Instream Flow needs for Steelhead in the Carmel River

Bypass flow recommendations for water supply projects using Carmel River waters

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Executive Summary

Diversions of water from the Carmel Valley Aquifer have had a significant direct effect on surface flow in the Carmel River. During most years, the Carmel River goes dry downstream from approximately river-mile (RM) 6 or 7 by July. These reductions of flow and the dewatering of the lower river have substantially reduced available steelhead habitat in the lower river. This report draws upon the extensive Carmel River fisheries and hydrologic data and other existing information to develop minimum flow guidelines and maximum rates of diversion for new off-stream storage projects for Carmel River water. The intent of this report is to provide information for developing long-term solutions for resolving ongoing impacts to steelhead and water supply needs for the Carmel River Valley.

This report identifies key seasons and steelhead life stages needing different levels of flow: winter (December 15 - April 14) when flows are generally high and adult steelhead migrate and spawn; spring (April 15 - May 31), the primary period of smolt outmigration following the winter spawning season; and the summer-fall low flow season (June 1 to December 15).

During the winter season, recommended bypass flows at diversions are based on the need to preserve “attraction flows” (*i.e.*, inflows > 200 cfs to the Lagoon) that draw steelhead into the river and “spawning flows” that protect habitat conditions for steelhead spawning. Accordingly, during wet, normal, and below normal years, an attraction event begins when it is projected that an unimpaired flow of 200 cfs or more would reach the Lagoon. When an attraction event is projected, diversions must not reduce inflows to the Lagoon below 200 cfs for the duration of the attraction event. During dry and critically dry years, attraction events are defined as estimated unimpaired inflows to the Lagoon of at least 200 cfs, 100 cfs, and 75 cfs, in January, February, and March, respectively. We recommend that during dry and critically dry years, a minimum of 150 cfs to the Lagoon be maintained during the attraction event. In all water years, when flows subside below the attraction event level, migration flows of 200 to 60 cfs will be maintained to the Lagoon according to a scheduled recession rate. We recommend that, following an attraction event and the subsequent ramp down, new stream diversions during winter should maintain bypass flows of 100 cfs at sites between Los Padres Dam and San Clemente Dam, 90 cfs for sites between San Clemente Dam and Rivermile 5.5, and 60 cfs for sites between Rivermile 5.5 and the Lagoon. The lower minimum bypass flow of 60 cfs is justifiable below RM 5.5 because spawning habitat is very limited and of poor quality; however, 60 cfs must be maintained to facilitate passage through shallow riffles.

Spring flows must be conserved in order to protect outmigrating juvenile steelhead (i.e., smolts). Travel rates of smolts are directly related to stream flow, and increased travel rate promotes smolt survival. To protect this sensitive life stage, we recommend that flows be conserved between April 15 and May 31 by both maintaining minimum bypass flows of 80 cfs between San Clemente Dam and the Lagoon and limiting the cumulative maximum instantaneous rate of diversion in the watershed to 80 cfs.

It is appropriate to conserve and restore both surface and subterranean flows in the lower Carmel River during the low flow season, because of the value of summer flows in 1) creating rearing habitat, 2) minimizing the stranding and dessication of juvenile fish, 3) providing a migratory corridor for the movements of fish and other aquatic life, 4) restoring riparian vegetation and habitats, and 5) restoring the quality of the Lagoon as habitat. We recommend that no new diversions be permitted, authorized, or otherwise sanctioned for the period June 1 to October 31. During November, new diversions should be operated with minimum bypass flows of 20 cfs. We recommend that diversions during the month of December be operated with minimum bypass flows of 40 cfs, unless "Attraction Flows" occur after December 15, at which point diversions should be operated consistent with the guidelines for the winter season. Authorized, existing diversions during summer and fall should be curtailed to the maximum extent practicable to promote protection and restoration of the Carmel River. Those with existing, authorized diversions from the Carmel River during summer and early fall should be encouraged to pursue alternative sources of water. For example, where possible, direct diversions for irrigation or municipal use should be converted to projects that divert and store winter flow in lined, off-stream reservoirs or aquifer storage projects. Where possible, reclaimed water should be used to reduce direct diversions.

In addition to providing the flows needed to support habitat for various life stages of steelhead, it is important to preserve the river's natural hydrograph. The preservation of natural flow variability and high stream flows are important for maintaining stream ecosystem function. High flows are essential for cleansing fine sediments from coarse substrates and for otherwise maintaining the integrity of stream channels. To accommodate the need to conserve high channel maintenance flows, while allowing for reasonable diversions of water, we recommend the provision of a cumulative maximum rate of withdrawal. Using information concerning channel maintenance flow needs below dams, we recommend that in the absence of site-specific studies, cumulative maximum instantaneous rates of diversion from the river should not exceed 5% of Q_2 (*i.e.*, the average 2 year high flow event). This is equivalent to an average daily flow of 72 cfs or an instantaneous rate of about 115 cfs.

To determine the potential volume of water available for diversion with the recommended minimum bypass flows and diversion rates, we have constructed a model that displays average daily flow at the Robles del Rio gage under conditions with and without additional diversions consistent with the recommendations. Alternative scenarios are presented for a dry water year (1994), a median water year (1979), a near mean water year (1984), and an above-normal water year (1973), when about 12,000 AF, 46,000 AF, 65,000 AF, and 108,500 AF are passed at the Robles del Rio gage, respectively. The results are a preliminary analysis and are not finely tuned for differences in stream flow at varying points along the river, nor do they include tributary flow below Robles del Rio gage or gains associated with removing unauthorized diversions from the river. Nevertheless, the results show that there is substantial water (>10,000 AF) available for diversion during average water years and even more would be available during above-normal and wet years. However, the results also demonstrate that during relatively dry years representing roughly 20% of the years, relatively little “surplus” flow (< 1000 AF) is available for withdrawal without potentially adversely affecting steelhead. To further refine estimates of available water under the recommended bypass flow requirements and limited diversion rates, we recommend that additional analysis of channel maintenance flow needs be performed and these requirements be incorporated in a water availability model such as CVSIM.

Acknowledgments

Two drafts of this report were reviewed by staff of the Monterey Peninsula Water Management District (MPWMD) and the Monterey Field Office for Region 3 of the California Department of Fish & Game. We greatly appreciate the many helpful comments, criticisms, and suggestions received from Mr. Darby Fuerst (MPWMD), Mr. David Dettman (MPWMD), and Mr. Kevan Urquhart (DFG-Monterey) in the course of that review. We also wish to acknowledge the extensive efforts of many other DFG, MPWMD, and private sector biologists who previously participated in the numerous investigations of the Carmel River and its steelhead. Those studies form the scientific basis of our recommendations.

1.0 Introduction

For over 20 years, excessive water diversions from the Carmel River have had a significant adverse effect upon the aquatic biological resources of the Carmel River. Nehlsen et al. (1991), who listed Carmel River steelhead as being at a high risk of extinction, suggested that this population was primarily affected by water withdrawals. Titus et al. (1999) attributed the decline in the population of steelhead in the Carmel River to the extensive water diversions and blocked access to historic spawning and rearing areas upstream of dams. SWRCB Order 95-10 concluded that Cal-Am diversions are having an adverse effect on the riparian corridor along the river below San Clemente Dam and upon steelhead which spawn in the river. In 1997, the National Marine Fisheries Service (NMFS) listed steelhead in the South-Central California Coast Evolutionarily Significant Unit (ESU), which includes the steelhead of the Carmel River, as a federally listed threatened species (62 FR 43937, August 18, 1997). In 2000, NMFS designated the Carmel River as critical habitat for this ESU (65 FR 7764, February 16, 2000).

California American Water Company (Cal-Am) is responsible for approximately 85% of the total water diversions from the Carmel River system and its associated subterranean flow (Monterey Peninsula Water Management District Water Production Summaries: July 1,1998 to June 30,2000). The remaining diversions are due to a diverse group of water users including 14 nonCal-Am entities that are responsible for an additional 12 to 13% of the total water withdrawn from the Carmel River. Of the approximately 14,000 acre feet (AF) of water annually diverted from the Carmel River by Cal-Am in recent years, 3,376 AF are appropriated through legal pre-1914, riparian and appropriative rights; the remainder is diverted without a basis of water right (SWRCB Order 95-10).

SWRCB Order 95-10 ordered Cal-Am to diligently implement one or more of the following actions to terminate its unlawful diversions from the Carmel River: (1) obtain appropriative permits for water being unlawfully diverted from the Carmel River, (2) obtain water from other sources of supply and make one-for-one reductions in unlawful diversions from the Carmel, and/or (3) contract with another agency having appropriative rights to divert and use water from the Carmel River. To meet this obligation, Cal-Am has pursued approval for a water supply project that would include creation of a new on-stream dam and a 24,000 AF reservoir (Carmel River Dam and Reservoir Project) in the headwaters of the Carmel River watershed. However, NMFS has expressed strong reservations about the potential adverse effects of such a project upon the steelhead fisheries in the Carmel River (NMFS letter to D. Fuerst, MPWMD, May 24, 2001). A new on-stream reservoir project would have a dramatic adverse effect on the natural hydrology of the river; it would inundate very high quality spawning and nursery habitat, and the reservoir would be a significant barrier to downstream migrating juvenile and adult fish. NMFS recommended that instead of pursuing an on-stream storage project, Cal-Am should pursue development of an off-stream water supply project and other remedies. The California State Public Utilities Commission (PUC) developed an alternative, multifaceted water supply project for the Carmel River Valley that includes diversions for an Aquifer Storage and Recharge (ASR) Project, desalination plant, conservation, and reclaimed water use (Raines, Melton and Carella, Inc. 2001).

Stream flows in the Carmel River are periodically high during winter and spring. Removal of a portion of this high flow would probably have no significant adverse effect on steelhead or stream ecosystem function. However, seasonal high flows should not be fully regulated and stored behind a tall dam; instead a portion of them should be diverted to off-stream storage facilities, either to surface ponds, to aquifer storage, or a combination of both.

To develop a significant off-stream storage project for Carmel River waters, it is necessary to identify the instream flows needed to protect aquatic resources in that river. This requires understanding of the river's hydrology and the relationship between stream discharge and available habitat. Information about the effects of stream flow on fish migrations are also needed. Fortunately, much of this information has already been developed for Carmel River steelhead. Several previous studies have dealt directly with the issue of instream flows needed to protect and enhance steelhead habitat in the river. Although most of this work was performed in support of the construction of the Carmel River Dam and Reservoir Project, the information obtained from those studies can be used to identify the flows needed to sustain steelhead under scenarios involving diversions to off-stream storage.

This report draws upon the extensive Carmel River fisheries and hydrologic data and other existing information to develop minimum flow guidelines and maximum rates of diversion for new off-stream storage projects for Carmel River water. Section 2 provides the reader with a brief review of the project area and existing stream flow conditions in the Carmel River. Section 3 discusses stream flow needs to maintain fluvial geomorphologic processes and flows needed to sustain various life stages of steelhead. Section 4 examines the effects of instream flow requirements on potential water yield to off-stream storage and other human uses.

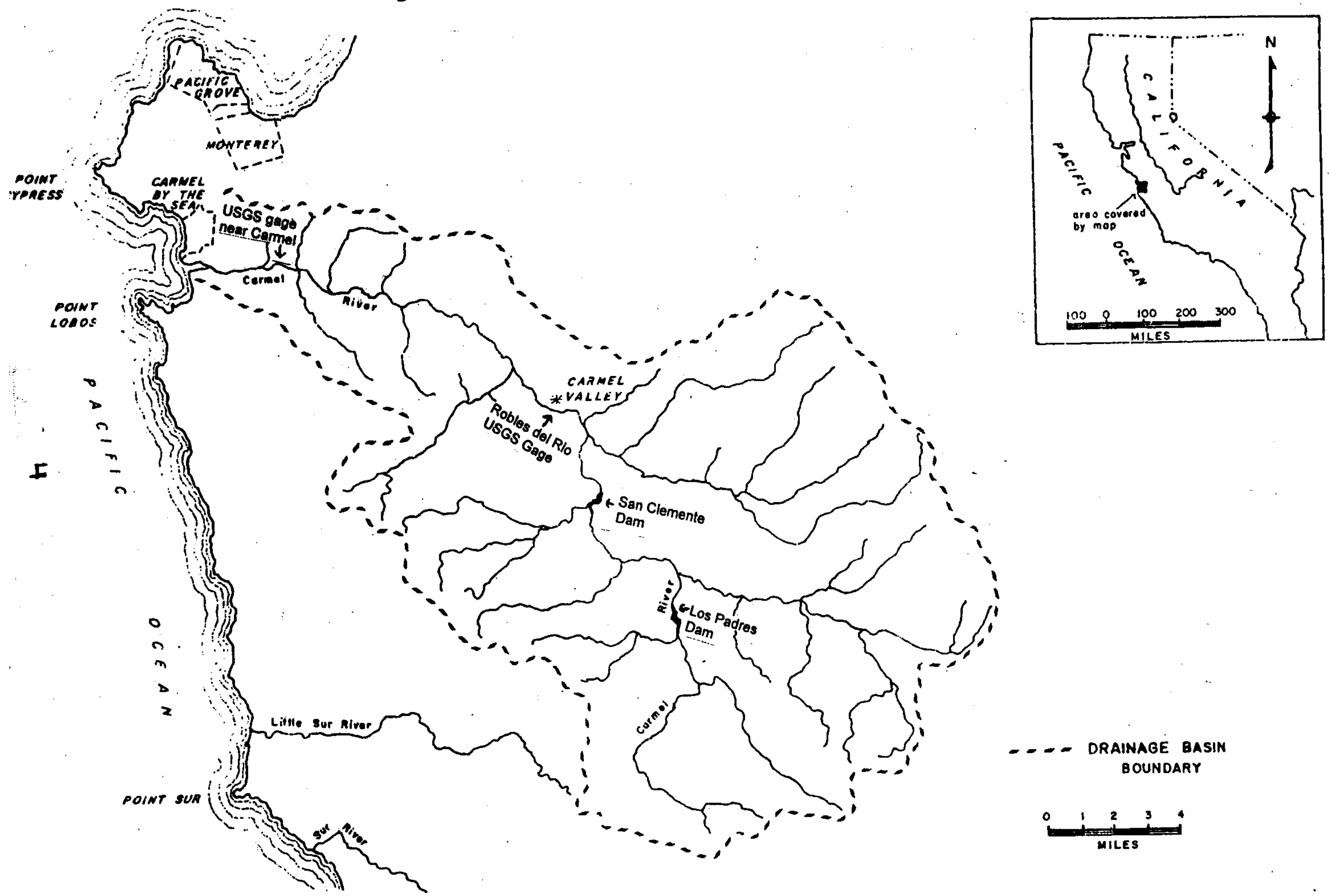
2.0 Background

The Carmel River is a central California coastal stream that drains a 255 square mile watershed to the Pacific Ocean (Figure 1). The river has two dams on its mainstem: the 85 foot high San Clemente Dam located at Rivermile (RM) 18.6, and the 148 foot high Los Padres Dam located at RM 23.5. Water is diverted from the Carmel River at numerous points. Cal-Am has the ability to withdraw and convey surface water from the pond behind the San Clemente Dam to Cal-Am's Carmel Valley Filter Plant (CVFP) at a rate of 32 AF per day or an instantaneous rate of 16.2 cubic feet per second (cfs). Diversions at San Clemente Dam are limited to periods of relatively high flow by a Memorandum Of Understanding (MOU) between Cal-Am, the California Department of Fish & Game (CDFG), and the Monterey Peninsula Water Management District (MPWMD). They are also limited by a Conservation Agreement between Cal-Am and NMFS. In addition to this surface diversion, Cal-Am operates a series of 19 active wells that divert flow from the Carmel River Aquifer, subterranean flow that is interconnected to the surface flow of the river. Diversions from the Carmel Valley Aquifer have a direct effect on surface flow in the Carmel River. Cal-Am's wells along the Carmel River are scattered from RM 16.2 to RM 3 and have a combined capacity of 66.6 AF per day or an instantaneous rate of 33.6 cfs. Several other wells, operated by relatively minor water users, likewise make use of subterranean flow in the Carmel River Aquifer.

As a result of these diversions, the Carmel River usually goes dry downstream from approximately RM 6 or 7 by July of each year. From July until the winter rains begin, the only water remaining in the lower river is in isolated pools that gradually dry up as the groundwater table declines in response to pumping. Surface flow from the Carmel River into the lagoon normally recedes after the rainy season in late spring, and ceases in summer as rates of water extraction from the river and alluvial aquifer exceed baseflow discharge (Denise Duffy, 1998).

Tables 1 and 2 show the flow exceedence values for each month at the two respective USGS gages on the Carmel River, the Robles del Rio gage at RM 14.4 and the Near Carmel gage at RM 3.6. Exceedence values are the flows that were exceeded a certain percentage of the time during the period of record. For example, Table 1 shows that over the 42 year period of record for the Robles del Rio gage, stream flow exceeded 460 cfs on 20% of the days in February. Table 1 indicates that historical stream flows at Robles del Rio were usually less than about 2 cfs during August, September, and October, except during the wetter years. However, during the most recent seven years, as the result of higher precipitation, reduced summer diversions at San Clemente Dam, and management of releases from Los Padres Dam, flows at this site have generally exceeded 4 to 5 cfs during late summer.

Figure 1. Location of Carmel River watershed, Monterey County



In support of water supply planning, MPWMD constructed a hydrologic model (CVSIM) of unimpaired flows in the Carmel River. A model of unimpaired flows is especially important for analysis of flows during summer and fall, because stream diversions during low flow periods have effectively eliminated surface flows in the lower Carmel River during the past several decades (see Table 2). On behalf of NMFS, Natural Resources Consulting Engineers (NRCE) reviewed the CVSIM model and the associated RECON and CVSIM2 programs for the purpose of evaluating the reasonableness and adequacy of its underlying assumptions and model inputs. NRCE suggested minor improvements to the model and generated improved estimates of unimpaired flow at Robles del Rio and at the Near Carmel USGS gage site (NRCE 2002). Tables 3 and 4 provide estimates of unimpaired flow at these two sites in terms of monthly flow exceedence values.

Table 1. Average daily stream flow (cfs) expressed as percent exceedence at the USGS Robles del Rio gage on the Carmel River during each month for the period Water Year 1958 to 1999.

Exceedence	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10%	566	955	670	404	147	63	17	7.7	7.4	7.1	32	130
20%	262	460	413	241	95	35	11	4.4	3.9	3.8	8.8	55
50%	36	109	107	70	26	6.8	2.3	0.8	0.7	1.1	2.1	9.0
80%	4.1	22	25	9.2	3.3	0.7	0.0	0.0	0.0	0.0	0.0	1.1
90%	0.9	5.8	4.3	3.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2. Average daily stream flow (cfs) expressed as percent exceedence at the USGS Near Carmel gage during each month for the period Water Year 1963 to 1999.

Exceedence	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10%	643	1175	813	482	205	78	20	1.7	1.2	1.6	21	154
20%	328	527	505	304	115	40	4.8	0.5	0.3	0.4	1.3	53
50%	31	123	133	94	30	2.7	0.0	0.0	0.0	0.0	0.0	0.8
80%	0.0	20	15	7.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

In addition to serving as the principal water source for the Carmel Valley, the Carmel River currently supports the most significant run of steelhead trout within the South-Central California Coast ESU. The annual run of steelhead in the Carmel River historically sustained a popular fishery that supported over 10,000 angling hours per year, the second largest steelhead fishery south of San Francisco (Snider 1983). Steelhead returns to the Carmel River are now greatly reduced from historic levels. Recent adult returns to the SCD are estimated to be in the hundreds, whereas, historic

Table 3. Estimated average daily unimpaired stream flow (cfs) expressed as percent exceedence at the USGS Robles del Rio gage on the Carmel River during each month (data from NRCE 2002).

Exceedence	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10%	583	962	685	423	165	81	38	17	13	13	57	163
20%	281	475	427	251	112	52	25	10	7.4	8.5	24	75
50%	48	116	117	81	41	21	7.5	1.6	0.3	1.9	8.5	23
80%	17	37	41	25	15	6.1	0.1	0.0	0.0	0.0	0.2	8.7
90%	11	19	23	16	9.0	2.2	0.0	0.0	0.0	0.0	0.0	4.0

Table 4. Estimated average daily unimpaired stream flow (cfs) expressed as percent exceedence at the USGS Near Carmel gage near Carmel during each month (data from NRCE 2002).

Exceedence	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10%	686	1172	803	502	196	93	43	19	14	13	52	179
20%	320	553	501	293	131	60	28	12	7.9	8.9	22	79
50%	48	134	134	89	44	22	8.3	1.7	0.4	1.7	7.6	21
80%	15	36	42	25	14	5.6	0.1	0.0	0.0	0.0	0.0	5.9
90%	9.4	18	22	16	8.3	1.7	0.0	0.0	0.0	0.0	0.0	1.5

returns to the river have been estimated to be as high as 12,000 to 20,000 adult fish (Snider 1983; CACSS 1988). Given this decline and the need to recover steelhead populations, potential opportunities for achieving significant enhancements to this population must be carefully evaluated. Options for managing water supply in the Carmel Valley provide an important opportunity for achieving potential long-term enhancements and recovery of steelhead in the Carmel River.

The reductions of flow and the dewatering of the lower river have substantially reduced available steelhead habitat downstream of the Narrows (a river constriction at rivermile 9.6). Although many steelhead spawn in the Carmel River, the actual production of juveniles is reduced because survival depends upon stream flows sustaining quality habitat in the mainstem and Lagoon throughout summer and fall months. Impacts to steelhead occur not only from the dewatering of stream channels that eliminates habitat, causes stranding, and increases the rates of predation. The pumping of subterranean flows also adversely affects riparian vegetation, which in turn promotes bank erosion and the destabilization of the river channel. Many sites along the banks of the Carmel River have been hardened with rip-rap, resulting in additional losses of habitat for steelhead.

Long-term solutions to resolving the impacts of excessive water diversions will require alternative sources of water for the Carmel Valley during periods of low flow. Recognizing that the development of long-term solutions will take several years to accomplish, SWRCB Orders 95-10 and 98-04 required Cal-Am to develop and implement interim measures for at least partially mitigating diversion impacts. In late 2001, Cal-Am and NMFS completed a "Conservation Agreement" whereby Cal-Am will work cooperatively with NMFS and other resource agencies in a scheduled program for modifying diversion practices for the purpose of mitigating impacts to steelhead. Under the "Conservation Agreement" excessive water diversions will continue; however, steps will be taken for partially mitigating their impacts, and the development and implementation of long-term solutions to eliminating significant impacts will be expedited. This report concerning flow needs for Carmel River steelhead contributes to efforts to develop long-term solutions for resolving ongoing impacts to steelhead and water supply needs for the Carmel River Valley.

3.0 Stream Flows to Protect and Restore Steelhead in the Carmel River

A Fishery Working Group (FWG), comprised of representatives of the MPWMD, CDFG, and NMFS, developed flow requirements for the Carmel River for the purpose of preserving and protecting the Carmel River steelhead resource (FWG 1994). The stream flows recommended by the FWG were developed as operational requirements for the New Los Padres Dam and Reservoir Project, a precursor of the Carmel River Dam and Reservoir Project. Because they were developed for a large on-stream project, the flow requirements recommended by FWG (1994) assumed that unregulated flows could be augmented with water from the on-stream reservoir. This is especially true for low flow seasons (summer and fall) when flow requirements of the FWG exceed natural, unimpaired flows. In addition, FWG recommendations for "spawning flows" assumed that substrate conditions were substantially improved through habitat improvement efforts. Nevertheless, the FWG recommendations provide useful insights into seasonal differences in flow needs and flow requirements for adult migration and spawning in downstream reaches.

FWG (1994) identified key seasons and steelhead life stages needing different levels of flow. Three seasons were identified: the winter period when flows are generally high and adult steelhead migrate and spawn (January 1 - March 31), the spring period of smolt outmigration (April 1 - May 31), and the summer-fall period of low flows that support juvenile rearing (June 1 - December 31). For the most part, this seasonal scheme adequately describes the principal flow periods and their associated key life stages. We recommend adoption of these seasons with the exception that the winter migration period should begin prior to January 1 and it should end in mid-April. Dettman and Kelley (1986) report the arrival of steelhead at San Clemente Dam during late December in 1964 and 1973. Their analysis, which compares historical flows with the arrival of steelhead at the San Clemente Dam, indicates that the average time for fish to reach the Dam is about four days after an attraction flow. However, their data also suggest that elevated flows in early December do not promote early arrival of steelhead at the dam. For those reasons, we recommend that the summer-fall period end on December 14, and the winter migration/spawning season should begin on December 15. Likewise, fish passage records at the San Clemente Dam document that on several years about 10 to 20% of the steelhead run passed the San Clemente Dam during the first two to three weeks of April (MPWMD unpublished data). Therefore, the winter migration/spawning season should be extended until April 15 and the spring period should extend from April 15 to May 31.

In addition to FWG (1994), numerous other technical studies have addressed the issue of stream flow needs for steelhead in the Carmel River. Many provide useful information for developing stream flow recommendations. For example, Snider (1983), who reviewed the status of steelhead in the Carmel River, examined the relationship between the numbers of returning adult steelhead and seasonal stream flows. Snider also provided estimates of available habitat and juvenile densities in the mainstem and tributaries. Dettman and Kelley (1986) described the results of intensive field investigations of flows needed to facilitate upstream migration of adults, and the relationships between flow, available habitat and production of steelhead in various segments of the Carmel River mainstem and its major tributaries. Dettman and Kelley (1987) used the results of earlier studies to develop stream flow recommendations for alternative on-stream water supply projects. A series of studies by D.W. Alley & Associates examined the relationships between stream flow and steelhead habitat upstream from Los Padres Dam (Alley 1996), in the segment between Los Padres Dam and San Clemente Dam (Alley 1990; Alley 1998), and in the segment downstream from San Clemente Dam (Alley 1992; Alley 1998). The U.S. Fish & Wildlife Service (1980) also evaluated habitat-flow relations for steelhead in reaches downstream from the San Clemente Dam.

In addition to providing the flows needed to support habitat for various life stages of steelhead, it is important to preserve the river's natural hydrograph. The preservation of natural flow variability and high stream flows are equally important for maintaining stream ecosystem function (Barinaga 1996; Poff et al. 1997). High flows are essential for cleansing fine sediments from coarse substrates and for otherwise maintaining the integrity of stream channels (Cushman 1985; Reiser et al. 1985; Kondolf 1999). High winter stream flows remove encroaching riparian vegetation and contribute to the deposition of instream woody cover. Elevated stream flows are also important cues for the migratory movements of fishes (Poff et al. 1997; Banks 1969). To accommodate the need to conserve high channel maintenance flows, while allowing for reasonable diversions of water, we recommend the provision of a cumulative maximum rate of withdrawal (see Section 3.4).

3.1 Winter Flows (December 15 - April 15)

Any instream flow requirement for winter months must protect upstream adult migration and conditions for steelhead spawning. These are the key life stages for developing winter flow requirements, because adult migration and spawning habitat generally require higher sustained flows than other activities and life stages such as fry or juvenile stages (Raleigh et al. 1984; Bjornn and Reiser 1991; Groot and Margolis 1991). Overwintering juveniles typically reside in low velocity backwaters and pools that are sensitive to sudden losses of stream flow, but they are not necessarily dependent on high flow. (Nickelson et al. 1992; McMahon and Hartman 1989). Overwintering juveniles can be protected by the avoidance of unnatural sudden drops in stream flow.

As discussed above, the adult migration of steelhead commences in the Carmel River in early winter, with the earliest observations of steelhead at the San Clemente Dam occurring in late December. Therefore, flows for upstream migration should be protected beginning no later than mid-December (December 15) and they should continue until April 15. Based on analyses by Dettman and Kelley (1986; 1987) and critical riffle assessments by MPWMD staff (Dettman 1989), FWG (1994) recommended the following attraction flow requirements for adult steelhead:

1. During wet, normal, and below normal years, an attraction event begins when it is projected that an unimpaired flow (*i.e.*, no diversions in the watershed on that day) of 200 cfs or more would reach the Lagoon. Projections of unimpaired flow are determined using gage data and estimated losses of flow by diversion. Whenever an attraction event is projected, a minimum of 200 cfs to the Lagoon will be maintained for the duration of the attraction event. When flows subside below 200 cfs, migration flows of 200 to 60 cfs will be maintained to the Lagoon, depending upon estimated natural recession rates.

2. During dry and critically-dry years, the attraction flow is 200 cfs in January; but it is reduced in February and March to reflect observed migration behavior and to increase the number of attraction opportunities. During February and March of dry or critically-dry years, the attraction events begin when 100 cfs is projected in February or when 75 cfs is projected in March. Thus, in dry and critically-dry years, when the respective attraction events are projected, at least 200 cfs, 100 cfs, and 75 cfs will be maintained to the Lagoon during January, February, and March, respectively, for the duration of the attraction event.

With the exception of minimum flow requirements in February and March during dry and critically dry years, these recommended attraction flows for migrating steelhead appear reasonable and supported by site specific studies. Hydrologic data for the Carmel River in dry years show that stream flows can exceed 150 cfs on several days in February and March. Instituting the FWG (1994) minimum flow of 100 cfs in February and 75 cfs in March in dry years as a bypass flow requirement would appreciably reduce natural inflows that could be 200 cfs or higher. It is unreasonable to reduce minimum flows during attraction events to 100 or 75 cfs when it is known that higher flows (*e.g.*, 200 cfs) are superior for attracting steelhead. Therefore NMFS recommends that the FWG (1994) terms for attraction flow be adopted as minimum standards for long-term water supply planning, with the exception that in dry and critically-dry years attraction events of 100 cfs in February and 75 cfs in March should be associated with a minimum bypass flow of 150 cfs. The lower attraction flow threshold in dry years would ensure that spawning flows would be provided in most years, while the minimum bypass flow of 150 cfs during attraction events would conserve the magnitude of natural attraction flows. We recommend that dry and critically-dry years be determined using methods of the FWG (1994), which stated, "*Water year classifications are based on selected exceedence frequency and conditional probability values computed from the long-term reconstructed record of unimpaired flows at the San Clemente Dam (1902-1992). These classifications are updated each month during the Water Year and reflect expected conditions for the entire Water Year. The Water Year classifications can be updated within a month if significant rainfall or runoff occur*."

FWG (1994) recommended that once an attraction event occurs, a minimum level of flow must be maintained for the duration of the spawning period in order to provide spawning habitat. This is appropriate given that the initial attraction flow facilitates movement of steelhead upstream for the purpose of spawning. However, the requirement for spawning flows is probably only appropriate in segments providing spawning habitat. Dettman and Kelley (1986) reported that steelhead generally do not spawn in the Carmel River below Schulte Road Bridge at about RM 7. They reported that the transport and deposition of elevated levels of sand downstream from Schulte Road Bridge probably limited successful fry emergence in reaches below RM 7. Elevated levels of fine sediments in the river below RM 7 were partly the result of bank erosion associated with the 1976 -77 drought and subsequent floods. However, the stream has partly recovered from that erosion, and both gravel bars and spawning steelhead have often been observed in the river as far downstream as RM 5.5 (D.Dettman, MPWMD, personal communication). Therefore, flows below RM 5.5 should be based on criteria other than spawning needs.

A variety of studies have evaluated the relationship of Carmel River stream flows and spawning habitat for steelhead. These studies have differed in their evaluation techniques and the specific segment that was evaluated. Dettman and Kelley (1986) measured depths and surface water velocity over spawning gravel at three flows in five reaches below San Clemente Dam. From these measurements they estimated that there was at least five times more spawning habitat when flow at the Robles del Rio gage was 150 cfs than when it was 77 cfs. The Instream Flow Incremental Methodology (IFIM) is a more widely known quantitative method for ascertaining the relationship between stream flow and available habitat for individual life stages. Studies by D.W. Alley & Associates used the IFIM to determine habitat flow relations in various segments of the Carmel River, but their use of alternative habitat suitability index (HSI) criteria complicates their results and demonstrates the sensitivity of IFIM related habitat modeling to changes in HSI criteria (Table 5).

The results of IFIM associated stream habitat modeling describe the numerical relationship between stream flow and units of available habitat for individual life stages. In the parlance of IFIM, the standard unit of habitat is AWeighted Usable Area@ (WUA). One unit of WUA is equal to one square foot of optimal quality habitat as defined by the HSI criteria for the life stage. Alley & Associates= reports provide numerous graphical depictions of the relationship between stream flow and WUA in segments both upstream and downstream of San Clemente Dam. Decision makers using such data typically recommend project flows that provide either optimal conditions, near optimal conditions, or flows designated as inflection points. An inflection point on a WUA-Discharge curve is a flow where the rate of habitat gain noticeably declines with increasing flow. Table 5 shows the stream flows that maximize spawning habitat in two segments of the Carmel River based on alternative HSI criteria. Also shown in this table are stream flows providing 90% of maximum possible WUA and 80% of maximum possible WUA.

To fully recover steelhead to the Carmel River, it is appropriate to recommend that optimal or very nearly optimal flow conditions be retained for the spawning life stage. For that reason, we recommend that stream flows be protected with minimum bypass flows that maintain spawning habitat at levels that provide at least 90% of the maximum possible available spawning habitat for the species. Table 5 shows that, in the segment between Los Padres Dam and San Clemente Dam, flows of about 100 cfs provide approximately 90% of maximum WUA. Thus, during winter between attraction events, minimum bypass flows should be 100 cfs in the segment between the two dams.

Table 5. Stream discharges (Q) providing maximum Weighted Usable Area (WUA) , 90% maximum WUA, and 80% maximum WUA for spawning steelhead and adult rainbow trout in the Carmel River based on alternative Habitat Suitability Indices.

Lifestage	Reach[1]	Q @ Max WUA (cfs)	Q @ 90% max WUA (cfs)	Q @ 80% max WUA (cfs)	HSI Criteria	Reference
Steelhead Spawning	LP to SC	150	110	99	Bovee '78 w/ Alley depths	Alley 1998
Steelhead Spawning	LP to SC	135	99	87	Bovee '78 w/ Alley depth and Ideal substrate	Alley 1998
Steelhead Spawning	LP to SC	120	98	89	Bovee '78	Alley 1990 (per Alley 1998)
Steelhead Spawning	SC to Narrows	230	135	110	Bovee '78 w/ Alley depths	Alley 1998
Steelhead Spawning	SC to Narrows	230 +	About 150	About 120	Bovee '78 w/ Alley depth and Ideal substrate	Alley 1998
Rainbow trout Spawning	SC to Narrows	60	44	33	Bovee '78 (adult rainbow)	Alley 1992
Rainbow trout Spawning	SC to Narrows	150	93	70	Raleigh et al. '84 (adult rainbow)	Alley 1992
Steelhead Spawning	SC to Narrows	135	90	76	Bovee '78	Alley 1992
Steelhead Spawning	SC to Narrows	120	90	75	Bovee '78 w/ ideal substrate	Alley 1992
Steelhead Spawning	SC to Narrows	90	75	65	Bovee '78 w/ Dettman substrate	Alley 1992

LP = Los Padres Dam; SC = San Clemente Dam; Narrows = river constriction at RM 9.6.

In the case of the segment between San Clemente Dam and the Narrows (RM 18.5 to 9.6), the flow providing 90% of maximum WUA is less clear because of the differences in the HSI criteria used in the model runs. Alley (1998) used a modified depth criteria such that any depth greater than 1.15 feet was rated as optimal; whereas Alley (1992) rated depths between 1.15 and 1.2 feet as optimal, and depths greater than 3.5 feet were considered unuseable for spawning. Both of these studies by Alley used the velocity suitability criteria of Bovee (1978), although Alley (1992) also provided model runs using the criteria of Raleigh et al. (1984). The different depth criteria are the principal dissimilarity between the results of Alley (1992) and Alley (1998). Alley's (1998) use of criteria that rates depths of 5 to 10 feet as highly suitable for spawning seems inconsistent with observations that salmonids spawn typically in shallow riffles, often at hydraulic heads of riffles (Bjornn and Reiser 1991). Such areas typically have substantial hyporheic flow (*i.e.*, subsurface currents) that is needed to 1) transport high levels of dissolved oxygen to developing eggs and fry and 2) remove metabolic waste products from those lifestages. Deep runs and pools likely provide less favorable hydraulic conditions for spawning. For this reason, we believe the results of Alley (1992) probably better reflect habitat-discharge relations below San Clemente, than those of Alley (1998). Therefore, based on the results of Alley (1992), we recommend that, during winter between attraction events, a minimum bypass flow of 90 cfs or inflow be maintained in the Carmel River downstream of San Clemente Dam at least as far as RM 5.5, the approximate downstream extent of viable steelhead spawning habitat. As a final point regarding the decision to adopt the findings of Alley (1992), the results of Alley (1998) show that 90 cfs provides at least 95% of maximum WUA for spawning habitat at two out of three study sites using the Alley (1998) depth criteria.

For the segment downstream of RM 5.5, spawning flows may not be necessary; however, stream discharge must be conserved to ensure successful upstream passage. Dettman and Kelley (1986) and Dettman (1989) provide considerable analysis of this issue. Dettman and Kelley (1986) examined the flows needed for adult steelhead to successfully pass upstream through shallow "problem" riffles located downstream from San Clemente Dam. For that study, biologists identified five riffles between the Lagoon and San Clemente Dam that were among the most difficult passage barriers for adult steelhead. Of these, only one was located downstream of RM 5.5, and that downstream most riffle, named the Cement Blocks Riffle, required less flow for successful passage than three of the others. Dettman and Kelley (1986) concluded that, based on conditions when the field work was done (winter 1982), a flow of 75 cfs provided adequate passage conditions for adult steelhead at all but the most difficult riffle (the Paso Hondo Riffle). Their results also show that, based on conditions in winter 1982, a flow of 46 cfs would have been a minimal passage requirement at the Cement Blocks Riffle. Dettman (1989) reviewed previous studies (Dettman and Kelley 1986; USFWS 1980) concerning flow requirements for the lowermost reaches of the Carmel River. He reports that based on a refinement of habitat modeling by USFWS (1980), a minimum bypass flow of 58 cfs would be needed for adult migration through the reaches immediately upstream of Highway 1. However, Dettman (1989) defers to Dettman and Kelley's recommendation of 75 cfs for upstream passage, because the USFWS habitat modeling upstream of Highway 1 may not have included critical passage riffles, nor did it include transects across pools. Dettman (1989) ultimately concludes that more study is needed to determine if flows less than 75 cfs would be adequate for adult fish passage in the lower river segment (*e.g.*, downstream of Schulte Bridge).

We disagree that additional study is necessary for determining a recommendation for bypass flows to protect upstream migration in the lower river (*i.e.*, below RM 5.5). To address this issue, Dettman and Kelley (1986) "*repeatedly walked the Carmel River from the Lagoon to San Clemente Dam to locate and observe how stream flows affected the shallow riffles that constrain adult steelhead migration at low flows*." That effort yielded only one riffle (Cement Block) in the lower river, and it needed 46 cfs to meet minimum passage criteria. Additional analysis by Dettman (1989) indicated that one riffle modeled by USFWS (1980) needed 58 cfs to meet minimum passage criteria. Based on these results, we recommend that during winter when river flows drop below attraction flow thresholds, diversions should not decrease flows below 60 cfs in the segment between RM 5.5 and the Lagoon. However, we also recognize that stream channel conditions are variable over time. Therefore, we additionally recommend requiring annual monitoring of passage conditions for any scenario involving diversions with a minimum bypass of 60 cfs in the lower river. If channel conditions do not meet established passage criteria (*e.g.*, minimum depths at the shallowest riffles) at the minimum bypass flow of 60 cfs to the Lagoon, channel modifications would be necessary to meet those criteria.

One final point regarding winter stream flows concerns the issue of flow ramping when flows drop below the attraction flow threshold. FWG (1994) recommended that when flows subside below 200 cfs, migration flows of 200 to 60 cfs will be maintained to the Lagoon, depending upon estimated natural recession rates. A review of average daily stream flow at the USGS Robles del Rio gage show that the receding limbs of storm hydrographs seldom drop more than about 10% on succeeding days when flows are below 200 cfs. Therefore, we recommend that when estimated unimpaired flow to the Lagoon drops below 200 cfs, bypass flow in reaches between RM 5.5 and San Clemente Dam should be ramped down over a four day period, with consecutive days providing minimum bypass flows of 175 cfs, 150 cfs, 125 cfs, and the spawning minimum flow of 90 cfs. During dry years the ramp down would similarly extend for four days:150 cfs,125 cfs,100 cfs, and finally to 90 cfs. For the segment downstream from RM 5.5, we recommend a ramp down schedule of six days, with consecutive days providing minimum bypass flows of 175 cfs, 150 cfs, 125 cfs, 100 cfs, 80 cfs, and the final passage bypass flow of 60 cfs.

3.2 Spring flows (April 15 - May 31)

During spring, most adult steelhead in the river have completed spawning, and their eggs are incubating within the streambed gravels. At this time, most juveniles that have spent at least one year in the stream, migrate downstream to the ocean. The survival of these migrating juveniles is partly dependent on the level of flow. Therefore, this life stage must be protected by any flow requirement for spring months.

The migration of juveniles is controlled by the biological process of “smoltification” in which juvenile steelhead become physiologically adapted for downstream migration and entry into saltwater. Juvenile fish that have undergone smoltification are called smolts. The fish’s size and photoperiod are key factors determining the onset of smoltification (Schreck 1982; Raleigh 1984; Bjornn and Reiser 1991). Although smoltification may commence sometime in mid to late winter, juvenile steelhead generally become fully ready to make the migration sometime in spring. Snider (1983) states that in the Carmel River, most juvenile steelhead migrate to the ocean between April and June. This is the typical time for the smolt migration of steelhead and salmon in coastal watersheds along the western United States (Busby et al 1996; Weitkamp et al. 1995).

Bjornn and Reiser (1991) state that the timing of seaward migrations of salmonids that rear for an extended period in streams appears to be regulated by photoperiod, although stream flow, water temperature, and growth may be factors in some areas. Jonsson and Ruud-Hansen (1985) provide evidence that water temperature is the primary factor determining the timing of Atlantic salmon smolt migrations in many rivers. However, they also provide examples of rivers where seaward smolt migrations of steelhead and salmon coincide with increases in water discharge (White and Huntsman 1938; Allen 1944; Osterdahl 1969; Raymond 1979; Northcote 1984). Chapman (1965) also reported that relatively large freshets appeared to cause large downstream movements of juvenile coho.

Although not all smolt outmigrations are triggered by elevated flows, stream flow does affect the travel rates of most migrating smolts. The downstream migration of smolts is largely a passive process (Fried et al. 1978). Thorpe and Morgan (1978) reported that Atlantic salmon smolts appear to be unable or refuse to swim against water velocities greater than 2 body lengths per second. They state that there is “*a remarkable reduction of swimming performance at smolting*.” Thorpe et al. (1981) observed that “*it would be energetically inefficient and ecologically imprudent for smolts to swim actively downstream when a river could transport them passively over the same route. Pressure to evolve such active behavior would only arise if the passive transport system was too slow, or resulted in delivery of smolts into the sea at an inappropriate season*.” Berggren et al. (1993), who examined the time that it takes juvenile steelhead to migrate through reaches in the Snake and Columbia rivers, reported that estimates of smolt travel time for yearling steelhead were inversely related to average river flows. Fried et al. (1978) stated that water current was the main factor influencing routes and rates of smolt movements. Delays in the rate of downstream movement can influence smolt survival. Cada et al. (1994) concluded that relevant studies "generally supported the premise that increased flow led to increased smolt survival." Addressing conditions in the Carmel River, Snider (1983) states that there was a direct correlation between the flow conditions in April and May (the downstream migration period) and the number of adults counted at the San Clemente Dam fishway two years later. [*note to reader: steelhead generally spend two years in the ocean before returning to their natal stream to spawn*].

Because flow affects downstream travel time of smolts and higher flows can promote higher survival during the downstream migration, it is appropriate to conserve stream flows during April and May. Unfortunately there is no tool or standard for determining the precise flows needed for successful smolt migration. FWG (1994) recommended that during wet, normal, and below normal years, 40 cfs to the Lagoon would be an adequate flow for smolt outmigration. However, the support for that recommendation was insubstantial. Dettman (1993) indicates that 40 cfs was chosen for spring months because it provides near optimum flows for juvenile rearing habitat and food production. Dettman (1993) states that the 40 cfs for April and May and somewhat lower flows in dry and critically-dry years "*were recommended within the constraint of providing high quality habitat, without severely depleting reservoir storage*." The 40 cfs was not specifically selected for the purpose of facilitating smolt outmigrations.

To formulate a flow recommendation for spring flows, it is necessary to draw upon existing biological and hydrologic data and steelhead life history information. It is known that travel rates of smolts are directly related to stream flow, and that increased travel rate promotes smolt survival. Increased flow provides greater depths, currents, and surface turbulence all of which help to reduce rates of predation by birds. Snider (1983), who asserted that high spring flows promote smolt survival, observed that between 1960 and 1974, the best adult returns occurred two years after years with the highest spring flows (*i.e.*, 1963, 1965, 1967 and 1973). Dettman and Kelley (1986), who evaluated the relationship of winter stream flows to adult returns, pointed out the converse: Water Years 1962, 1970, and 1974 had poor returns, because spring flows were low two years earlier when juveniles were migrating. A review of minimum, maximum, and mean flows in April and May from 1958 to 1999 show that peak flows are often greater than 200 cfs in April and more than 100 cfs in May (Table 6). The spring flows that Snider contends contributed to large adult runs had mean April flows of more than 150 cfs, substantially higher flows than the overall average flow for April. For example, the mean monthly flow in April is at least 75 cfs during half of the years of record at the USGS Robles del Rio gage (Table 6). It is also worth noting that these data reflect impaired conditions due to historic diversions. Analysis of unimpaired flow at this site indicates that unimpaired flow at Robles del Rio is about 5 to 10 cfs higher than the impaired gage data (NRCE 2002). Therefore, unimpaired mean monthly flow in April at Robles del Rio gage was probably at least 80 to 85 cfs during half the years of record.

Two factors probably contributed to the observed positive relationship between spring stream flow and subsequent adult returns two years later. First, during the 1960's and 1970's, flashboards were installed at San Clemente Dam in the middle of the smolt outmigration during low flow years; whereas during wet years, this activity was delayed until late spring (D.Dettman, MPWMD, personal communication). These "early" installations of flashboards probably impeded the movements of smolts attempting to migrate past the dam. A second and perhaps more important factor was whether lagoon inflows were high enough to keep the mouth of the lagoon open during the smolt outmigration. James (1994) states that inflow to the lagoon of 200 cfs will maintain outflow to the ocean 100 percent of the time, and that inflow of 100 cfs keeps the lagoon mouth open 90 percent of the time. James reports that below 100 cfs, the lagoon mouth closes on an intermittent basis, and that when inflow recedes to 10 cfs or less the mouth remains closed, unless inflow substantially increases.

One solution for protecting the relatively high flows of April and May is a combination of minimum bypass flow <u>and</u> a maximum instantaneous rate of diversion on the river (*i.e.*, a maximum cumulative pumping rate). The minimum bypass flow would ensure that flows remain at some modest level for smolts, while a cumulative maximum instantaneous rate of diversion would preserve the natural hydrograph and its high flows. A maximum rate of diversion would ensure that the flow is not continuously maintained at the minimum level (*i.e.*, flatlined). In April and May, a minimum bypass flow of 80 cfs to the Lagoon together with a cumulative maximum instantaneous rate of withdrawal of less than about 100 cfs should adequately protect steelhead. A minimum flow of inflow or 80 cfs to the Lagoon from mid-April through May is a reasonable requirement, given that 1) the unimpaired <u>mean</u> flow in April is at least 80 cfs at Robles del Rio during half the years of record, and 2) smolt survival and subsequent adult returns are associated with years having relatively high spring flows. The additional provision for a maximum cumulative instantaneous rate of withdrawal of about 100 cfs from the river would protect the natural hydrograph and preserve April flows greater than 150 cfs during relatively wet springs. A recommended 80 cfs minimum bypass flow in May will appreciably exceed historic mean monthly flows in May. However, it is necessary to conserve the infrequent occurrences of relatively high flows in May given their importance to outmigrating smolts. The highest single daily flow (*i.e.*, monthly maximum) in May is often in the range of 80 to 200 cfs (Table 6). A collective capacity to divert 50 to 100 cfs in April would have the potential to greatly affect the natural hydrograph in May unless May flows were protected with a substantial minimum flow.

To conserve natural inflows of 80 cfs or less to the Lagoon from mid-April through May, it will be necessary to limit water diversions to the maximum extent possible when estimated unimpaired flows to the lagoon are less than 80 cfs during that period. Given the potential for cumulative impacts of existing legal diversions on stream flows between mid-April and May, we recommend that no additional diversions be permitted or otherwise be allowed to occur in the segment downstream of San Clemente Dam between April 15 and May 31 unless it is conditioned with a minimum bypass flow of 80 cfs or inflow, whichever is less. Diversions upstream from the San Clemente Dam should be conditioned with bypass flows that conserve natural inflows less than 80 cfs.

This can be accomplish by prorating a bypass flow requirement at San Clemente Dam, taking into account the accretion from the watershed below the dam and the estimated losses due to pumping in the subterranean aquifer.

Any recommendation concerning flow requirements to protect outmigrating smolts will have some associated level of uncertainty. The true relationship between smolt survival and spring flows in the Carmel River is not fully known. However, as discussed, smolt outmigration is likely benefitted by higher spring flows. Spring flow is a very important issue because, unlike spawning or juvenile habitat, adverse conditions for smolts in a small segment of the mainstem can impact the total annual production of steelhead in the entire watershed. All steelhead that reach the smolt stage must run the gauntlet through the lower mainstem during the relatively low flows of April and May. Flow conditions in the mainstem during this time can be a real limiting factor for the Carmel River steelhead population. Therefore, relatively high minimum flows and maximum instantaneous rates of diversion are warranted.

Table 6. Minimum, maximum and mean daily flows in the Carmel River at the USGS Robles del Rio gage during April and May for the period of record.

	April			May		
Water Year	Min	Max	Mean	Min	Max	Mean
1958	170	4800	1071	25	160	97
1959	7	27	15	1	12	4
1960	10	60	38	5	80	18
1961	0	14	3	0	1	0.5
1962	24	106	56	9	31	20
1963	180	994	375	79	272	149
1964	9	92	32	5	30	13
1965	60	322	163	4	91	41
1966	2	28	8	0	6	1
1967	241	915	513	92	413	193
1968	2	61	16	0.2	4	1
1969	105	414	227	41	116	76
1970	30	69	46	12	49	26
1971	13	50	36	12	29	21
1972	0.4	53	9	0	0.3	0.1
1973	91	276	159	17	88	61
1974	119	1320	310	44	124	73
1975	119	311	194	41	116	77
1976	0.7	1.7	1.1	0	1.1	0.3
1977	0	0	0	0	0	0
1978	216	457	285	89	224	142

	April			May		
Water Year	Min	Max	Mean	Min	Max	Mean
1979	82	385	163	37	822	59
1980	132	340	176	69	128	96
1981	51	195	96	9	50	33
1982	226	3430	829	79	205	125
1983	370	2700	706	195	1050	410
1984	28	76	49	11	36	24
1985	28	141	58	11	24	15
1986	97	247	154	18	94	57
1987	5	45	17	3	13	4
1988	1	5	2	2	5	3
1989	4	42	12	3	16	8
1990	3	5	4	2	4	3
1991	18	202	75	9	22	16
1992	22	94	51	10	22	16
1993	69	180	112	26	67	42
1994	13	18	15	11	18	14
1995	99	398	203	89	194	138
1996	75	285	137	42	199	67
1997	34	58	46	16	30	22
1998	265	664	455	180	300	237
1999	114	426	210	45	109	70

3.3 Summer and fall flows (June 1 to December 15)

During summer and fall, stream flow in the Carmel River generally declines steadily from June through October, except for unusual and brief episodes of minor precipitation that temporarily increase flow. In some years, flows increase in November or December with the onset of seasonal rainfall. However, in many years the higher seasonal flows of winter do not commence until January. By June, the adult steelhead, which entered the river to spawn months ago, have either returned to the ocean, perished, or become isolated in pools. The period of smolt migration is over sometime in June. In the life history of Carmel River steelhead, except for remnant smolt movements in June, summer and fall is a period of growth for rearing juveniles.

The growth and abundance of rearing juveniles in the Carmel River is related to stream flow. Dettman and Kelley (1987) estimated the production of juvenile steelhead between the Narrows and San Clemente Dam associated with alternative summer monthly minimum flows that might be obtained from a new large onstream reservoir project. They found the best production occurred with minimum flows greater than 20 cfs (Table 7).

Table 7. Estimated production of young-of-year steelhead between the Narrows and San Clemente Dam at alternative summer low flows (Estimates per Dettman and Kelley 1987).

Minimum summer flow	Habitat Quality	Estimated production
<0.5 cfs	critical	Less than approx. 12,500 y-o-y
0.5 - 1.7 cfs	poor	Approx. 12,500 - 25,000 y-o-y
1.8 - 6.0 cfs	fair	Approx. 25,000 - 50, 000 y-o-y
6.1 - 20.0 cfs	good	Approx. 50,000 - 100,000 y-o-y
>20 cfs	excellent	> 100,000 y-o-y

Dettman and Kelley (1987) also rated alternative flows in terms of their potential for stranding juvenile steelhead below San Clemente Dam. They rated flows of between 1 and 10 cfs “at the Narrows and into the Lagoon” as having a “medium” risk for stranding juvenile steelhead, but that flows greater than 10 cfs had “zero” risk of stranding.

Alley (1990) documented relations between stream flow and habitat for fry and juvenile steelhead. He reported that in the reach between San Clemente Dam and Los Padres Dam, maximum habitat for fry and juvenile stages are attained with flows of 15 and 40 cfs, respectively. Near optimum habitat (*i.e.*, at least 90% of maximum WUA) for fry is reached with flows of 10 to 33 cfs, and near optimum flows for juvenile range from 23 to 64 cfs. USFWS (1980) utilized the IFIM to determine habitat flow relations for fry and juvenile steelhead in the segment between the San Clemente Dam and the Highway One bridge. They report that juvenile steelhead and steelhead fry have maximum habitat areas at flows of 100 and 50 cfs, respectively. However, their data also show that flows of about 40 cfs also provide near optimum conditions for juvenile steelhead.

Steelhead are also benefitted by inflow to the Lagoon. The quality of the Lagoon as habitat for rearing juvenile steelhead is dependent on the Lagoon's depth, salinity, dissolved oxygen, and temperature. These factors are all determined primarily by the amount of freshwater inflow and tidal wash over the sandbar. Depths in the Lagoon are critically dependent on inflow. The Lagoon will gradually trend toward equilibrium with the water table once river inflows are less than about 8 cfs (James 1994). Once surface flow has ceased to the Lagoon, the water surface elevation declines at a rate that has been estimated to range from .03 feet/day to .19 feet/day (PWA et al. 1999). After the Lagoon mouth closed in 1996, water surface elevation (WSE) declined from approximately 7.7 feet NGVD to 3.7 feet between July 1 and July 31 (MPWMD, unpublished data). With this loss in depth, the Lagoon volume decreased from over 50 AF to less than 17 AF, a 3-fold reduction in 30 days (ENTRIX 2001). The decreased depth and volume, in turn, reduces the habitat area and food availability for juveniles that descend downstream into the Lagoon. Kitting (1990) found that within the Carmel Lagoon, the deep marsh habitat had the highest densities of invertebrates, and that lack of summer flow reduced water levels to the point that most deep water marsh habitat was eliminated.

When there is ample freshwater inflow to the Lagoon, this system can be highly productive and provides substantial habitat for yearling steelhead. During the wet summer of 1998, CDFG estimated that the Lagoon supported 10,000 juvenile steelhead, with an approximate average size of 300 mm (Jennifer Nelson, CDFG, personal communication). During that survey, one pull of a 100-foot long beach seine caught approximately 3000 juvenile steelhead. Surface flow to the Lagoon in summer 1998 was unusually high, with a mean monthly flow in August of 27 cfs at the USGS gage near Carmel (approximately 2.5 miles upstream from the Lagoon). In October 1996 a mark-recapture study indicated that 5,000 to 6,000 juvenile steelhead inhabited the Carmel River Lagoon (Alley 1997). That study concluded that the Lagoon supports a significant number of smolt sized steelhead in wetter years when flows to the Lagoon continue through spring and into the summer. It is worth noting that during late summer 1996, inflow to the Lagoon was probably entirely subterranean. Flow at the USGS gage near Carmel ceased in early August 1996 and did not resume until mid-November. However, 1996 was a better than average water year in the Carmel Valley and the subterranean aquifer apparently provided sufficient inflow to the Lagoon.

The restoration of summer flows in the lower river and natural inflow to the Lagoon would contribute significantly to the recovery of steelhead runs in the Carmel River.

As previously noted, estimated unimpaired summer flows in the lower river are relatively low during normal years. Estimated unimpaired flows for September in the lower mainstem exceed 0.4 cfs only about half of the time (Table 3 and 4). If the stream was unimpaired by diversions, flows would likely exceed 0.4 cfs in the lower river only during normal or above normal water years; in dry years, the lower river would probably continue to go dry after June or July. Nevertheless, the return of summer flows during even half of the years would contribute to substantially higher production of steelhead. The conservation of surface flows during the summers of normal or wetter years would provide habitat for rearing juveniles, and it would provide a corridor through which juveniles threatened with stranding and dessication could move to the Lagoon. The conservation of subterranean flow in the lower river is equally important because of the adverse effects of well pumping on riparian vegetation and the quality of the Lagoon as habitat for steelhead. Therefore, the predominant summer flow in the lower river during dry years (*i.e*., subterranean flow) must also be restored.

It is appropriate to conserve and restore both surface and subterranean flows in the lower Carmel River during the low flow season, because of the value of summer flows in 1) creating rearing habitat, 2) minimizing the stranding and dessication of juvenile fish, 3) providing a migratory corridor for the movements of fish and other aquatic life, 4) restoring riparian vegetation and habitats, and 5) restoring the quality of the Lagoon as habitat. However, the restoration and protection of summer and fall stream flows in this river can not be accomplished unless objective minimum standards are established. Minimum stream flows must be maintained in the Carmel River regardless of whether that stream is naturally reduced to subterranean flow in some years. FWG (1994) recommended establishing a minimum flow of 5 cfs to the Lagoon during summer and fall months of dry, normal, and wet years, unless storage in the proposed 24,000 AF reservoir is lower than 5000 AF. In the event of the latter, FWG (1994) recommended that a flow of 10 cfs would be maintained at the Narrows and no minimum bypass flow would be required at the Lagoon. FWG (1994) states that with a minimum flow of 5 cfs to the Lagoon, 20 cfs is an implied minimum bypass flow for the Narrows. These summer flow recommendations have merit, given that 5 cfs would provide substantial rearing habitat in the lower river and a corridor for fish movements. A minimum bypass flow providing less than 5 cfs inflow to the Lagoon would preclude the benefits of higher summer flows that occur in wet years, such as 1998. A minimum bypass flow of 20 cfs at the Narrows is also a reasonable guideline for the low flow months of June through November, given that 1) available habitat for juvenile steelhead increases appreciably downstream from San Clemente Dam as flows increase up to 40 or 50 cfs (USFWS 1980; Dettman and Kelley1986), and 2) stream flow rarely exceeds 20 cfs below San Clemente Dam between June and late November.

Although adequate for much of the low flow season, a minimum bypass flow of 20 cfs at the Narrows is probably not sufficiently protective of steelhead during December because: 1) flows are relatively high in December (*e.g*., average daily flow at the Robles del Rio gage exceeds 55 cfs during 20% of the days of record in December), and 2) Snider (1983) states, "I*t appears that juvenile steelhead in the Carmel River initiate downstream migration during the early rainy season, from late fall to early winter, moving to the lower river where growth conditions are more favorable."* Therefore, to conserve the increased amounts of juvenile habitat during December, we recommend that during the month of December diversions between San Clemente Dam and the Lagoon be operated with minimum bypass flows of 40 cfs, unless Attraction Flows occur after December 15, at which point diversions should be operated consistent with the guidelines for the winter season. Similar to recommendations for the winter and spring period, we recommend that the cumulative maximum instantaneous rate of diversion during December be limited to 80 cfs, in order to conserve the natural hydrograph in December.

As a practical matter, during the summer season of June 1 through December 15, there is likely no additional available water for diversion during the low flow months of June through October. The only additional new water that might be physically available for diversion (without impacting steelhead) during this season is the flow associated with the occasional seasonal runoff events in November and December coupled with the recommended minimum bypass flows and cumulative maximum rates of diversion.

To protect and restore runs of steelhead and other aquatic resources, diversions from the Carmel River between June 1 and November 30 should be limited to times when stream flow at the Narrows exceeds 20 cfs and when surface inflow to the Lagoon exceeds 5 cfs. Most of the time, such conditions may be impractical given historic authorized diversion practices and the perfection of water rights by many parties in the Carmel Valley. Nevertheless at a minimum, unauthorized diversions in the watershed by Cal-Am and others should be terminated during the summer and fall seasons. The SWRCB declared the Carmel River and its tributaries to be a fully appropriated stream system from its mouth to its headwaters between May 1 and December 31 of each year (SWRCB Water Right Order 98-08). That Order promotes the protection of steelhead and their habitats, although as described in this report, some modest flow may be available without harm to the fisheries (if not legally available) during May, November, and December if adequate minimum bypass flows are provided. In addition to curbing unauthorized diversions, no new diversions should be permitted, authorized, or otherwise sanctioned for the period June 1 to October 31. Additional diversions during November and December should only be permitted consistent with the recommended minimum bypass flows and cumulative maximum rates of diversion. Furthermore, authorized existing diversions during summer and fall should be curtailed to the maximum extent practicable, in order to help restore riparian vegetation, the quality of the Lagoon, and existing stream habitat in the river below San Clemente Dam. To that end, those with existing, authorized diversions from the Carmel River during summer and early fall should be encouraged to pursue alternative sources of water. For example, where possible, direct diversions for irrigation or municipal use should be converted to projects that divert and store winter flow in lined, off-stream reservoirs or aquifer storage projects. Where possible, reclaimed water should be used to reduce direct diversions from the river and its subterranean flow.

3.4 Channel Maintenance Flows

The substantial alteration of a river's natural flow regime can cause severe, long-term impacts to the river's morphology, stream hydraulics, substrate conditions, and habitat quality (Reiser et al. 1985; Wesche et al. 1985; Poff et al. 1997). Reducing the magnitude and duration of high flow events can induce channel narrowing and sedimentation from fines (Kondolf and Williams 1999). Discussing this issue, Reiser et al. (1989) states,

> The movement of sediments in a stream is dependent on two factors: (1) the availability of sediment in the drainage, and (2) the sediment transporting ability (competency) of the stream. Either factor may limit sediment transport rates, and changes in both can occur in conjunction with water development projects and flow regulation. In general, most water developments tend to reduce or eliminate the natural peak flows of the stream thereby reducing its competency. The net effect is that sediment in the system tends to accumulate rather than being periodically removed. With time, such sediment deposition and aggradation can adversely affect important fish spawning and rearing habitats (Chevalier et al. 1984; Cordone and Kelley 1961; Everest et al. 1986)."

A substantial literature has documented the adverse effects of large, on-stream dams on flow regimes. Several researchers have explored ways in which artificial high flow releases from storage reservoirs can mitigate such impacts (Kondolf et al. 1987; Power et al. 1996; Wilcock et al. 1996). Reviewing approaches for specifying flow releases ("flushing flows") for channel maintenance, Kondolf and Williams (1999) state that in an undammed river, the flood occurring every two years on average (Q_2) or the bankful discharge may provide a good initial estimate of an adequate channel maintenance flow that mobilizes the channel. Kondolf and Williams also reported that the Montana Department of Fish and Game recommends flushing flows equivalent to the flow with a pre-regulation recurrence interval of 1.5 years ($Q_{1.5}$). They indicate that such recommendations are based on geomorphological research that indicates that in many rivers the 1.5 or 2.0-year flow is the dominant or channel forming discharge. They state that such findings are generalizations that apply to many rivers, but that for accurate determination of the true flows needed to mobilize sediment, empirical studies are required.

Given that 1) stream channels are often maintained by $Q_{1.5}$ or Q_2 flows, and 2) direct diversions and diversions to offstream storage from the Carmel River would likely not greatly affect the highest flows of winter, the conservation of $Q_{1.5}$ or Q_2 flows should adequately protect and maintain the Carmel River channel below major diversion sites. It is important to note that $Q_{1.5}$ and Q_2 flows refer to instantaneous flows, not average daily flows.

Table 8 provides the annual highest average daily flow and the annual peak instantaneous flow at the Robles del Rio gage for the period of record. These data show that the highest average daily flow exceeded 1600 cfs on 22 of 44 years (51%). A peak instantaneous flow of 2760 cfs was exceeded on 50 percent of the years of record. A log-Pearson Type 3 curve fit of these data (USWRC 1982) indicate that the approximate 2 year recurrence peak instantaneous flow is 2300 cfs, and the approximate 2 year recurrence mean daily flow is 1445 cfs. To avoid significantly impacting these channel forming events, we recommend that, in the absence of additional site-specific information, these flows not be reduced by more than about 5 percent. Thus, to protect stream channel processes, cumulative, maximum daily withdrawals should not exceed a daily average of about 72 cfs or an instantaneous withdrawal of about 115 cfs. Additional field study of the river's geomorphology and sediment transport characteristics may demonstrate that somewhat higher levels of diversion can be accommodated without undue adverse environmental impact.

Table 8. Highest average daily flow (cfs) and peak instantaneous flow at the USGS Robles del Rio gage in Water Years 1958 - 2000.

Water Year	Highest Ave Daily Flow	Peak Instant. Flow	Water Year	Highest Ave Daily Flow	Peak Instant. Flow	Water Year	Highest Ave Daily Flow	Peak Instant. Flow
1958	4800	7100	1973	2280	3110	1988	269	412
1959	1220	2500	1974	2100	2760	1989	201	309
1960	585	838	1975	2890	4740	1990	553	1230
1961	18	22	1976	29	81	1991	1440	2730
1962	1820	2490	1977	5	34	1992	2090	3600
1963	3670	4950	1978	2780	7030	1993	3270	5100
1964	592	995	1979	866	1140	1994	415	533
1965	1040	1220	1980	4130	5920	1995	6500	16,000
1966	536	594	1981	1340	2320	1996	1690	3110
1967	2850	4750	1982	3430	5250	1997	2650	3940
1968	138	224	1983	6260	8380	1998	9000	14,700
1969	3960	6900	1984	2800	3390	1999	1080	2120
1970	1810	3120	1985	354	937	2000	2230	3160
1971	779	1040	1986	4130	6680	2001	1730	2640
1972	287	545	1987	947	2120			

4.0 A Preliminary Analysis of the Effects of the Instream Flow Requirements on Water Yield to Off-Stream Storage

The adverse effects of Carmel River water diversions upon steelhead would be alleviated if existing diversion practices were modified to include the preceding recommended minimum bypass flows and cumulative rates of diversion (Table 9). Probably the greatest single opportunity for substantially mitigating these impacts would be for Cal-Am to: 1) increase its diversions during seasonal (winter) high flows, 2) adhere to the minimum bypass flows and cumulative diversion rate recommendations, 3) store the diverted winter waters offstream (either Aquifer storage or ponds) for use during periods of low flow, and 4) make concomitant reductions in its unlawful diversions from the Carmel River. With these actions, Cal-Am would greatly reduce its diversions during low flow periods, while offsetting those reductions with additional diversions during the high flows of winter.

Current human demand for water in the Carmel River Valley exceeds the total annual runoff of the Carmel River in about one in four years. Total annual demand in the Carmel River System is about 12,900 AF; whereas total annual stream flow at the Robles del Rio gage is less than 15,000 AF in 11 out of 42 years of record (Table 10). Therefore, annual flow in the Carmel River simply cannot supply the water needs of the Carmel River in every year. The diversion and storage of large volumes of water during above normal or wet years could supply multiple years of demand; however, storing two or more years of supply would require a large reservoir that, if constructed on-stream, would have undue adverse effects to the river's hydrology and aquatic resources, including steelhead. As noted previously, a new large on-stream reservoir would inundate very high quality steelhead spawning and nursery habitat, it would be a significant barrier to downstream migrating juvenile and adult fish, and it would have a dramatic adverse effect on the natural hydrology of the river. The storage of two or more years of supply in off-stream ponds or aquifers has not been fully explored for the Carmel Valley.

To determine the potential volume of water available for diversion with the recommended minimum bypass flows and diversion rates, we have constructed a model that displays average daily flow at the Robles del Rio gage under conditions with and without additional diversions consistent with the recommendations. The model is a simple computational spreadsheet that includes stream flow at Robles del Rio, minimum flow criteria, and maximum rates of withdrawal. Figures 2 through 11 present results for 1) a water year that provided close to the mean annual flow (1984 with about 65,000 AF), 2) a water year that provided close to the median annual flow (1979 with about 46,000 AF), 3) a relatively dry water year (1994 with about 12,000 AF), and 4) an above normal water year (1973 with about 108,500 AF). To provide perspective on the variability of flows in the Carmel River, 1994 was not the driest year during the period of record. At the Robles del Rio gage, the total annual volume of flow was only 1,380 AF, 36 AF, and 6,659 AF in 1961, 1977, and 1990, respectively. Likewise, 1973 was not among the wettest. The highest flow occurred in 1983, when about 320,000 AF of surface flow passed the gage, and in 1958, 1969 , and 1998, total annual flow was about 150,000 AF, 170,000 AF, and 250,000 AF, respectively.

The results of this preliminary analysis are useful for approximating the water availability for various diversion scenarios that apply the minimum flow recommendations and varying maximum rates of diversion. The results are not finely tuned for differences in stream flow at varying points between San Clemente Dam and the downstream most diversion sites. Instead, the results estimate stream flow based on conditions at the Robles del Rio gage. Nevertheless, the results are probably conservatively low predictors of yield, because 1) tributary inflow below this gage is not included, and 2) the historic flows at the USGS gage used to represent flow conditions were impaired by existing water diversions including Cal-Am diversions from San Clemente Dam and other sites. Without Cal-Am's diversions during those representative years, total stream flow would have been higher (by about 10-15 cfs) on many days. Therefore, under new operational scenarios that replace summer diversions with winter diversions to offstream storage, there would be additional water for diversion on several days on each of the representative modeled years.

Three scenarios are provided for the representative mean (1984) and median (1979) water years: 1) a minimum bypass flow of 60 cfs and a maximum cumulative diversion rate of 80 cfs from the river, 2) a minimum bypass flow of 60 cfs and a maximum cumulative diversion rate of 60 cfs, and 3) a minimum bypass flow of 100 cfs and a maximum cumulative diversion rate of 80 cfs. By cumulative diversion rate, we refer to the cumulative diversions of Cal-Am and other water users in the watershed. The first of these three options assumes that substantial, additional diversion capacity is obtained in the segment below RM 5.5 and Cal-Am's existing diversion facilities are made fully operational with the recommended bypass flows (*i.e.*, existing well capacity of 66 AFD and a maximum capacity of 32 AFD at the CVFP). The second scenario assumes that less additional diversion capacity is obtained in the segment below RM 5.5. The third scenario assumes that the cumulative maximum diversion rate is substantially increased to 80 cfs; however, the increased diversion capacity would be in upstream areas requiring a minimum flow of 100 cfs for spawning.

For the representative dry (1994) and above normal (1973) years, two scenarios are presented: 1) a minimum bypass flow of 60 cfs and a maximum cumulative diversion rate of 80 cfs, and 2) a minimum bypass flow of 60 cfs and a maximum cumulative diversion rate of 60 cfs. Estimated total yield from these diversion scenarios are shown in Table 11.

The potential yield of water from winter diversion to offstream storage may actually be considerably higher than that estimated for median, mean, and above normal years. Additional yield may be possible through additional investigation of flushing flow needs for the river. Kondolf and Williams (1999) point out that the most accurate determinations of flushing flow needs are derived from site specific studies. The present recommendations call for limiting the maximum rate of withdrawal to only 5.5% of the estimated two-year recurrence mean daily flow (*i.e.*, 80 cfs). Additional investigation of channel dynamics may show that, as long as minimum bypass flows are sustained, the maximum rate of diversion could be somewhat higher without adversely affecting stream morphology and sediment conditions within the Carmel River.

Although additional analysis of cumulative maximum diversion rates would be useful and this preliminary analysis does not provide reach-by-reach analysis of the effects of pumping on stream flows along the lower river, the results show that there is substantial water (>10,000 AF) available for diversion during average water years and even more would be available during above normal and wet years. However, the results also demonstrate that during relatively dry years representing roughly 20% of the years, relatively little "surplus" flow (< 1000 AF) is available for withdrawal without potentially adversely affecting steelhead. To further refine estimates of available water under the recommended bypass flow requirements and limited diversion rates, we recommend that additional analysis of channel maintenance flow needs be performed and these requirements be incorporated in a water availability model such as CVSIM.

Table 9. Recommended minimum instream surface flows and cumulative maximum rates of withdrawal for new water diversions on the Carmel River.

Winter **Dec. 15 - April 15**	**Spring** **April 15 - May 31**	**Summer - Fall** **June 1 - December 15**
Wet, Normal, Below Normal Water Years Prior to 1st Attraction event continue December bypass flows. Attraction event: estimated unimpaired flow to the Lagoon of 200 cfs. During Attraction events bypass sufficient to maintain 200 cfs to Lagoon. Following Attraction events, provide minimum bypass flow of 100 cfs between LPD[1] and SCD; a minimum bypass flow of 90 cfs between SCD and RM 5.5; a minimum bypass flow of 60 cfs between RM 5.5 and the Lagoon. Limit cumulative maximum average daily diversion rate to 80 cfs.	Wet, Normal, Below Normal Water Years New projects must bypass 80 cfs between SCD and the Lagoon; above SCD, new projects must provide prorated flows yielding 80 cfs or inflow at SCD. Limit the cumulative maximum average daily diversion rate to 80 cfs.	Wet, Normal, Below Normal Water Years No new diversions are warranted June 1 to October 31. If feasible, June 1 to October 31, authorized diversions upstream of the Narrows should divert only when flow at the Narrows exceeds 20 cfs; authorized diversions downstream of the Narrows should divert only when inflow to the lagoon exceeds 5 cfs. November: New projects can divert with minimum bypass of 20 cfs at Narrows and 5 cfs at Lagoon. December 1-15: New projects can divert with minimum bypass of 40 cfs.
Dry and Critically Dry Water Years Attraction event: estimated unimpaired flow to Lagoon = 200 cfs in January; 100 cfs in February; 75 cfs in March. During Attraction events bypass sufficient to maintain 150 cfs to Lagoon. Following Attraction events, provide minimum bypass flow of 100 cfs between LPD[1] and SCD; a minimum bypass flow of 90 cfs between SCD and RM 5.5; a minimum bypass flow of 60 cfs between RM 5.5 and the Lagoon. Limit the cumulative maximum average daily diversion rate to 80 cfs.	Dry and Critically Dry Water Years same as for normal and below normal water years	Dry and Critically Dry Water Years same as for normal and below normal water years

[1]LPD = Los Padres Dam; SCD = San Clemente Dam

Table 10. Total annual runoff (Acre-ft) passing the Robles del Rio gage for Water Years 1958 to 1999.

Water year	Volume (Acre-ft)	Water Year	Volume (Acre-ft)
1958	150,253	1980	139,436
1959	23,314	1981	36,699
1960	14,652	1982	125,028
1961	1,380	1983	319,821
1962	42,397	1984	65,022
1963	78,721	1985	20,961
1964	19,286	1986	122,384
1965	41,704	1987	11,757
1966	19,974	1988	5,757
1967	107,641	1989	6,463
1968	6,332	1990	6,659
1969	170,378	1991	24,070
1970	47,558	1992	38,239
1971	26,971	1993	109,024
1972	8,309	1994	11,797
1973	108,547	1995	154,963
1974	80,787	1996	75,207
1975	82,075	1997	99,342
1976	683	1998	250,304
1977	36	1999	54,644
1978	149,114		
1979	45,983		

Table 11. Approximate yield from additional winter and spring diversions from the Carmel River under alternative minimum flow and maximum rate of diversion scenarios.

Water Year Type	Representative Year	Total Annual Runoff[1] (AF)	Scenario	Approx. Yield from Diversion (AF)
Mean	1984	65,022	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	12,474
Mean	1984	65,022	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 60 cfs	10,490
Mean	1984	65,022	Dec-Mar min flow = 90 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	9,631
Near median	1979	45,983	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	9,490
Near median	1979	45,983	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 60 cfs	8,215
Near median	1979	45,983	Dec-Mar min flow = 90 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	8,173
Dry	1994	11,797	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	875
Dry	1994	11,797	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 60 cfs	788
Above Normal	1973	108,547	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 80 cfs	16,836
Above Normal	1973	108,547	Dec-Mar min flow = 60 cfs Apr-May min flow = 80 cfs max diversion rate = 60 cfs	13,585

[1]Annual runoff at Robles del Rio gage

Figure 2. Winter stream flows at Robles del Rio gage during winter 1984 (mean water year with 65,000 AF) with minimum flow of 60 cfs and maximum diversion of 80 cfs

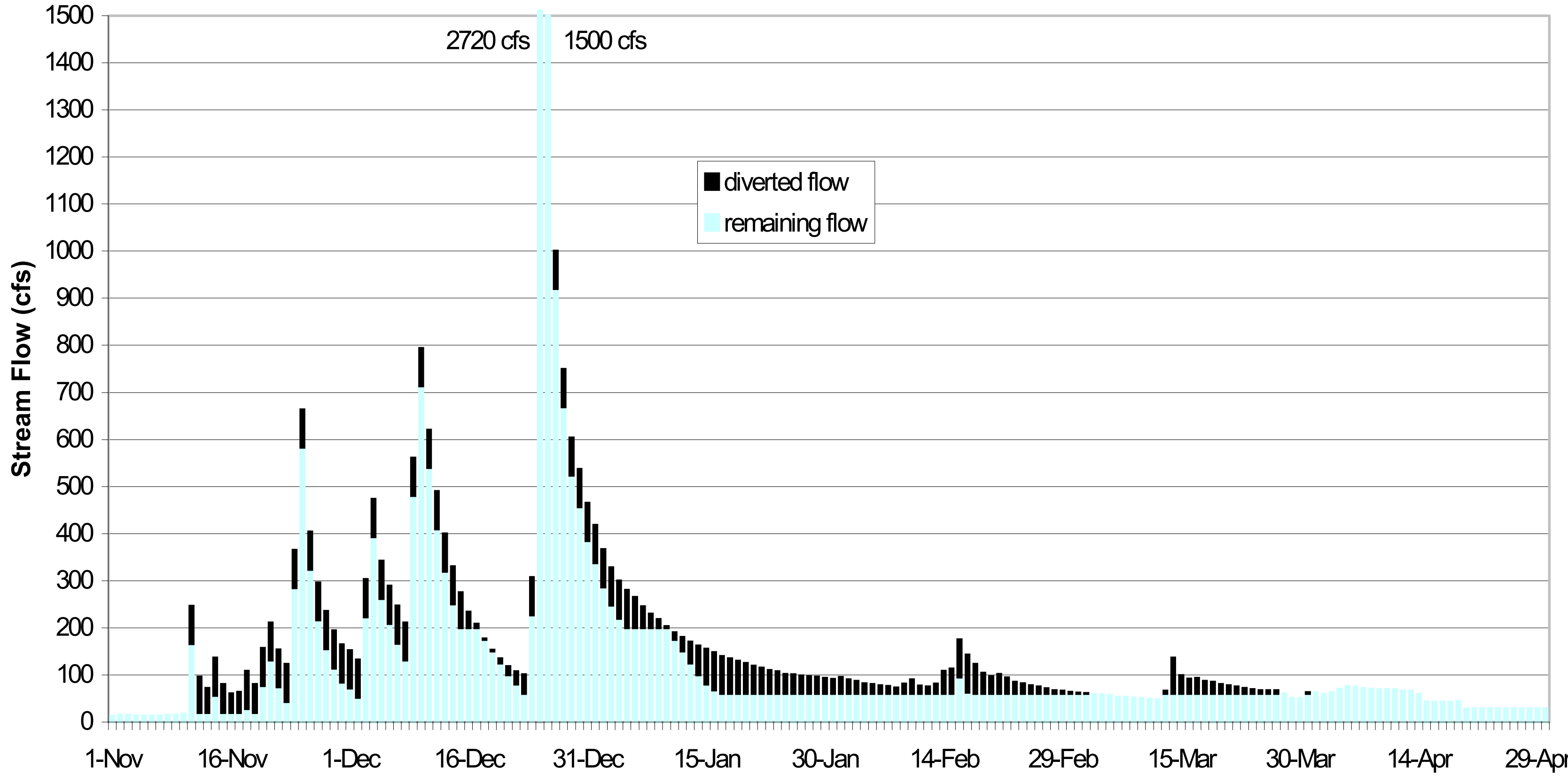


Figure 3. Winter stream flows at Robles del Rio gage during winter 1984 (mean water year with 65,000 AF) with minimum flow of 60 cfs and maximum diversion of 60 cfs.

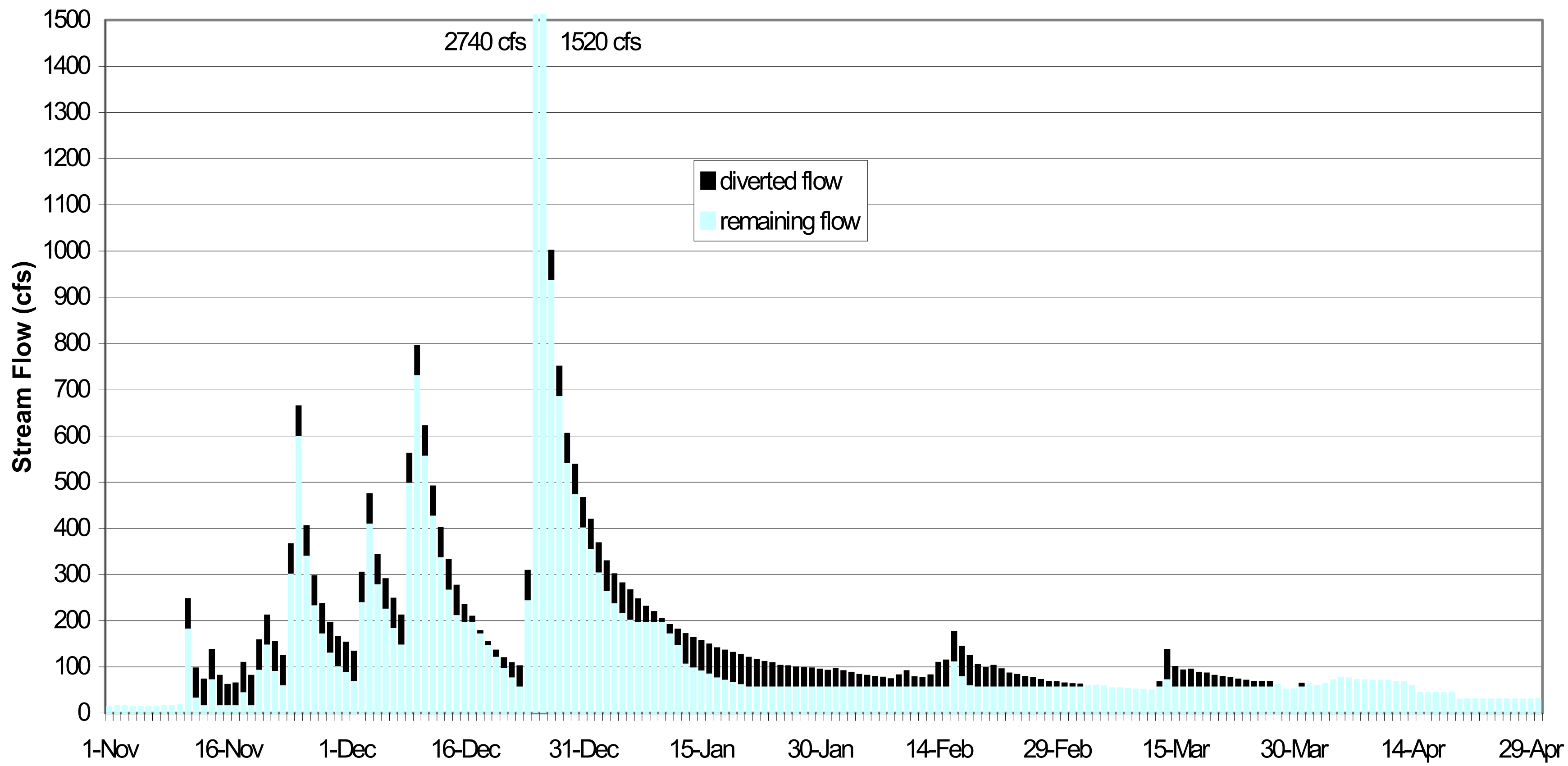


Figure 4. Winter stream flows at Robles del Rio gage during winter 1984 (mean water year with 65,000 AF) with minimum flow of 90 cfs and maximum diversion of 80 cfs

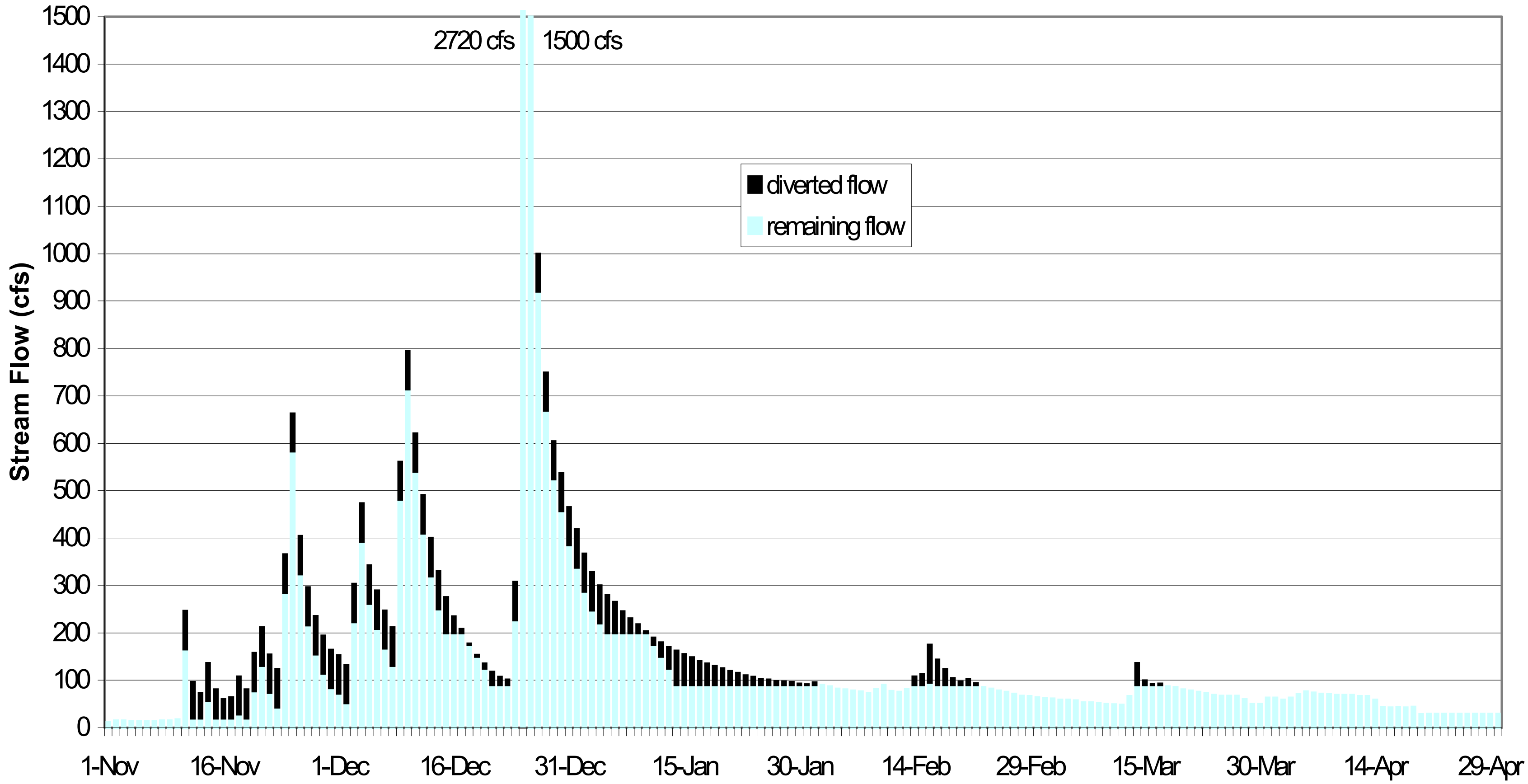


Figure 5. Winter stream flows at Robles del Rio gage during winter 1979 (near median water year with 46,000 AF) with minimum flow of 60 cfs and maximum diversion of 80 cfs

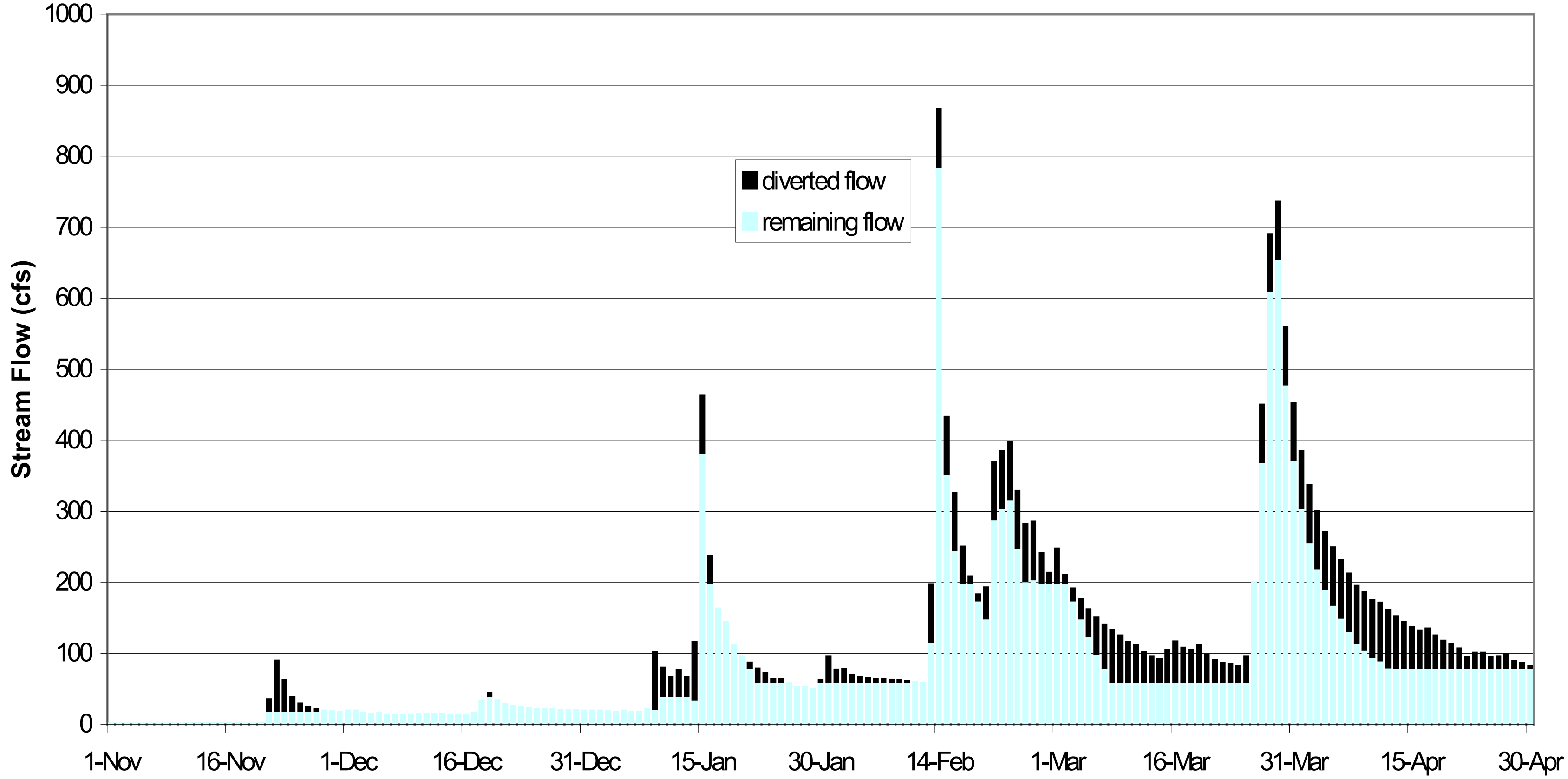


Figure 6. Winter stream flows at Robles del Rio gage during winter 1979 (near median water year with 46,000 AF) with minimum flow of 60 cfs and maximum diversion of 60 cfs

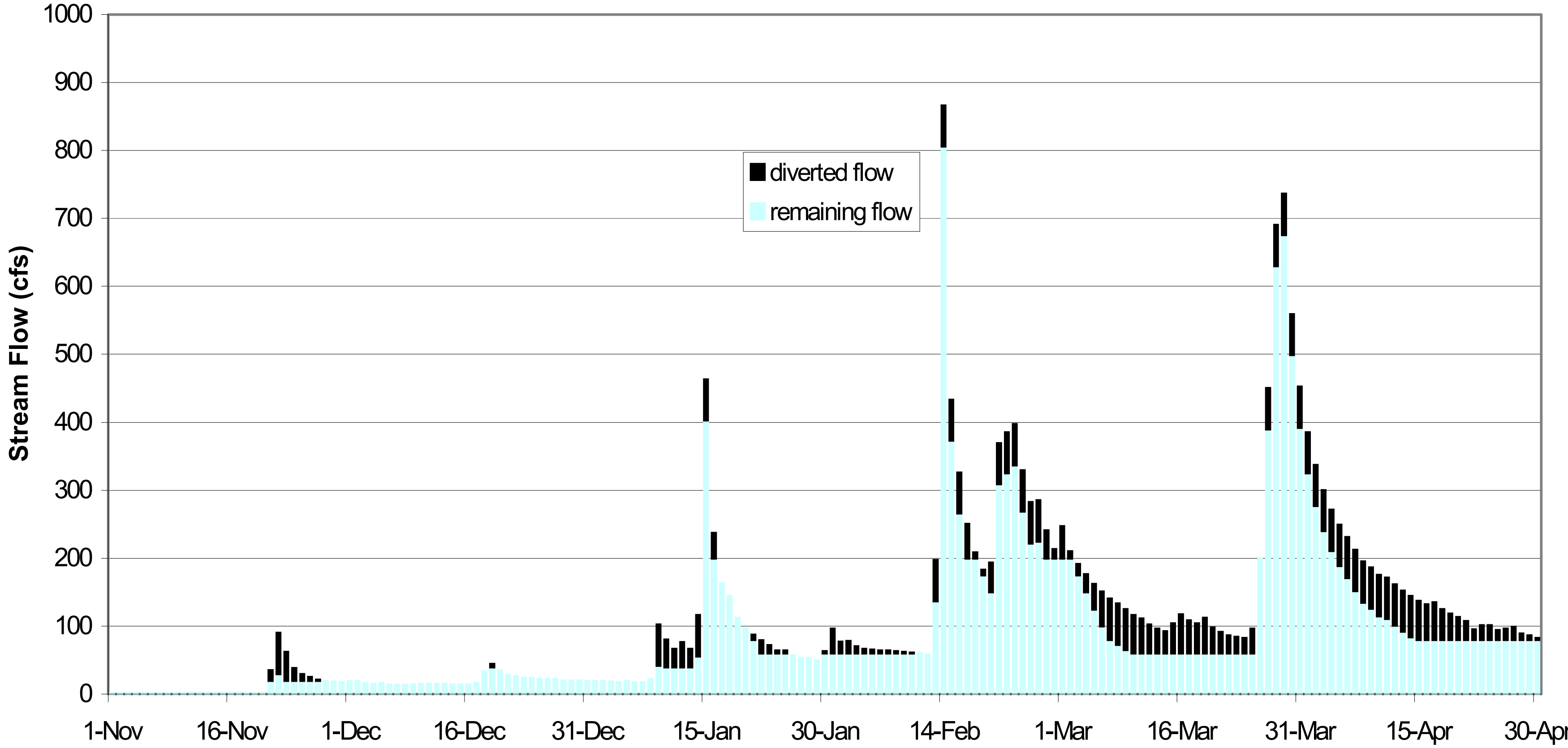


Figure 7. Winter stream flows at Robles del Rio gage during winter 1979 (near median water year with 46,000 AF) with minimum flow of 90 cfs and maximum diversion of 80 cfs

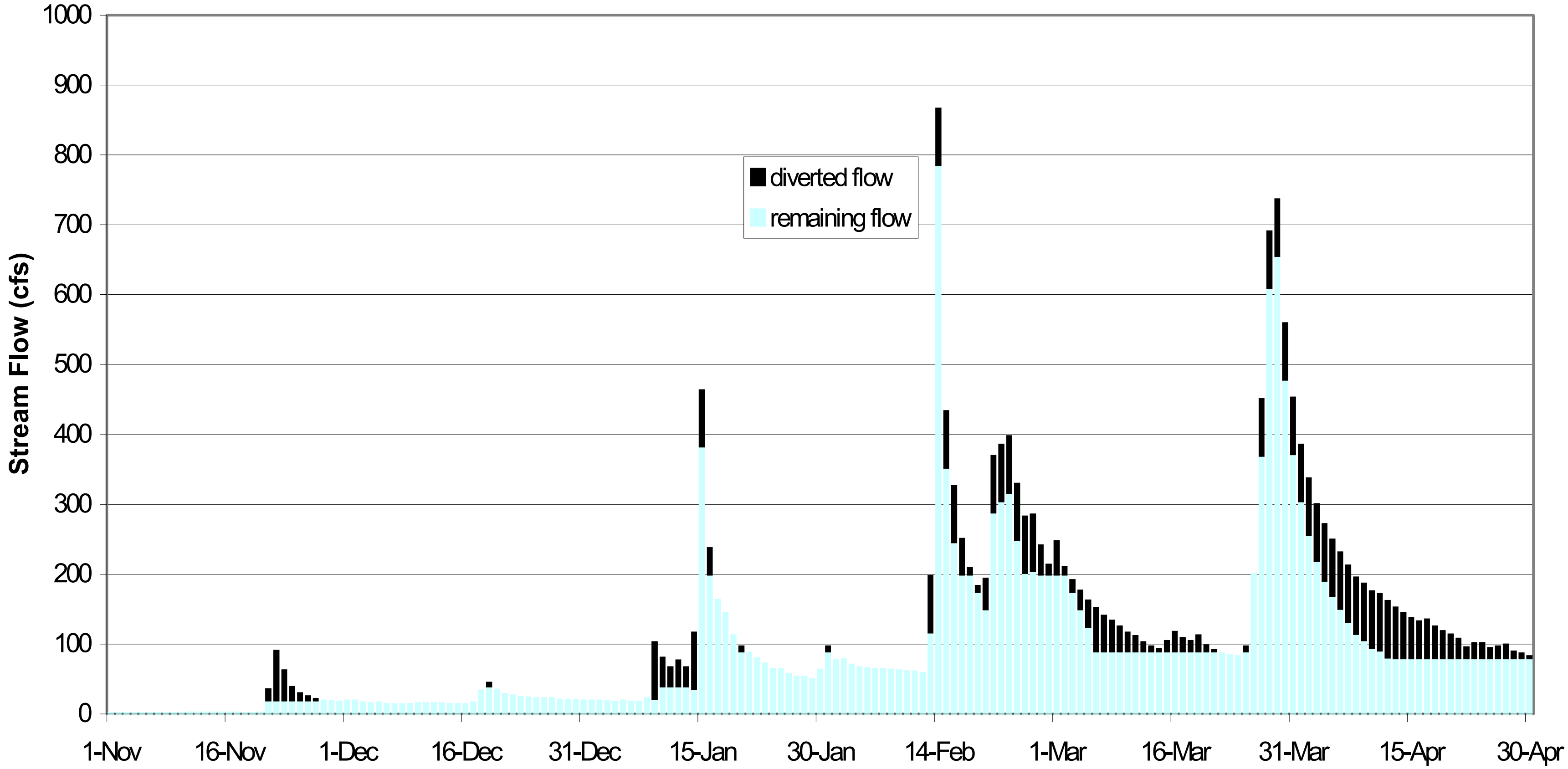


Figure 8. Winter stream flows at Robles del Rio gage during winter 1994 (dry water year with 12,000 AF) with minimum flow of 60 cfs and maximum diversion of 80 cfs

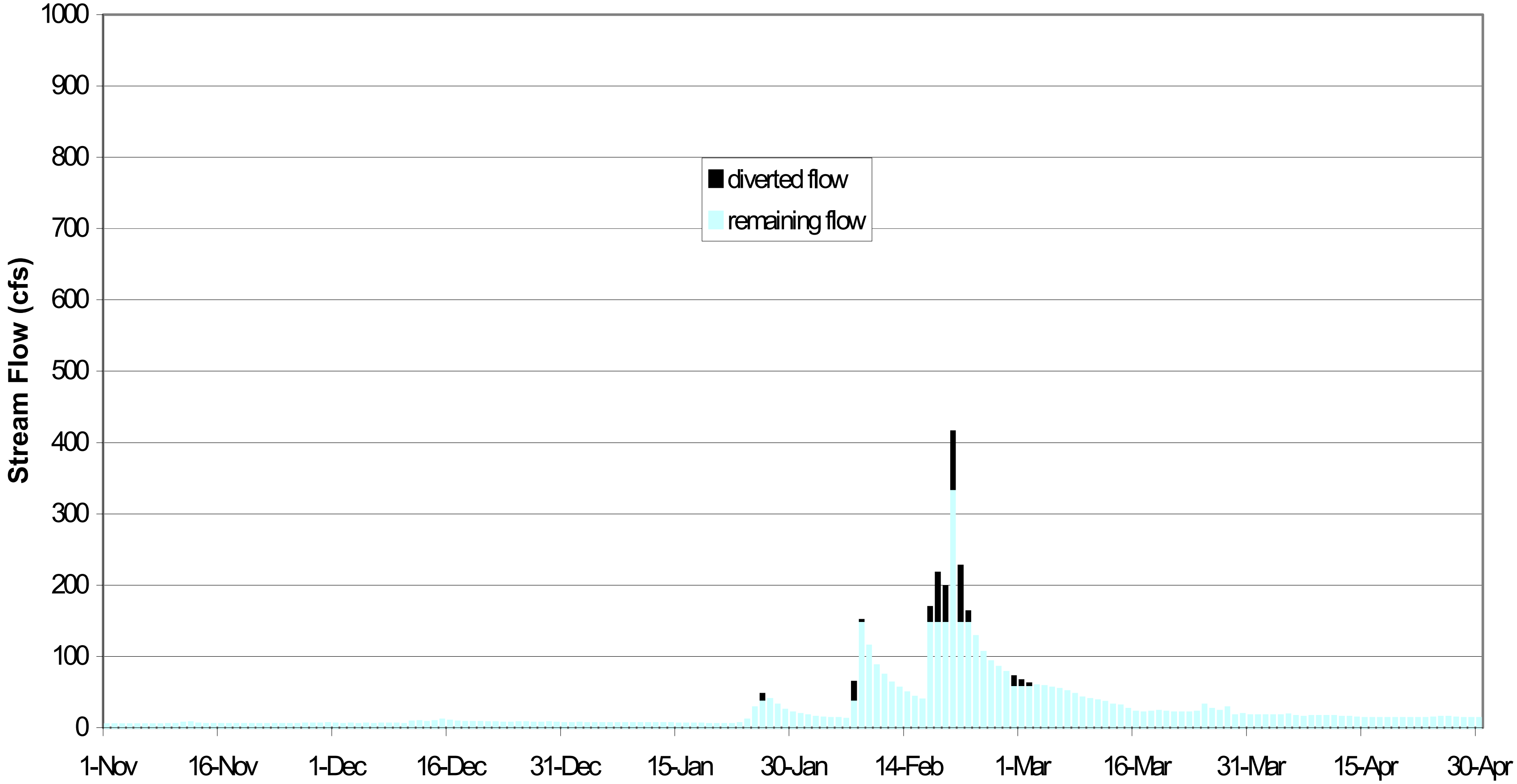


Figure 9. Winter stream flows at Robles del Rio gage during winter 1994 (dry water year with 12,000 AF) with minimum flow of 60 cfs and maximum diversion of 60 cfs

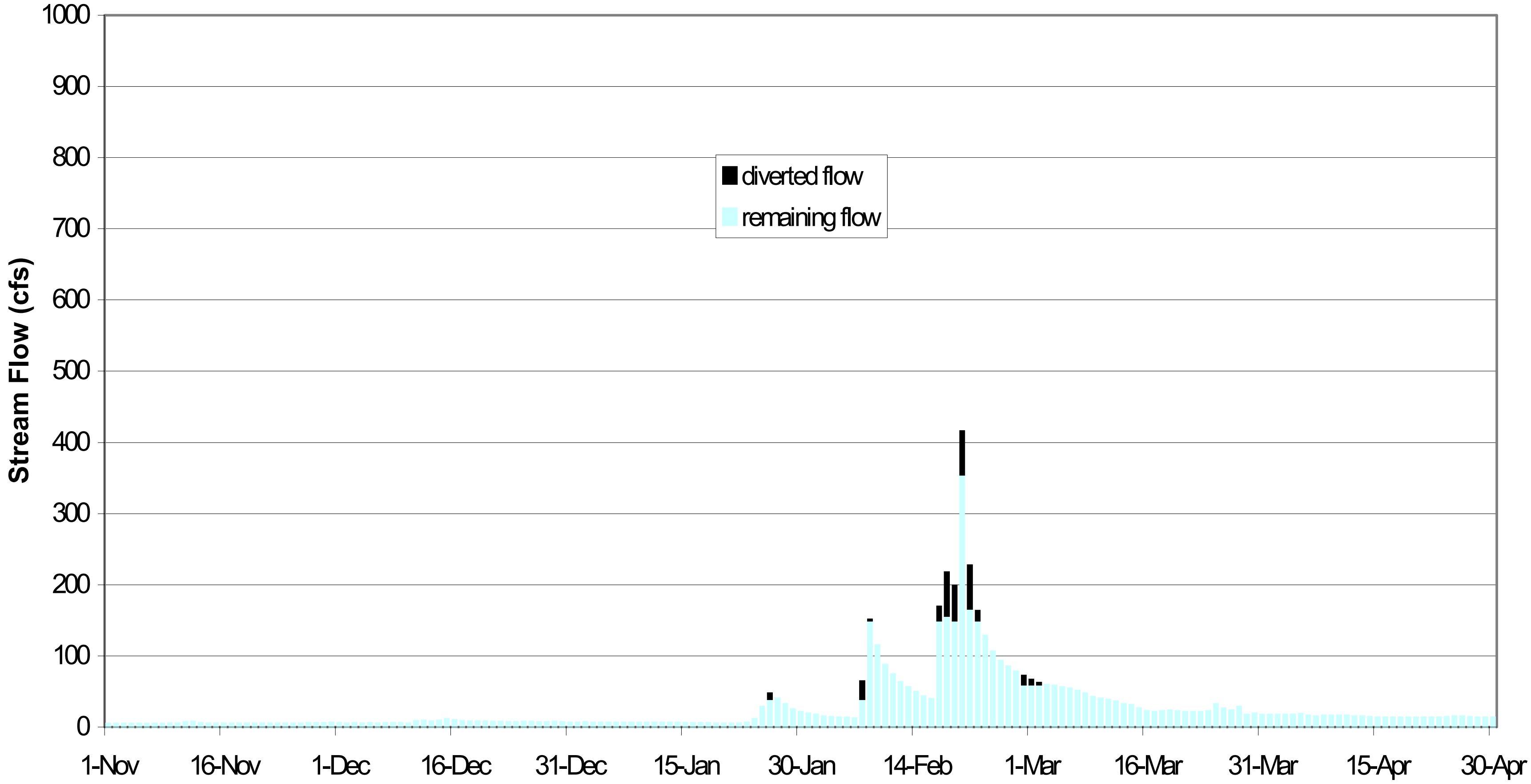


Figure 10. Winter stream flows at Robles del Rio gage during winter 1973 (above normal water year with 108,500 AF) with minimum flow of 60 cfs and maximum diversion of 80 cfs

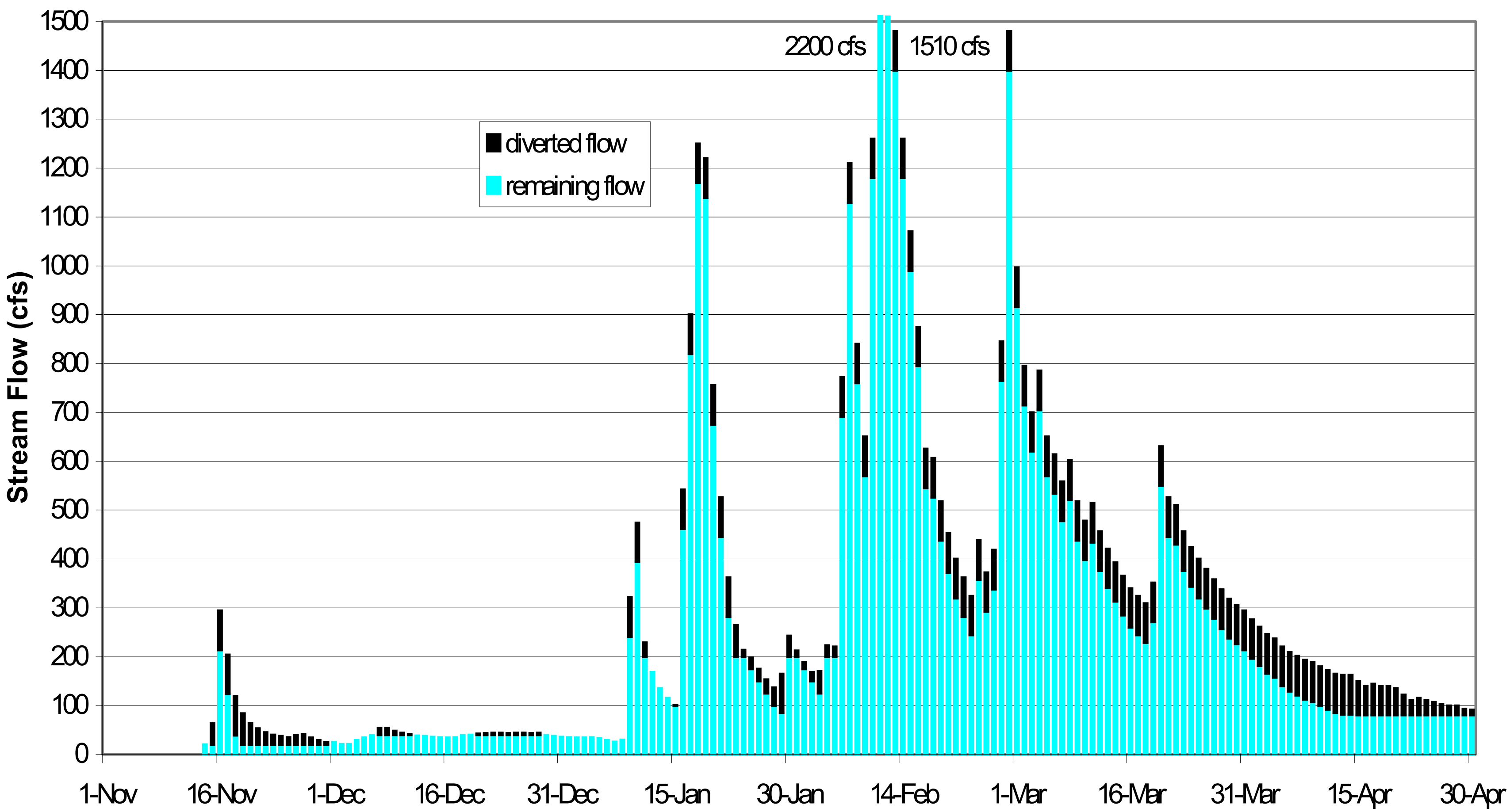
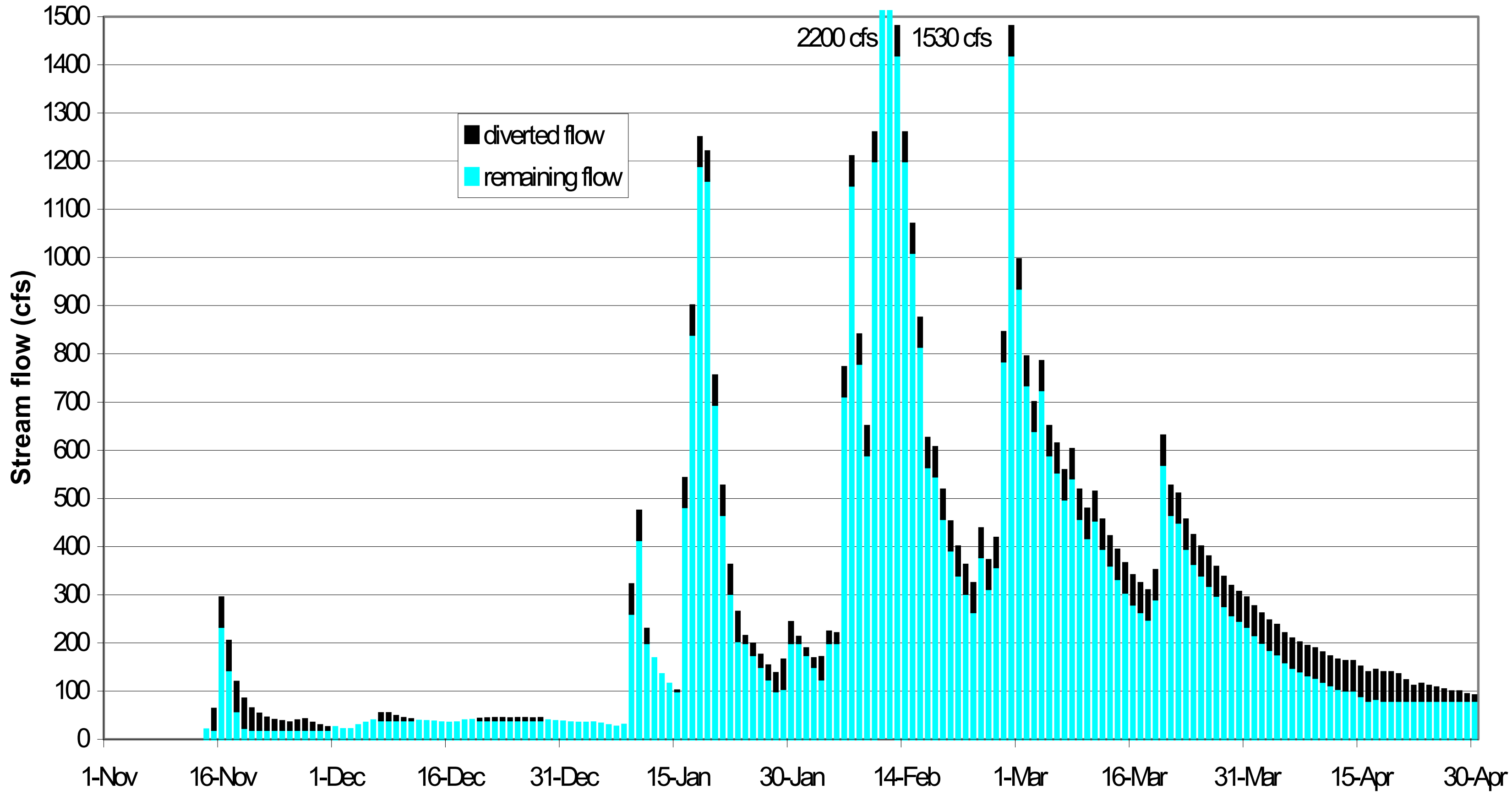


Figure 11. Winter stream flows at Robles del Rio gage during winter 1973 (above normal water year with 108,500AF) with minimum flow of 60 cfs and maximum diversion of 60 cfs



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