of Santa Ynez upstream of Refugio Bridge and Gainey Crossing. The channel form in this transect area is generally characterized by a single thread channel 100 to 200 feet wide and intermittently split by mid-channel gravel bars. The channel has a fine to coarse grained substrate and is confined by large, coarse grained longitudinal gravel bars within which the active channel gently meanders.

The transect locations were selected in areas where geomorphic features indicate that riffles are constant over time. The analysis assumes that similar passage problems are present each year; that is, there may be insufficient depth over some riffles. Although the bed profiles at the individual transects may change somewhat, the hydraulic characteristics of the riffles remain similar. The riffles selected are assumed to represent a typical problem riffle. This concept is termed a state of "dynamic equilibrium" (Morhardt *et al*., 1983).

2.3 DATA COLLECTION

After placement of the cross-sectional profile transect, each transect was surveyed using standard surveying techniques. Elevations of the head pins and water surface were determined within 0.03 ft. Hydraulic data were collected for at least 20 verticals across each transect to describe the depth and velocity distribution at each study flow. Water surface elevations and hydraulic data were collected at 3 flows at each transect. The flows at which data were collected varied with stream reach and when the information was collected. At the Refugio and Alisal sites, data were collected at approximately 40-200 cfs, except that the data on the additional transects at Alisal were collected at flows of 10 to 35 cfs.

2.4 ANALYTICAL METHODS

To determine the suitability of transects for passage of adult steelhead during their upstream migration, all transect data were entered into single flow IFG-4 models. This allowed us to model depth and velocity at flows ranging from 5 to 100 cfs. The resulting depths and velocities for each cell on each transect were evaluated to determine the flow that would allow steelhead to pass upstream. To conduct this analysis we used several sets of passage criteria based in part on Thompson's (1972) passage criteria for adult steelhead.

Based on work conducted in Oregon, Thompson (1972) defined passage criteria for steelhead as a depth of greater than 0.6 feet over 25 percent of the wetted channel width, with at least 10 percent being contiguous, and velocities of less than eight feet per second. These conditions would provide excellent conditions for passage, however, in southern California rivers, these passage conditions often do not exist under unimpaired flows, yet fish still manage to migrate upstream in these systems. We evaluated the criteria to determine what the critical elements were relative to allowing passage. The two elements of Thompson criteria are the width of portion of the channel meeting the passage requirements and the depth at which fish can pass. We determined that adult steelhead passage was achieved with less than 25% of contiguous stream channel width.

Adult steelhead are commonly observed in very small streams with total widths of less than 10 ft. We determined passage flows based on widths of 3 ft, 5 ft and 8 ft of contiguous channel and relative widths of 10% and 25% of the wetted channel. We also looked at the depth criteria developed by Thompson. Thompson found that water 0.6 ft deep provided excellent passage conditions. In smaller streams, steelhead and other Pacific salmon have also been frequently observed moving upstream through riffles so shallow that their backs emerge from the water. To evaluate the sensitivity of the analysis to depth criteria, we determined the flows that would be required to achieve passage using two different depth criteria: 0.6 ft and 0.5 ft.

3.1 PASSAGE FLOWS

Flow levels needed to meet the passage criteria varied among the transects and with criteria. In general, passage criteria are met at most transects if flows are between 10 and 30 cfs (Table 1). The minimum passage flow at most transects is relatively insensitive to the width of channel needed for passage, but was somewhat more sensitive to the depth needed for passage.

The exception is the Lompoc 1 transect. This transect is one of the first that steelhead entering the Santa Ynez River will encounter. Using the relative width criteria of 10 and 25 percent for the top width, the Lompoc 1 transect required the largest amount of flow for steelhead to pass. This transect is located in a sandy channel with a top width of 125 ft at 25 cfs and nearly 200 ft at 100 cfs. The passage criteria of 0.6 ft of depth over 25 percent of the channel indicated passage here would require flows in excess of 100 cfs. Because of the broad profile of this transect that means that the transect is not deemed passable until the water depth is 0.6 ft across 50 ft of channel.

However, the characteristics of the Lompoc 1 transect may make it less of a problem for passage than indicated in the analysis. Using a passage requirement of a contiguous width of 8 ft and minimum depth of 0.6 ft, 30 cfs is required for passage and when using a set minimum widths of 5 or 3 ft, passage is achieved at this transect at less than 20 cfs. The depth criteria also indicated that the results were sensitive to small changes in depth. At the Lompoc 1 transect, flows needed to meet the passage criteria changed from 70 to 20 cfs when the depth criterion was reduced by 0.1 ft to 0.5 ft. The transect fails to meet the passage criteria only when we use the relative width criteria requiring 25% of the channel to be 0.6 ft deep. Steelhead can and have passed through much narrower channels than this successfully, as evidenced by their presence in many small streams throughout their range, and in Salsipuedes and Hilton creeks within the Santa Ynez River drainage. The lower recommended minimum flow for passage at the Lompoc 1 transect is supported by the capture of more than 15 adult steelhead/rainbow trout in Salsipuedes Creek in 1999 before mainstem flows had exceeded 40 cfs (SYRTAC data).

3.2 PASSAGE OPPORTUNITY

Using the Santa Ynez River Hydraulic Model, we evaluated the frequency of flows meeting the passage criteria flows to determine the number and frequency of passage opportunities for adult steelhead to migrate upstream between 1942 and 1993. The flows at three sets of minimum passage criteria were selected for use in this analysis: 8 ft of contiguous channel width with a depth of 0.6 ft, 10 percent of the contiguous channel width with a depth of 0.6 ft, and 25 percent of the total channel width (not contiguous) with a minimum depth of 0.6 ft (Table 2). We used daily flow hydrologic data for

January through April at four locations on the river to reflect passage opportunities under project operations. We also simulated the passage conditions that would have existed without the project in place using the same period of record.

The frequency of occurrence of these target flows was evaluated at Lompoc, Cargasachi, Alisal and Solvang. These different locations were selected because passage conditions may differ between these areas based on tributary inflows. Sequential passage past these areas are presumed to provide steelhead access to suitable spawning habitat in Salsipuedes/El Jaro, Alisal, Quiota, and the mainstem below the dam and Hilton Creek, respectively. In some years, fish may be able to reach Salsipuedes Creek but may not have sufficient flow to reach Hilton Creek near the base of Bradbury Dam.

An evaluation was performed of the frequency with which the minimum flows identified would be available for periods of 1, 3, 5, and 10 consecutive days between January 1 and April 30. These are intended to represent the amount of time it might take an adult steelhead to migrate upstream to spawning areas. Of course a steelhead may hold over somewhere along the river if it does not reach a suitable spawning area within this time, but assuming that migration takes place during a single event this provides a conservative estimate of the passage opportunity. A second analysis examined what percentage of years would provide a given number of passage opportunities based on daily flows provided by the SYR model.

Prior to a steelhead negotiating the passage obstructions in the river itself, it must first be able to enter the river from the ocean. As discussed elsewhere in this document, the mouth of the Santa Ynez River is frequently closed by the presence of a sandbar across its mouth. This bar forms during the summer when flows are low and wave energy is also low. It is breached in the winter by a combination of higher river flows and greater wave energy (although either of these elements may be able to breach the bar by themselves). No information is available about the frequency with which the bar is broken or what flows might be required to accomplish this. It is thought that flow from Salsipuedes Creek may be sufficient to breach the bar on its own when runoff in that system is good. The bar has occasionally been opened manually, but this is not a regular practice. The passage analysis that follows presumes that steelhead have already gained access to the river.

3.2.1 Frequency of Single Passage Opportunities

Table 3 compares the percentage of years during which a single passage opportunity would occur based on the target flow level at each location and on a specified passage event duration. This table indicates that under current project operations, the percentage of years providing passage opportunities is decreased. The size of the decrease is dependent on the required duration of the passage event. Generally, the decrease in the number years with one day passage events is much less than the decrease in the number of years with 10 day passage events.

Under unimpared flows (without Cachuma operations), steelhead would be able to migrate past Lompoc between 62 and 83 percent of years, depending on the passage event duration. The percentage of years with passage events at the more upstream locations is slightly greater, with a notable exception for one day passage events. The greater frequency of one day events at Lompoc indicates that Salsipuedes Creek contributes strongly to flows in this reach, but that the contribution tends to be flashy, related to rain events. However, as Salsipuedes Creek is only about 15 miles from the lagoon, a one day passage event is likely sufficient to allow most adults to move upstream into Salsipuedes Creek.

Under existing conditions, steelhead would be able to migrate past Lompoc between 50 and 83 percent of years, with a net reduction of 0 to 12 percent relative to the unimpaired flow condition. The percentage of years when one day opportunities is available is not decreased, again indicating the importance of Salsipuedes Creek to flows in this area. The percentage of years in which three, five, and ten day passage events occur is decreased relative to the unimpaired flows. The reduction in the percentage of years when passage would be available ranges from 9 to 14 percent at Cargasachi, 10 to 25 percent at Alisal and 13 to 25 percent at Refugio, depending on passage duration. The percentage of years with passage opportunities at these locations generally being less than that at Lompoc with Cachuma operations. This contrasts with the unimpaired flow condition where these stations generally had a greater percentage of years when fish could pass than did Lompoc. This indicates that the dam has its greatest influence on passage opportunities in the more upstream portion of the basin.

3.2.2 FREQUENCY OF MULTIPLE PASSAGE OPPORTUNITIES

While a single passage opportunity may provide an index for comparison, obviously an upstream migrant steelhead must be in the correct location to take advantage of this opportunity. Steelhead are known for their plasticity when it comes to migration periods, particularly in the southern end of their range where natural conditions are dry and the fish may have to wait for the mouth to open prior to entering the stream. However, if only one event occurs in a given year, some steelhead may miss the opportunity. Therefore it is generally preferable that there be more than one opportunity for steelhead to migrate in a given year. The frequency of years with multiple three-day and one day passage opportunities is evaluated in this section. Figures 1 to 4 show the percentage of years when a given number of 3-day passage opportunities are available at the different stations. Figures 5 to 8 show the percentage of years when a given number of 1-day passage opportunities are available. These figures show that fish either have many passage opportunities or none, reflecting the fact that water years within the basin tend to be either wet or dry, with few years falling in-between.

For the 8 ft contiguous width criteria, flows of 30, 15, 25 and 25 cfs are required to achieve passage through Lompoc Narrows, Cargasachi, Alisal and Refugio, respectively. Under the historic condition (without the Cachuma Project), 12 or more 3-day passage opportunities would have occurred approximately 57 percent or more years (upper plots in Figures 1 through 4). The Cachuma Project reduces the percentage of years with 12 or more 3-day passage opportunities to 32 to 55 percent of years, with greater reductions at Alisal and Refugio than at Lompoc. The number of years without 3-day passage opportunities is greatest at Lompoc (31 percent) and least at Cargasachi and Alisal (25 percent).

Twelve or more 1-day passage opportunities would have occurred 63 percent or more years at all locations without the Cachuma Project in place (upper plots in Figures 5 through 8). The number of years without a 1-day passage event would have ranged from 17 to 25 percent of years. With the project in place, the percent of years with 12 or more 1-day passage events declines to 41 to 62 percent, with the greatest affect again occurring in the Alisal and Refugio areas. Between 17 and 38 percent of years do not provide a 1-day passage opportunity with the project in place. The change in the number of 1-day passage events with and without the project is not as pronounced as it was for three-day passage events.

Similar results are observed using the 10 percent contiguous and 25 percent of total width criteria to those described above. Some change in frequency is noted, as would be expected because of the higher flow levels required for passage, but the general trends are the same. The plots for these criteria sets, respectively, are shown in the central and bottom panels of Figures 1 through 8.

It appears that a target flow of 30 cfs would be adequate for the passage of adult steelhead over critical riffles on the Santa Ynez River at each transect based on the analysis conducted. This flow would provide a minimum depth of 0.6 ft over more than 8 ft of contiguous channel at all transects. It would also provide a minimum depth of 0.6 ft over 10% of the wetted channel at all transects except Lompoc 1 where a minimum depth of 0.5 ft would occur contiguously for 10% of the wetted channel. The recommended flow level will also meet the 0.6 ft depth and 25 percent of width criteria at all but the Lompoc 1 transect, where 9.3 ft of the channel would have minimum depth of 0.6 ft. In order to set target flows for migration through the lower river, the hydrology of the basin must be considered. With increasing distance downstream from Bradbury Dam, there is accretion due to inflow from the tributaries such as Salsipuedes Creek during the wet season.

Under historical flow, with the current channel configuration, steelhead had greater passage opportunities than they do with current Cachuma Operations. The Historic condition has a lower percentage of years with no passage opportunities under all conditions at all locations. It also has a higher percentage of years with more than 12 passage opportunities at all locations. In addition, the difference between the passage exceedances (e.g., 1, 3, 5, or 10-day opportunity, see Table 2) for without Cachuma Operations and with Cachuma Operations increased in an upstream direction. This reflects the accretion that occurs with increasing distance downstream from tributaries in the lower basin. Thus passage flows needed at particular locations within the lower river should be targeted to the flow observed at particular locations in the river, rather than releases from Bradbury Dam.

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APPENDIX A

TABLES

Table 1. Flow at which passage criteria are met for each transect.

	Location										
	Lompoc 1	**Lompoc 2**	**Cargasachi**	**Alisal 1**	**Alisal 3**	**Alisal 4**	**Alisal 1(a)**	**Alisal 2 (a)**	**Refugio 1**	**Refugio 2**	**Refugio 3**
Top Width @ 25 cfs	*125 ft*	*187 ft*	*139 ft*	*85 ft*	*74 ft*	*70 ft*	*41 ft*	*33 ft*	*79 ft*	*110 ft*	*70 ft*
Criteria											
3 ft wide 0.5 ft deep	5	5	5	5	5	10	5	5	5	5	10
3 ft wide 0.6 ft deep	25	5	5	10	10	15	15	5	10	5	15
5 ft wide 0.5 ft deep	5	5	5	5	15	10	10	5	10	5	10
5 ft wide 0.6 ft deep	25	5	5	10	20	15	15	10	15	5	20
8 ft wide 0.5 ft deep	5	5	5	5	15	15	10	5	10	5	15
8 ft wide 0.6 ft deep	30	5	15	10	20	25	20	10	15	5	25
10% Contg. 0.5 ft deep	20	5	5	5	5	10	5	5	10	5	10
10% Contg. 0.6 ft deep	70	5	15	10	20	15	15	5	15	5	20
25% 0.5 ft deep	55	5	20	15	15	10	10	5	15	5	25
25% 0.6 ft deep	100+	5	25	30	25	20	20	10	20	5	30

Table 2. Minimum flow required to achieve passage by reach and by criteria set. Minimum depth for passage is 0.6 feet for all width criteria.

Width Criteria	Location			
	Lompoc Narrows	Cargasachi	Alisal	Refugio
8 ft. Contiguous	30	15	25	25
10% Contiguous	70	15	20	20
25% of Total Width	100	25	30	30

Table 3. Percent of years with at least one passage event, based on 8 feet of contiguous channel with a depth of 0.6 feet (January through April 1942-1993).

Reach:	Lompoc	Cargasachi	Alisal	Refugio
Flow Exceeded	30 cfs	15 cfs	25 cfs	25 cfs
Without Cachuma Operations				
Flow Exceeded for:				
1-Day	83%	75%	79%	75%
3-Day	69%	71%	69%	69%
5-Day	63%	67%	67%	67%
10-Day	62%	67%	67%	67%
With Cachuma Operations				
Flow Exceeded for:				
1-Day	83%	69%	69%	62%
3-Day	63%	60%	54%	52%
5-Day	58%	60%	50%	46%
10-Day	50%	58%	42%	42%

APPENDIX B

FIGURES

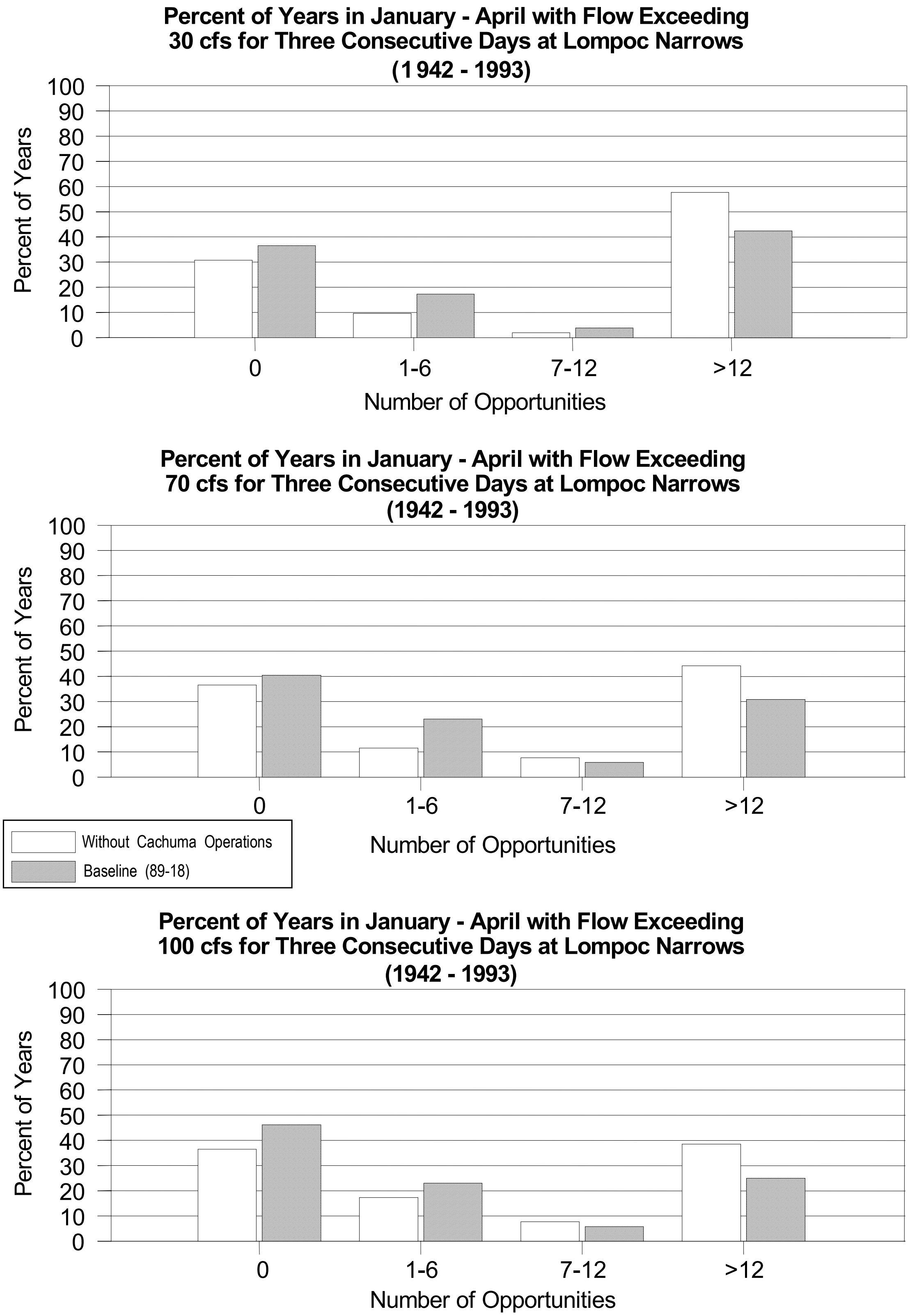

Figure 1. Number of 3-day passage opportunities at Lompoc Narrows.

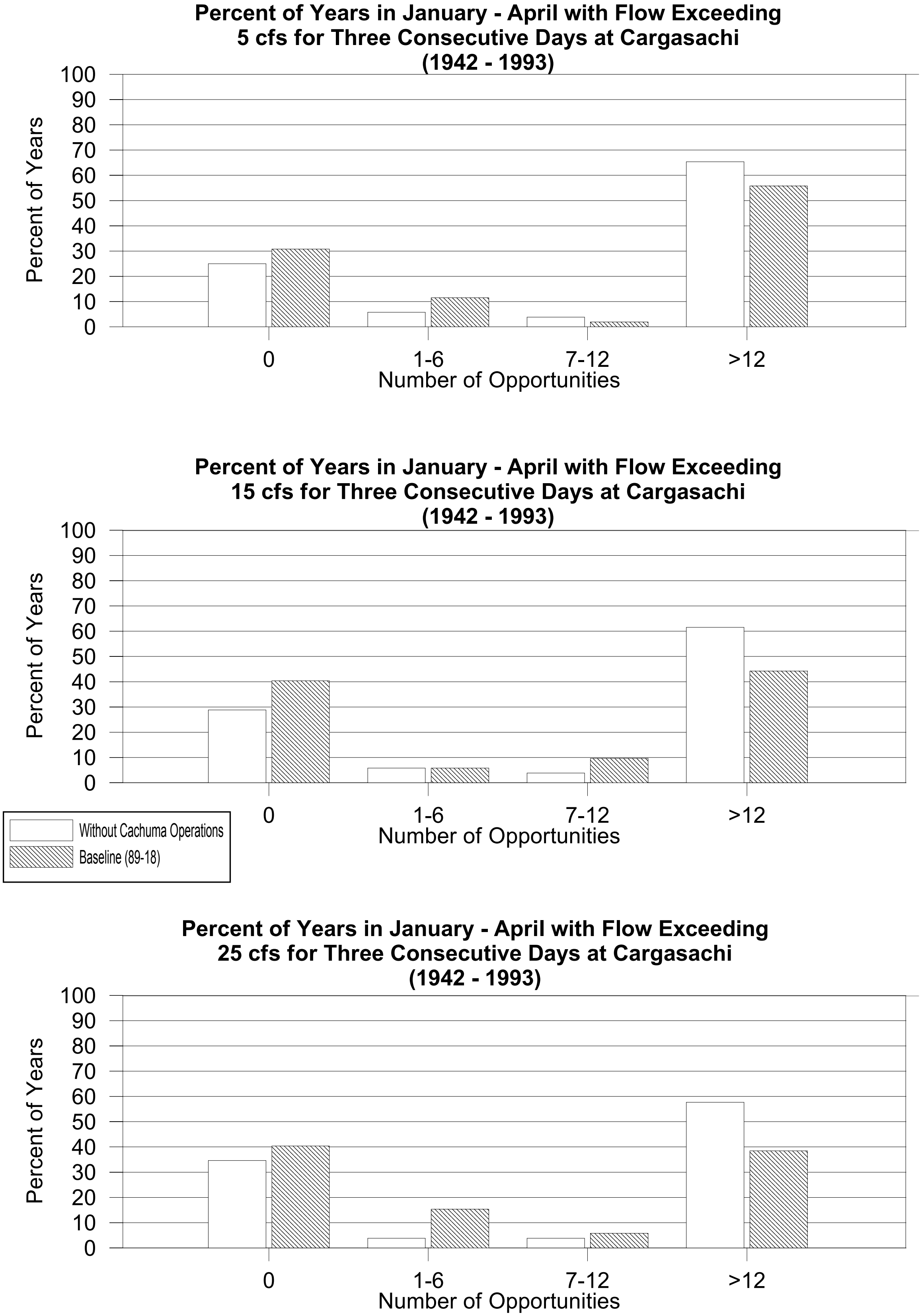

Figure 2. Number of 3-day passage opportunities at Cargasachi.

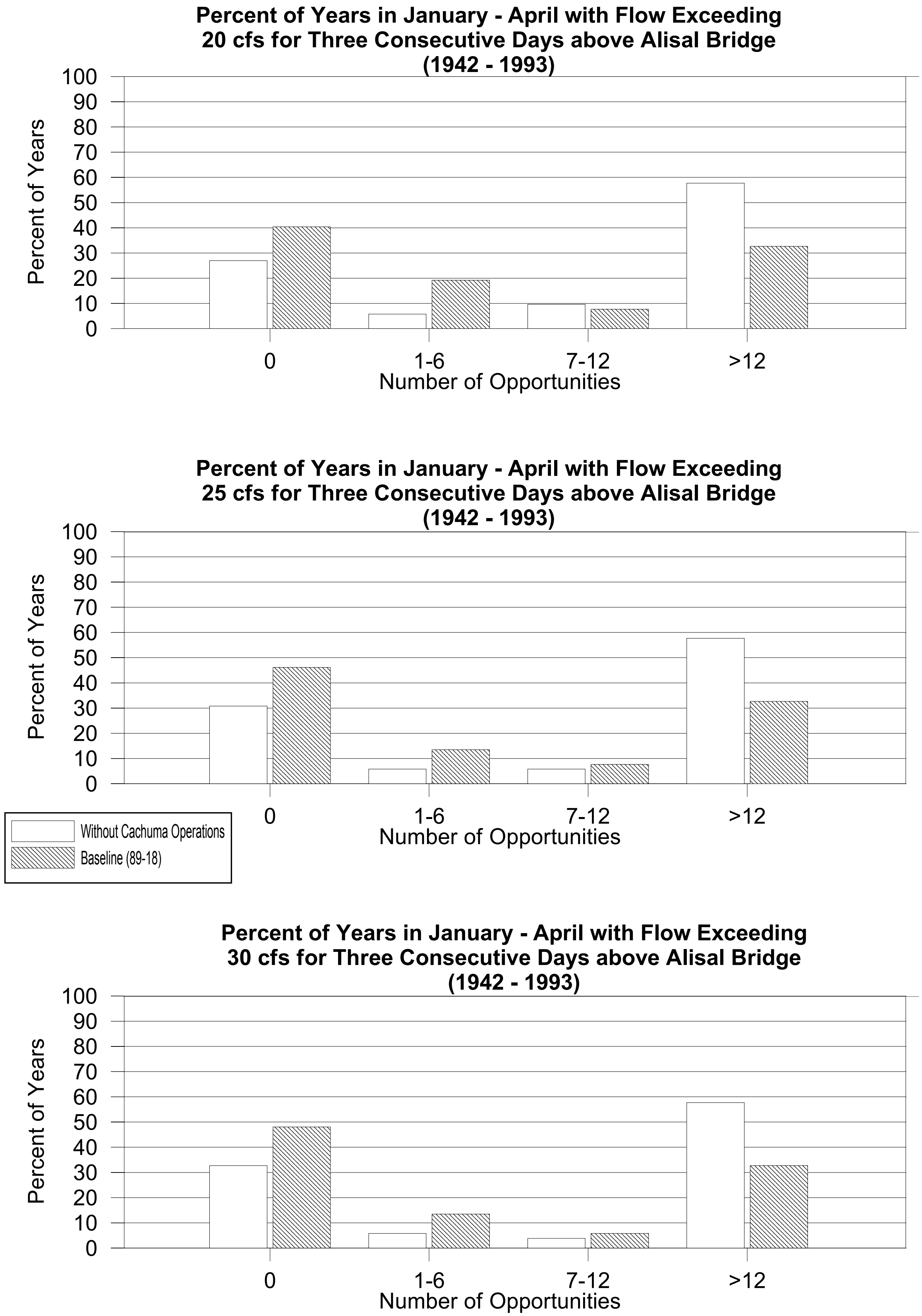

Figure 3. Number of 3-day passage opportunities at Alisal Road.

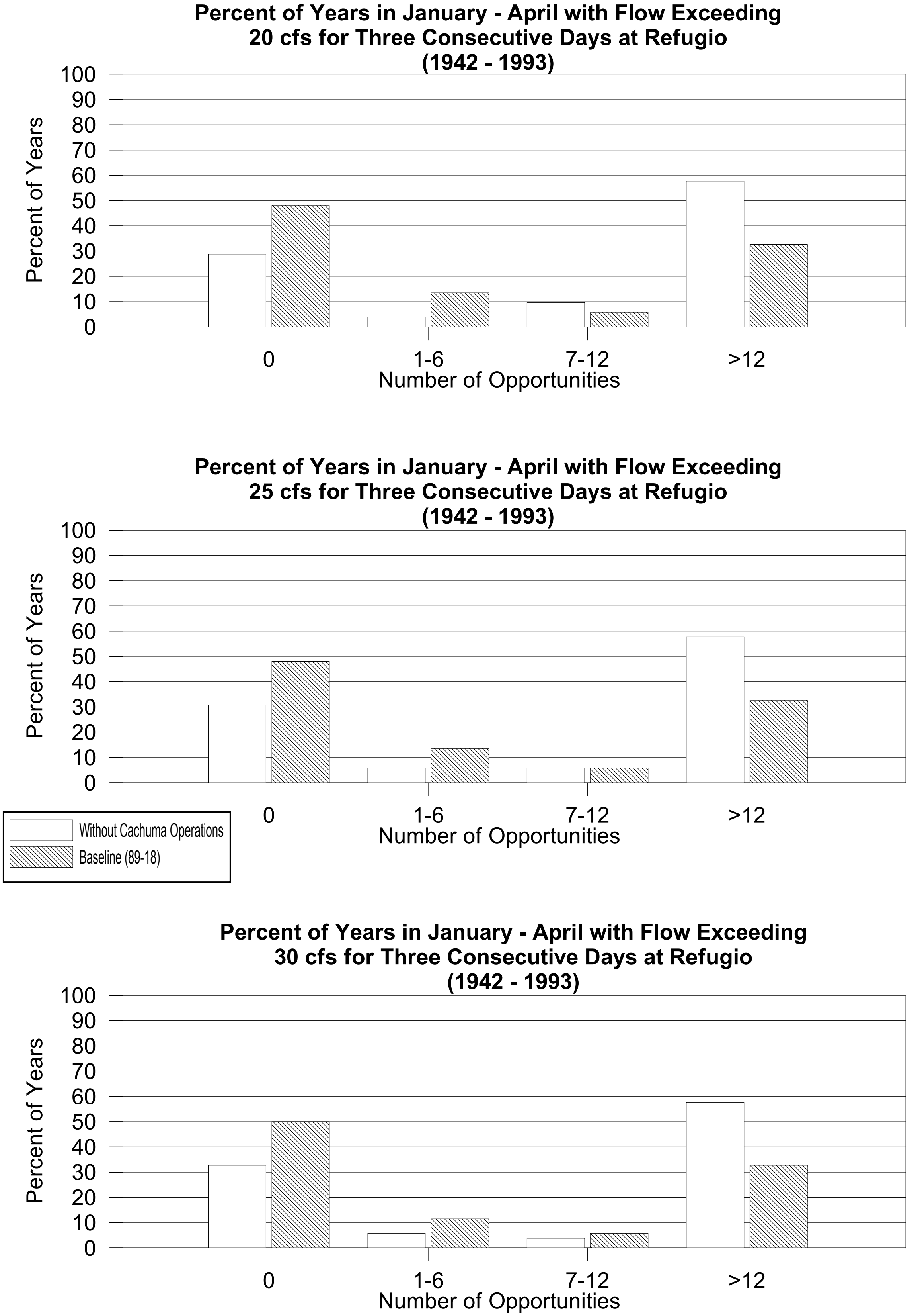

Figure 4. **Number of 3-day passage opportunities at Refugio Road.**

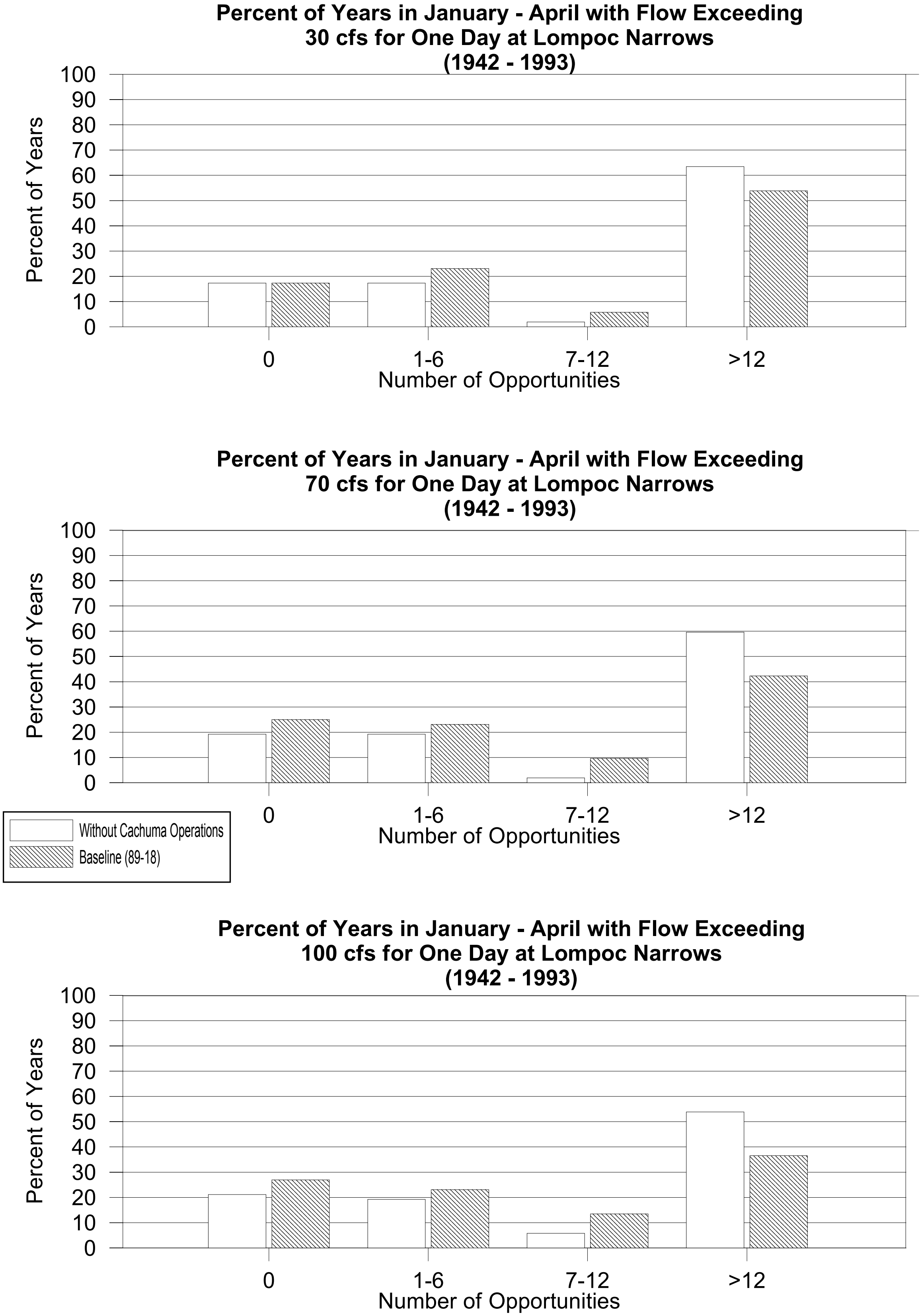

Figure 5. Number of 1-day passage opportunities at Lompoc Narrows.

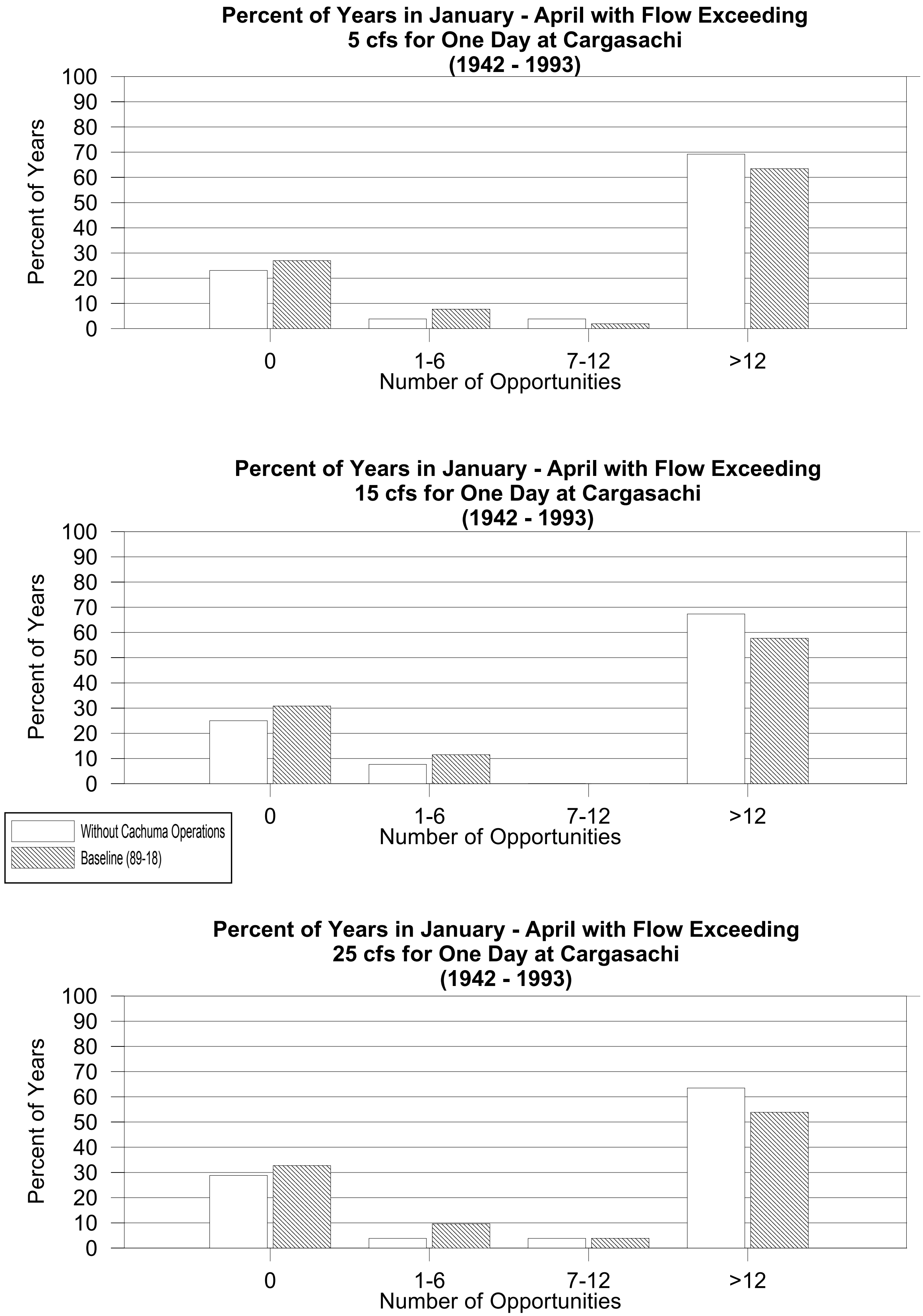

Figure 6. Number of 1-day passage opportunities at Cargasachi.

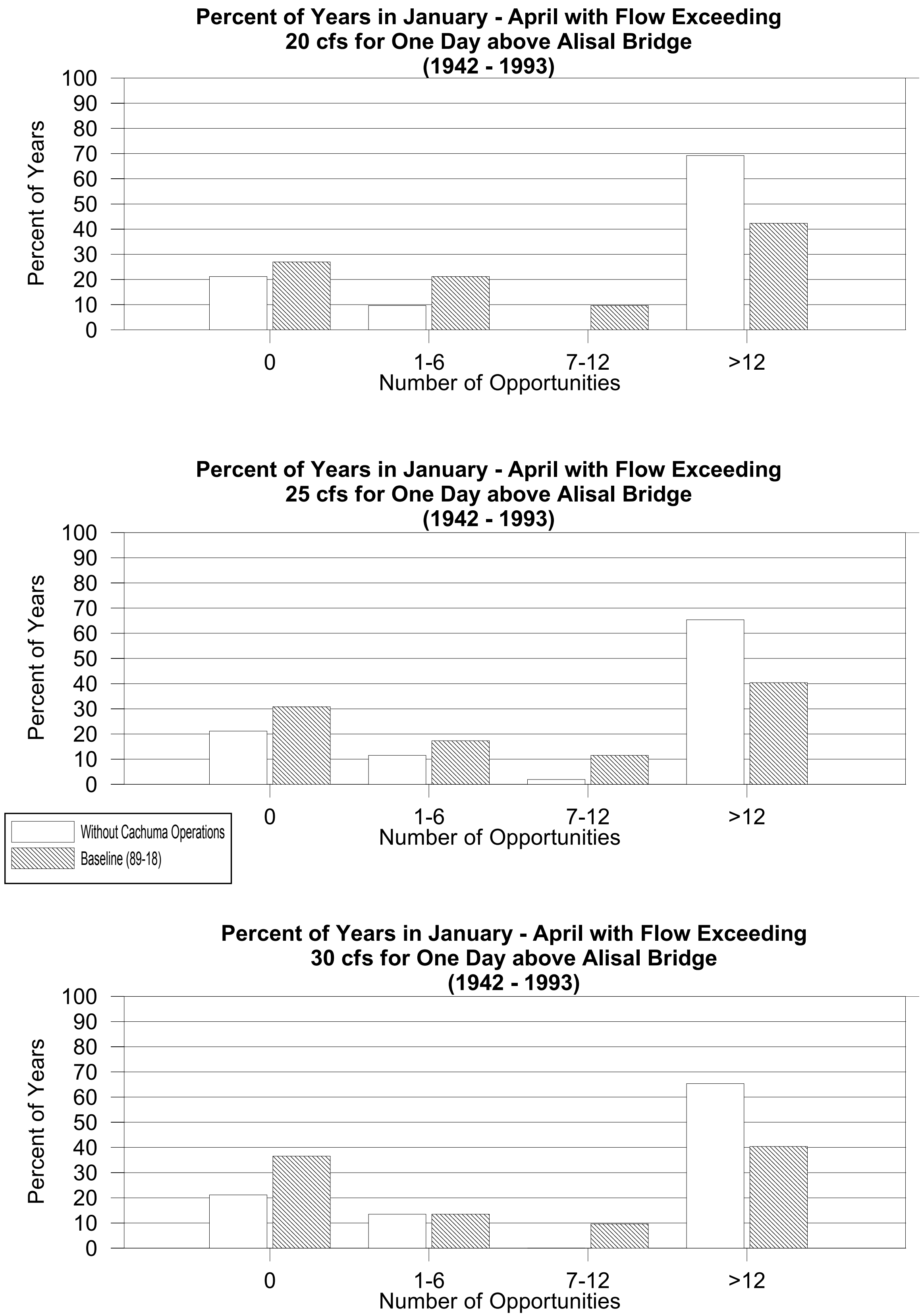

Figure 7. Number of 1-day passage opportunities at Alisal Road.

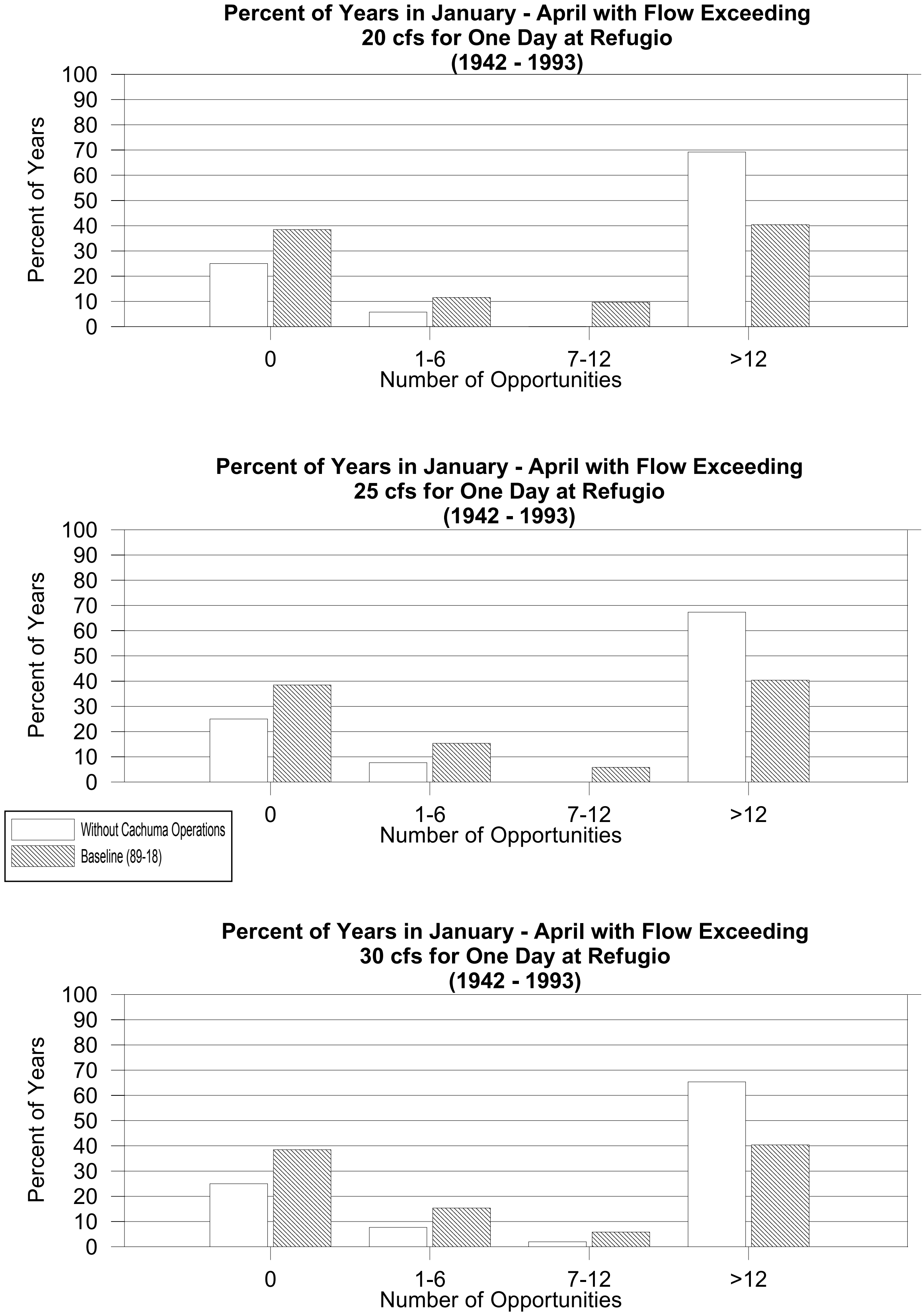

Figure 8. Number of 1-day passage opportunities at Refugio Road.