Aquatic Biota in the San Miguel Watershed

A Product of the San Miguel Pilot Project

Submitted: 3/22/21

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Prepared For:

TROUT UNLIMITED

SAN MIGUEL WATERSHED COALITION

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1 Introduction

Stakeholders participating in the San Miguel Pilot Project requested an evaluation of aquatic biota in the San Miguel watershed. Aquatic habitat quality and availability within a stream network is affected not only by infrastructure like culverts and water diversion structures that impact connectivity, but also by temporally variable hydrological and hydraulic conditions within channels. Various aquatic species/life-stages exhibit preferences for certain habitat types, as described by several hydraulic characteristics (e.g., water depth and velocity in riffles). Where optimal conditions exist, aquatic biota can utilize local habitat for feeding, reproducing, etc. Localized changes in streamflow (in timing, magnitude, and frequency) impact channel hydraulics. Suboptimal hydraulic conditions not only preclude use of local habitat but may present a significant barrier to passage that limits utilization of some upstream or downstream portion(s) of the stream network. In recognition of the value of both cold and warmwater fisheries (native and sport) throughout the San Miguel watershed, stakeholders elected to evaluate relationships between local channel structure, the hydrological regime, and aquatic habitat quality and extent on the San Miguel River and major tributaries where fisheries were documented and where sufficient data existed to complete an analysis.

2 Literature Review and Data Analysis

This assessment includes a discussion of the aquatic and terrestrial species present in streams and river across the watershed. A coarse analysis of aquatic habitat connectivity is provided. Relationships between hydrology, channel hydraulics, ice floes and aquatic habitat quality are also investigated.

2.1 Aquatic Species of Interest

The fisheries supported by streams and rivers throughout the San Miguel watershed are typically broken into two basic classifications: warmwater and coldwater. Both fishery classifications include native and non-native fish and several state or federally-listed species of concern. The lower San Miguel basin provides important habitat to support several warmwater fish species, including roundtail chub, flannelmouth sucker, and bluehead sucker. Non-native species include several species of dace, bass, suckers, pike, some species of minnow, and catfish. Native coldwater fish in the San Miguel watershed include Colorado cutthroat trout mottled sculpin and speckled dace. Non-native coldwater species in the San Miguel watershed comprise the main sport fishery and include rainbow trout, brown trout, and brook trout (Figure 1). Both native coldwater and warmwater fisheries exhibit significant alteration due to historic human management activities but demonstrate some recent movement back toward historical conditions. Fishery health in both the San Miguel River and the Dolores River below the confluence is supported by a relatively natural hydrological regime in the basin. Primary challenges to fishery health in the San Miguel include habitat loss and competition/hybridization between native and non-native species.

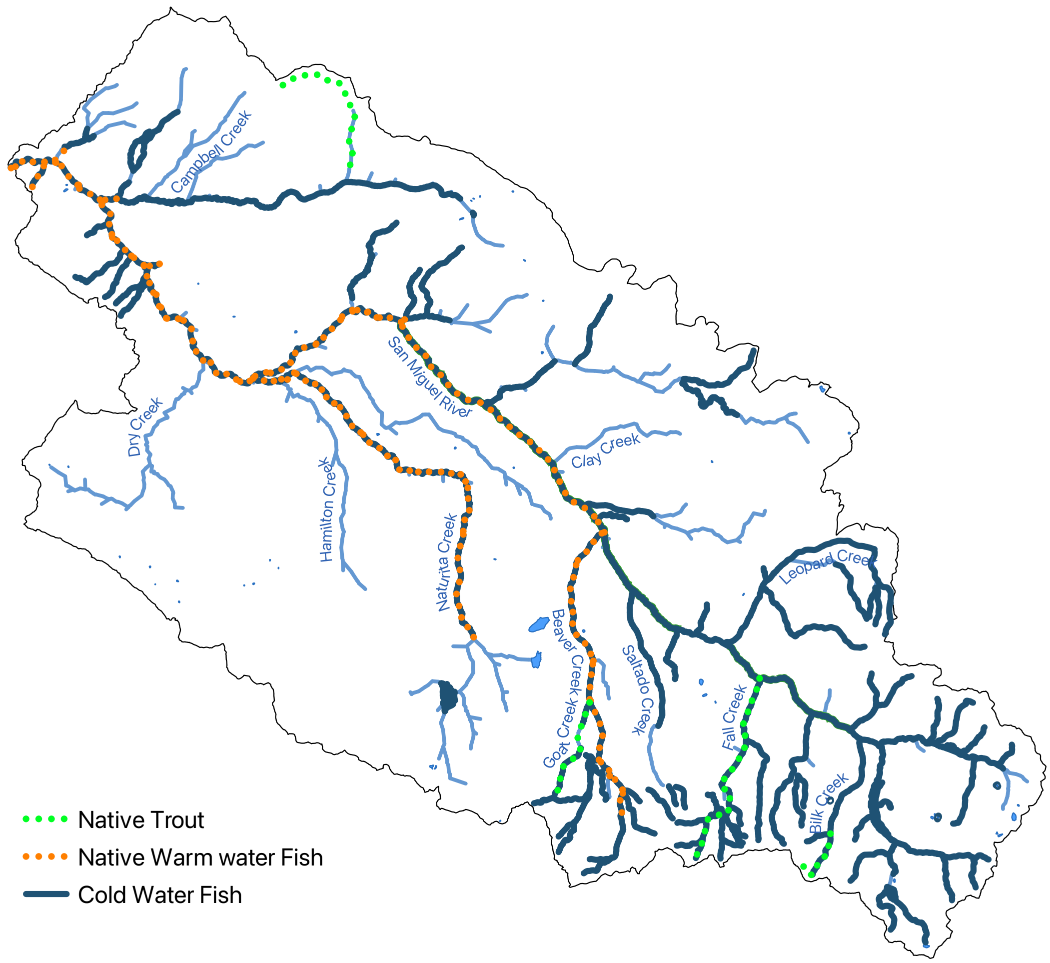


Figure 1. Stream segments in the San Miguel watershed with known populations or potential to support native warmwater, native coldwater, and sport fisheries.

Warmwater fish species typically reside in the San Miguel River mainstem and its tributaries below Horsefly Creek. These species also use the mainstem and tributaries between Horsefly Creek and Beaver Creek for spring spawning migration (*personal communication with CPW aquatic biologist*). The lower watershed is home to several species of note, including roundtail chub, bluehead sucker and flannelmouth sucker. All three are BLM-listed Sensitive Species due to significant reductions in historic range and largely unprotected habitat [1]. Historic population reductions resulting from mining-related water quality impacts and habitat loss due to surface water depletions have recently stabilized and each species now occurs throughout their historic ranges in the San Miguel watershed. However, persistent population decline in surrounding basins and unprotected habitat throughout the region keep these species on the Sensitive Species list (*personal communication with CPW aquatic biologist)*.

Of the three native warmwater species, the bluehead sucker ranges highest in the basin, as they prefer steeper, faster streams. Species success is dependent on adequate base flows and the availability of high-quality of riffle habitat [2]. Bluehead suckers prefer rocky-bottomed streams with moderately cool temperatures (~68° F). Spawning is triggered by a critical water temperature (~60° F) and, therefore, starts earlier for fish residing at lower elevations in the watershed. Young bluehead suckers prefer slow-moving water close to streambanks. They move to deeper, covered areas away from streambanks as they progress into juvenile and adult life stages. Feeding preferences mirror habitat preferences: larval fish find vertebrates in the deep rocky pools and riffles near shore, and older fish feast on algae, plant detritus and invertebrates in their covered pools and riffles further away from streambanks [3].

Like the bluehead sucker, the flannelmouth sucker is also dependent on adequate base flows and the quality of riffle and run morphology [2]. Flannelmouth suckers generally inhabit unvegetated murky pools or riffle/run areas in gravel, rock, sand, or mud bottomed streams. Younger fish seek out shallow riffles and eddies near the shore, migrating towards the deeper riffles and runs in adulthood. Larval flannelmouth suckers prey on invertebrates, transitioning to a variety of algae, detritus, plant debris and invertebrates in later life stages. This species will migrate long distances in the spring to find suitable spawning habitat [3].

Roundtail chub are habitat generalists; however, the species remains sensitive to baseflow reductions [2]. Roundtail chub prefer slow-moving, deep pools for cover and feeding but will inhabit streams with a variety of substrate types -- silt, sand, gravel -- and occur in both murky and clear water. Preferred habitat varies by lifestage. Juveniles and young-of-year seek out pools and quiet backwaters, while adults gravitate towards eddies and pools adjacent to strong currents. Spawning is triggered by water temperatures, beginning in June or early July when temperatures have reached 65° F. Roundtail chub are carnivorous, opportunistically feeding on available insects, fish, snails, crustaceans, algae and sometimes lizards. They are more likely to be limited by available food resources than by habitat [3].

Water quality impacts from numerous legacy mining operations and whirling disease contributed to population declines in the recent past. Warmwater fishery health experienced marked improvement following the completion of uranium mining cleanup efforts around Uravan. Despite these gains, cumulative water diversions on the mainstem and tributaries below the CC-Highline Ditch decrease water quantity, increase water temperatures, and reduce stream network connectivity, impacting the quantity and quality of available aquatic habitat for warmwater species.

The CC-Highline Ditch is generally considered the dividing line between the expected ranges for coldwater and warmwater fish species. This is reflected in Colorado Water Quality Control Division 305(b) segmentation under the Clean Water Act and the accompanying water quality standards for aquatic life health. However, local knowledge and observations indicate viable coldwater trout habitat could exist below the CC-Highline Ditch if and when water temperatures were suitable. Furthermore, CPW believes that certain warmwater fish species move up the tributaries near Norwood Hill to spawn in the spring, though there is no documentation of this due to typical monitoring timeframes by CPW in the San Miguel (*personal communication with CPW aquatic biologist)*.

Coldwater native fish species, including Colorado cutthroat trout, mottled sculpin, and speckled dace occur at higher elevations on the San Miguel River mainstem and its tributaries. The Colorado cutthroat trout is designated a Colorado Species of Concern. Cutthroat trout lost approximately 90% of their original habitat range in the San Miguel and experienced significant population reductions due to impacts from water diversion, stocking of non-native fish species, and mining. Populations stabilized in recent years, but vulnerability to population declines in the future persists due to a significant reduction in range [3],[2],[4],[1]. Cutthroat trout tend to occupy lower order streams and alpine lakes. Occurrence in these streams is correlated to habitat characteristics unfavorable to non-native fish. Populations of cutthroat in the San Miguel watershed exist in Fall Creek, Muddy Creek, Leopard Creek, Elk Creek, East Beaver Creek, Middle, East and West Beaver Creeks, Deep Creek, upper Bilk Creek, Goat Creek, and Red Feather Canyon. Isolated populations also exist in Red Feather Canyon off Horsefly Creek and in the North Fork of Tabeguache Creek. CPW stocks Woods Lake, which feeds Muddy and Fall Creek, with genetically pure hatchery-raised cutthroat trout. The Colorado Natural Heritage Program has delineated Protected Conservation Areas along Elk Creek and Red Feather Canyon to protect cutthroat populations in those tributaries [3],[2],[4],[1].

Seasonal migration to smaller perennial streams for spawning is triggered by increased flow from spring runoff. Once in spawning habitat, cutthroat wait until water temperatures reach 44-50° F and peak runoff subsides before depositing redds and returning to their stream of origin. The extent of movement between spawning grounds and streams of origin is largely dictated by stream network connectivity. After emergence, fry move to shallow, slow moving areas near spawning zones before migrating to larger streams. Juveniles and adults favor covered, slow-moving pools and protected areas for feeding in the summer and deep pools, beaver ponds and groundwater upwelling zones during the winter [5].

The dominant non-native coldwater species in the San Miguel watershed include brown trout, rainbow trout and brook trout. These species occupy similar ecological niches to Colorado cutthroat trout, and have become important keystone species and indicators of overall health of riverine ecosystems. Additionally, USFS considers them a Management Indicator Species. Non-native trout populations in the San Miguel are considered stable, but natural reproduction rates are low. These populations are stocked, managed and promoted by CPW as a sports fishery. Rainbow trout are stocked regularly, and brown trout and brook trout only occasionally. Brown trout require less stocking because they are generally successful in establishing self-sustaining populations. Ecological concerns regarding the impact of stocked brook trout on the viability of Colorado cutthroat trout populations significantly influence management decisions regarding sport fish.

Both brook and brown trout prefer clear streams that support robust and diverse riparian vegetative cover. Brook trout can exist in high population densities, thriving in beaver ponds and other confined areas. Brown trout prefer slightly deeper, slower and warmer water, undercut banks and covered bankside areas, and can tolerate lower quality habitat. Rainbow trout are habitat generalist, but often occupy mid-channel areas. Rainbow and brook trout feed mainly on insects, while brown trout are piscivorous, surviving mainly on other fish [6]. Non-native trout need warmer water temperatures than native cutthroat trout. Of the three non-native species, brook trout tolerates the coldest water temperatures (~57° F). Rainbow trout prefer warmer water temperatures (~70° F), and brown trout need the warmest water temperatures of the three, (~65-75° F) and are, therefore, generally found in the lowest elevations. Spawning and incubation periods for all non-native trout species are partially queued by and dependent on photoperiods and water temperatures. Brook and brown trout spawn in the late fall (September-November) when days get shorter and water temperatures fall. Rainbow trout spawn in the spring when water temperatures begin to rise (Table 1).

Table 1. Months of critical concern for various cold water fish life stages.

Species and Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
RB AD	X	X	X	X	X	X	X	X	X	X	X	X
RB JUV	X	X	X	X	X	X	X	X	X	X	X	X
RB FRY							X	X				
RB SP				X								
RB IHE				X	X	X	X					
BR AD	X	X	X	X	X	X	X	X	X	X	X	X
BR JUV	X	X	X	X	X	X	X	X	X	X	X	X
BR FRY						X	X					
BR SP										X	X	
BR IHE	X	X	X	X	X	X				X	X	X

Key: RB = Rainbow trout, BR = Brown Trout, AD = Adult, JUV = Juvenile, FRY = Fry, SP = Spawning adults, IHE = Incubation, hatching and emergence

The mainstem San Miguel River exhibits insect abundance and high-quality spring and summer habitat capable of supporting robust fisheries. However, the mainstem is consistently impacted by large winter ice floes. These events frequently scour habitat and may produce high mortality among over-wintering fish populations [7]. Recognizing this, CPW manages the river as a stocking stream, stocking catchable-size rainbow trout that typically survive one winter at best.

2.2 Terrestrial Species of Interest

The San Miguel watershed is also home to many avian, amphibian, and mammalian species that inhabit the riparian areas. Notable indicator species include bald eagles, river otters, and great blue heron. Just as characterizing the extent and condition of fisheries throughout the watershed can promote understanding of physical and biological processes that promote or degrade ecosystem resilience, so too can examination of the presence and condition of these species across the San Miguel watershed.

The mid-watershed serves as an important wintering area for the bald eagle. Bald eagles roost and nest in tall cottonwood and ponderosa pines along the river, moving around areas seasonally based on regional weather patterns and current weather conditions. They are sensitive to human activity near nesting areas. Populations, historically, have been severely impacted by DDT poisoning and habitat destruction nationwide, earning Federal Threatened and Endangered Species listing. Populations have since recovered, and the bird was delisted from Federal listing but is still on the State species list of Special Concern. Populations in the San Miguel are threatened by riparian habitat destruction from oil/gas, residential, and agricultural development in floodplains and human intrusion on nearby roosting and nesting sites. Important bald eagle habitat exists in riparian zones along Horsefly Creek, the San Miguel River through Norwood Canyon, Wright's Mesa, and the Dry Creek Basin [4], [8].

After disappearing from Colorado completely following initial settlement, CPW began reintroducing river otters to waterways throughout the state in the 1970's. The river otter was reintroduced to the Dolores River in the late 1980's and has since established an expanded population along the mainstem San Miguel River between the Dolores River and the Town of Telluride. They typically occur in riparian areas, frequently near abandoned beaver dens, and subsist on a variety of aquatic animals. The river otter is listed as a State Threatened Species [1], [8] and remains sensitive to development or resource management activities that alter the quality and availability of riparian habitat.

2.3 Aquatic Habitat Connectivity

Connectivity refers the physical and biological linkages between stream segments throughout the watershed, as well as linkages between streams and the upland landscape. Longitudinal connectivity relates to upstream-downstream travel of aquatic species and downstream transport of sediment, nutrients, and woody debris. In the management context, stream network connectivity most often relates to the ability for fish and other aquatic species to move throughout a stream network and utilize a range of habitats within a basin or watershed. For many species, unimpeded upstream-downstream movement is vital to spawning success and migration. Wide ranging native fish species may be particularly sensitive to reductions in network connectivity. Connections between large and small streams in different geomorphological settings allows organisms to locate and utilize refugia during short-term stressful events (e.g. summer temperature warming events). The degree of network connectivity may also dictate how biota within the physical system are able to respond to the long-term land use changes or the effects of climate change.

Barriers to longitudinal connectivity include large dams and small impoundments, push-up dams or other water delivery infrastructure, culverts, flow-depleted stream reaches too shallow for fish and other organisms to traverse, and natural features such as waterfalls or extended steep cascades. The significance of different features varies by species. Some fish, such as brook and cutthroat trout, can ascend very steep and powerful headwaters reaches. A course-level analysis of network connectivity provides a basis for understanding the spatial arrangement of connectivity and network fragmentation.

The connectivity analysis provided here used available spatial data to locate stream reaches with potential connectivity reductions. This analysis assumed that most road crossings on small headwaters and tributaries use culvert-type installations rather than bridges spanning the complete channel and floodplain and that these crossings likely present problems for aquatic organism passage (Figure 2). Road crossings on the mainstem San Miguel below the South Fork confluence generally feature channel-spanning bridges and were not assumed to cause reductions in longitudinal connectivity. Several surface water diversion features in Norwood Canyon were included as potential barriers, although their impact is most important during low flow periods. Connectivity potential and network fragmentation were evaluated by calculating the length of uninterrupted stream network extending between potential barriers. This assessment of network connectivity potential did not attempt to identify an ideal degree of connectivity within the watershed but findings might help highlight areas deserving of focused discussion in future planning phases.

2.4 Ice Floes

Stakeholders indicated some interest in considering ice floes in this assessment. The San Miguel is naturally conducive to ice floes, but flow and temperature conditions created by Trout Lake and Ames Hydroelectric Project may increase rates of ice formation. Super-cooled water released from Trout Lake in combination with low flow conditions created by reduced nighttime releases from Ames creates idea conditions for frazil ice formation. Over time, frazil ice grows into ice dams, eventually collapsing from the force of water impounded behind them. The ice, water, debris slurry formed after these collapses scour the channel and banks, cause erosion, uproots riparian vegetation, and impact aquatic habitat fish—one of the biggest stressors to already winter-stressed fish populations. These events also damage near-river structures and may be a threat to human safety. Ice floes are problematic in mid-winter from the South Fork to Specie Creek. The physical conditions that produce ice floes were previously investigated by U.S. Army Corps of Engineers (USACE) and others [12], [13]. Assessment results and recommendations produced by these efforts were considered the best available information and are directly referenced here without further investigation into water management needs for limiting ice floe formation. USACE recommends a year-round minimum 3 cfs outflow on the South Fork of the San Miguel River below Trout Lake and a year-round minimum 13 cfs outflow on the South Fork of the San Miguel River below the Ames powerhouse to limit ice floe formation

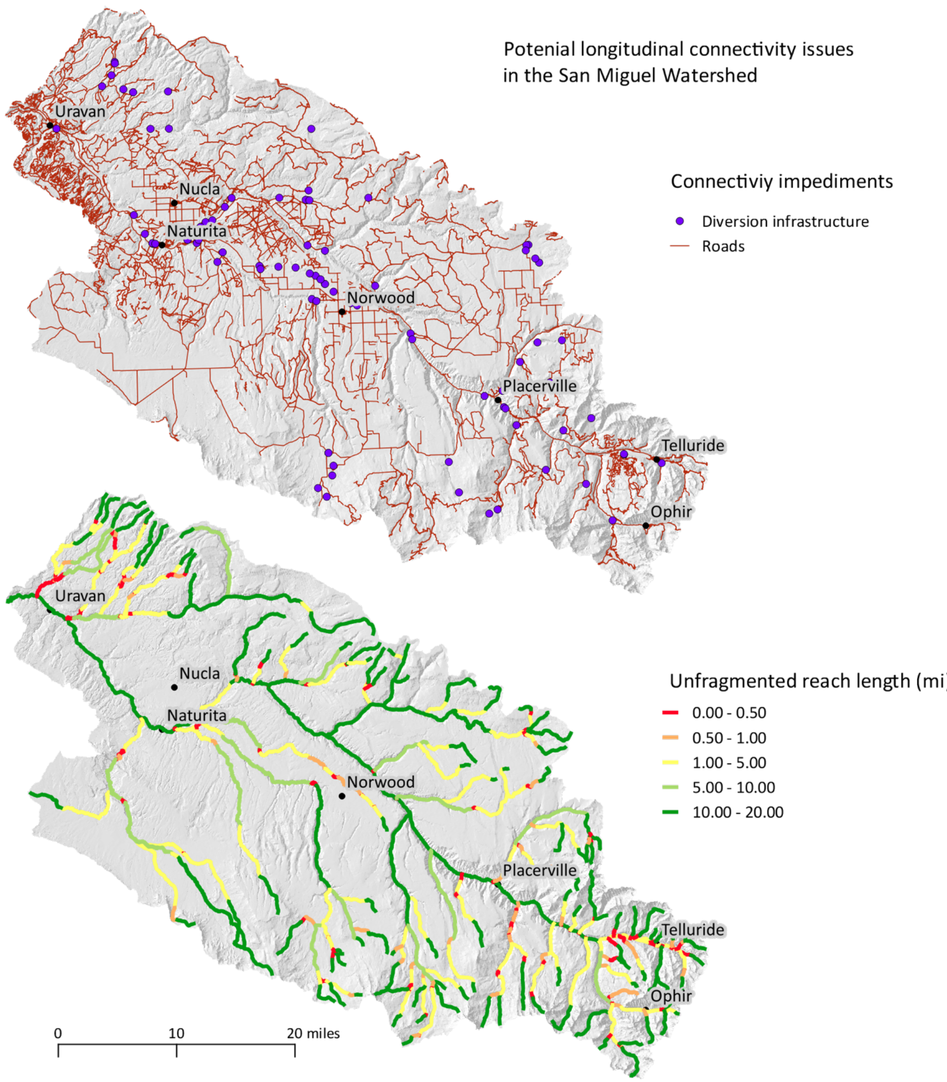


Figure 2. Potential stream network fragmentation mapped as a function of road crossings and locations of diversion infrastructure, then color-coded based on the length of uninterrupted stream distance. Habitat connectivity is likely impacted by surface water diversion structures, flow depletions, road crossings, and natural barriers at locations across the watershed.

The potential for stream network fragmentation is most severe on small tributary streams. Private and public road networks that crisscross the watershed include an abundance of road crossings. Assuming that most of these crossings on small streams utilize culverts and that those culverts are not designed or installed for optimal aquatic life passage, network connectivity is likely impacted in several important cutthroat trout habitats in the upper watershed. In some tributary basins, reduced network connectivity isolates high-quality habitat for native trout and reduces the likelihood of hybridization with non-native species. In other areas, increased connectivity may help increase cutthroat population size and range. Thus, consideration of overlaps between connectivity reduction and important conservation fish populations like cutthroat can aid planning for habitat restoration or invasive species exclusion.

2.5 Channel Hydraulics and Habitat Quality

Several methodologies exist for assessing local hydraulic conditions against the preferred conditions for various aquatic species. These methodologies include R2Cross, PHABSIM, RHABSIM, the wetted-perimeter method, the Tennant method, and others. Colorado Water Conservation Board and Colorado Parks and Wildlife rely extensively on the R2Cross methodology [14] to describe minimum flow needs for assemblages of fish as support for development of Instream Flow (ISF) water rights on rivers across Colorado. The methodology uses quickly obtainable hydraulic geometry data and assumes that streamflows sufficient to maintain aquatic habitat in critical riffle segments will also maintain habitat quality in other channel segments such as runs and pools. Riffle habitat is critical to many species/life stages for spawning, egg incubation, feeding/cover, and migration. Riffle habitat is also the most sensitive habitat type to changes in hydraulic characteristics produced by changing streamflow. The R2Cross methodology evaluates streamflow against three hydraulic parameters: mean depth, percent bankfull wetted perimeter, and mean velocity. To accommodate changing habitat needs and water availability that occur throughout a given year, seasonal streamflow needs are determined based on the number of hydraulic criteria met at any given time (Table 2). The R2Cross methodology was used as the basis for many ISF filings on stream segments across the San Miguel watershed. On the San Miguel River mainstem, additional methodologies (i.e. PHABSIM, R2Cross, and wetted-perimeter) were used by Colorado Parks and Wildlife, BLM, and others to describe streamflow needs for aquatic biota. Importantly, existing ISF water rights were not used in this assessment as the benchmark for describing optimal minimum aquatic habitat flow needs in the San Miguel watershed, as many of these filings reflect adjustments to account for water availability and do not necessarily reflect the biological needs assessed for a particular stream reach.

Table 2. Hydraulic criteria evaluated by the R2Cross methodology. Streamflow satisfying 2-of-3 criteria are typically used as the biological basis for winter instream flow needs. Streamflow satisfying 3-of-3 criteria are typically used as the biological basis for summer instream flow needs [14].

Stream-top width (ft)	Mean depth (ft)	Percentage of wetted perimeter (%)	Mean velocity (ft/s)
1-20	0.2	50	1
21-40	0.2-0.4	50	1
41-60	0.4-0.6	50-60	1
61-100	0.6-1.0	>70	1

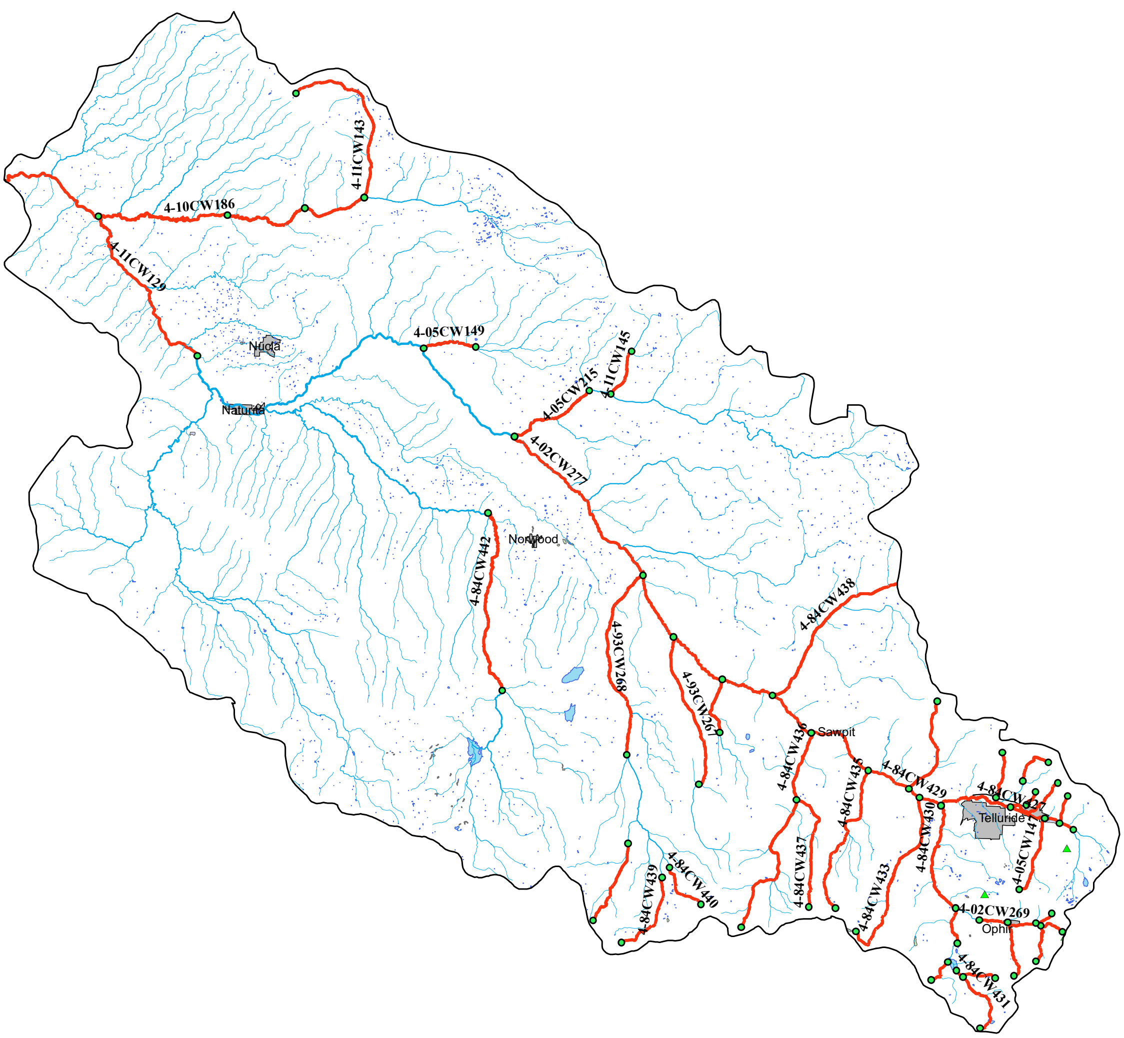


Figure 3. River segments with instream flow water rights.

Streamflow thresholds for fisheries reported by this assessment were derived from the biological basis for ISF filings (Figure 3). The biological opinions supporting acquisition of CWCB ISF rights can be found as addendums to many ISF filings. Additional notes and produced by USFS, BLM, CPW were also reviewed. The biologically-based recommendations for streamflow protections differ from the ISF water rights in several locations. If no notes or biological opinions could be found, the decreed ISF water right was used as the biological flow recommendation. For several stream segments, historical channel geometry and hydraulic information collected by CWCB, BLM, CPW, and others was augmented with field data collected in the summer and fall of 2016. New information was used to create one-dimensional hydraulic models and evaluate R2Cross criteria. New R2Cross results were used to fill data gaps and/or assess whether changes in channel geometry between an original ISF filing date and present-day might alter biological flow recommendations for a reach.

Table 3. Minimum flow recommendations for streams and rivers across the San Miguel watershed.

Reach ID	Stream Name	Reach Start	Reach End	Biological Flow Recommendations
BBC_1	Big Bear Creek	Headwaters	San Miguel River	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
BLK_1	Bilk Creek	Headwaters	San Miguel River	9.5 cfs 5/01 - 9/30, 5.3 cfs 10/1 - 4/30
BRC_1	Bear Creek	Headwaters	San Miguel River	4.2 cfs 5/01 - 9/30, 2 cfs 10/1 - 4/30
BVR_1	Beaver Creek	Headwaters	Gurley Ditch	2.5 cfs 1/01 - 12/31
BVR_2	Beaver Creek	Gurley Ditch	San Miguel River	6 cfs 5/01 - 9/30, 3 cfs 10/1 - 4/30
DEP_1	Deep Creek	Headwaters	San Miguel River	4 cfs 1/01 - 12/31
DRY_1	Dry Creek	Headwaters	San Miguel River	2.5 cfs 1/01 - 12/31
EBV_1	East Beaver	Headwaters	Gurley Ditch	0.8 cfs 1/01 - 12/31
ELK_1	Elk Creek	Headwaters	Fall Creek	2.5 cfs 1/01 - 12/31
FLC_1	Fall Creek	Headwaters	San Miguel River	6.4 cfs 5/01 - 9/30, 4.4 cfs 10/1 - 4/30
HRS_1	Horsefly Creek	Sheep Creek	San Miguel River	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
HFK_1	Howards Fork	Headwaters	Waterfall Creek	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
HFK_2	Howards Fork	Waterfall Creek	South Fork San Miguel River	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
LKF_1	Lake Fork	Headwaters	Trout Lake	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30

LKF_2	Lake Fork	Trout Lake	South Fork San Miguel River	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
LPD_1	Leopard Creek	E./W. Fork Leopard Creek	San Miguel River	3 cfs 1/01 - 12/31
NAT_1	Naturita Creek	Headwaters	Mirimonte Reservoir	0.5 cfs 5/01 - 9/30, 0.3 cfs 10/1 - 4/30
NAT_2	Naturita Creek	Mirimonte Reservoir	San Miguel River	4.7 cfs 5/01 - 9/30, 0.9 cfs 10/1 - 4/30
NFT_1	North Fork Tabeguache Creek	Headwaters	Tabeguache Creek	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
SFK_1	South Fork San Miguel River	Lake Fork	San Miguel River	9 cfs 1/01 - 12/31
SMR_1	San Miguel River	Bridal Veil Creek	Bear Creek	6.5 cfs 1/01 - 12/31
SMR_2	San Miguel River	Bear Creek	Prospect Creek	10.5 cfs 5/15 - 10/31, 6.5 cfs 10/1 - 4/30
SMR_3	San Miguel River	Prospect Creek	South Fork San Miguel River	
SMR_4	San Miguel River	South Fork San Miguel River	Bilk Creek	47.5 cfs 5/01 - 9/30, 19.5 cfs 10/1 - 4/30
SMR_5	San Miguel River	Bilk Creek	Deep Creek	
SMR_6	San Miguel River	Deep Creek	Fall Creek	
SMR_7	San Miguel River	Fall Creek	Leopard Creek	85 cfs 4/01 - 4/30, 100 cfs 5/01 - 5/31, 125 cfs 6/1 - 8/31, 100 cfs 9/01 - 9/30, 75 cfs 10/01 - 10/30, 60 cfs 11/01 - 3/31
SMR_8	San Miguel River	Leopard Creek	Specie Creek	
SMR_9	San Miguel River	Specie Creek	Saltado Creek	
SMR_10	San Miguel River	Saltado Creek	Beaver Creek	
SMR_11	San Miguel River	Beaver Creek	Horsefly Creek	
SMR_12	San Miguel River	Horsefly Creek	Cottonwood Creek	No Data
SMR_13	San Miguel River	Cottonwood Creek	Naturita Creek	
SMR_14	San Miguel River	Naturita Creek	Calamity Draw	
SMR_15	San Miguel River	Calamity Draw	Tabeguache Creek	325 cfs 4/15 - 6/14, 170 cfs 6/15 - 7/31, 115 cfs 10/1 - 4/30
SMR_16	San Miguel River	Tabeguache Creek	Dolores River	
SPC_1	Specie Creek	Headwaters	San Miguel River	2.3 cfs 5/01 - 9/30, 1.4 cfs 10/1 - 4/30
SLT_1	Saltado Creek	Headwaters	San Miguel River	2 cfs 5/01 - 9/30, 1 cfs 10/1 - 4/30
TAB_1	Tabeguache Creek	North Fork Tabeguache	Forty-Seven Creek	3.5 cfs 4/15 - 6/30, 3 cfs 7/1 - 4/14
TAB_2	Tabeguache Creek	Forty-Seven Creek	Templeon Ditch	4.8 cfs 5/01 - 9/30, 2.3 cfs 10/1 - 4/30
TAB_3	Tabeguache Creek	Templeton Ditch	San Miguel River	4.7 cfs 4/01 - 6/30
WBV_1	West Beaver Creek	Headwaters	Beaver Highline Ditch	1.5 cfs 1/01 - 12/31

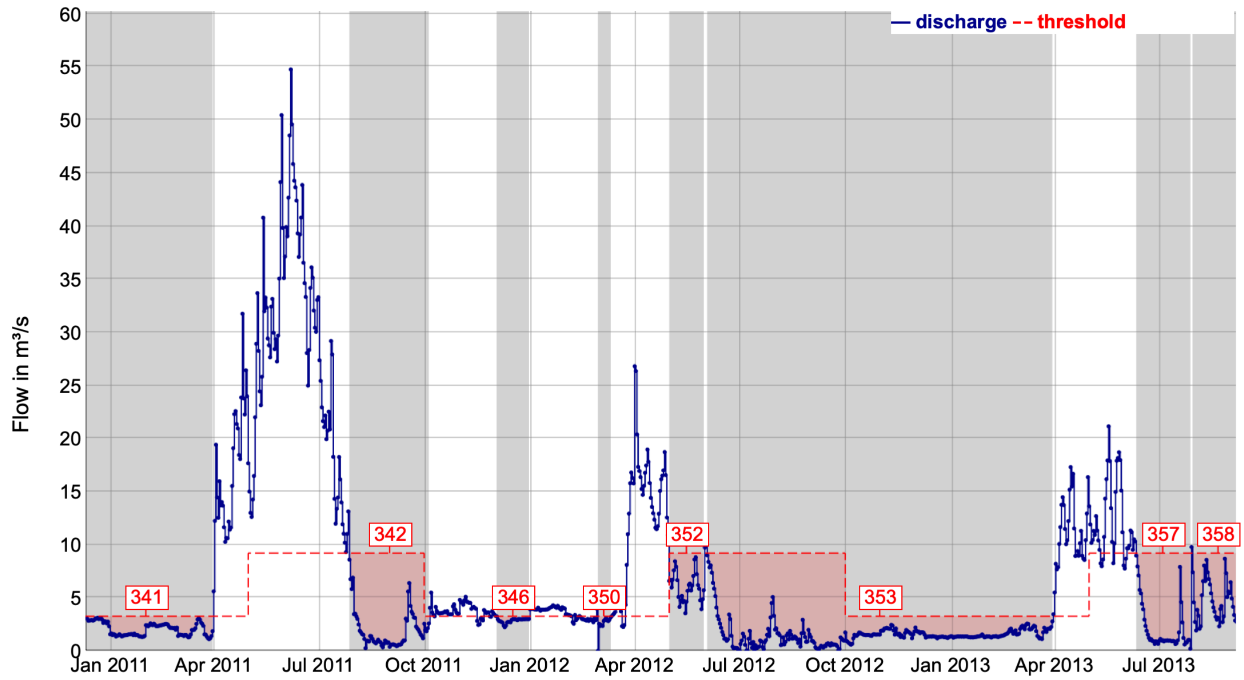


Figure 4. Example of how stream discharge (blue line) is compared to R2Cross identified thresholds (red dashed line) considered important for maintaining healthy fisheries in order to compute environmental needs gaps (shaded red area).

2.6 Existing Conditions

Identifying biologically-based flow thresholds provides a basis for comparative assessment of flow needs between year types and between locations across the watershed (Figure 4). Streamflow data derived from water rights and hydrological simulation modeling were summarized into representative wet, dry, and average annual streamflow time series. These time series were compared directly to biologically recommended threshold flows in the R statistical computing environment. Comparing flow thresholds to observed or simulated streamflows also provided an indication of the magnitude and duration of flows needed to reach optimal conditions on stream segments where flows frequently fail to reach recommended minimums (Table 4). All computations of environmental needs gaps reported here are approximate. Estimates reported for the mainstem San Miguel River below the South Fork San Miguel River can be verified against observed streamflow data from USGS stream gauges. Estimates reported for most tributary streams cannot be verified with contemporary, observed data and, thus, retain a higher degree of uncertainty.

Table 4. Water supply gaps for fisheries as determined by delineating flow thresholds and comparing to simulated wet, average, and dry year hydrographs.

		Wet Year Deficit			Average Year Deficit			Dry Year Deficit		
Reach ID	**Node ID**	**Volume (af)**	**Duration (days)**	**Median Flow (cfs)**	**Volume (af)**	**Duration (days)**	**Median Flow (cfs)**	**Volume (af)**	**Duration (days)**	**Median Flow (cfs)**
BBC_1	600736	1287	365	1	1287	365	1	1287	365	1
BLK_1	600659	1142	209	3	1694	244	4	2325	278	4
BVR_2	9173000	412	146	2	1049	270	2	1536	284	3
DEP_1	600627	1363	258	3	1638	284	3	1912	308	4
DRY_1	600735	0	0	0	0	0	0	27	67	0
ELK_1	600678	5	43	0	108	90	1	302	150	1
FLC_1	9172000	53	57	0	250	91	1	623	167	2
HRS_1	601358	47	45	0	926	130	4	1985	151	7
NAT_2	600831	0	0	0	0	0	0	4	17	0
TAB_3	602070	0	0	0	0	0	0	5	1	3
LPD_1	9172100	0	0	0	0	0	0	71	87	0.4
SMR_8	9172500	0	0	0	593	72	4	2940	160	9
SMR_10	600578	0	0	0	446	59	3	2559	139	9
SMR_12	600633	-	-	-	-	-	-	-	-	-
SMR_13	600520	-	-	-	-	-	-	-	-	-
SMR_14	9175500	-	-	-	-	-	-	-	-	-
SMR_15	602119	2090	48	27	11197	145	36	28046	251	46
SMR_16	9177000	281	31	4	8605	176	21	28480	270	48

No previously-collected data were available for defining minimum flow thresholds on the San Miguel mainstem between Horsefly Creek and Calamity Draw. However, extensive work by federal and state agencies and non-governmental organizations went into defining those thresholds for both upstream and downstream segments of the San Miguel River. The section of river between Horsefly Creek and Calamity Draw shares morphological characteristics with upstream and downstream segments. Overlaying the time-varying low-flow thresholds from adjacent segments on simulated wet, average, and dry year streamflows for the San Miguel River at Naturita indicates significant environmental water supply gaps, regardless of which set of thresholds are used (Table 5)(Figure 5).

Table 5. Environmental water supply gaps calculated for the San Miguel River at Naturita using time-varying flow thresholds defined for upstream (top) and downstream (bottom) segments.

Flow Thresholds	Wet Year Deficit			Average Year Deficit			Dry Year Deficit		
	Volume (af)	Duration (days)	Median Flow (cfs)	Volume (af)	Duration (days)	Median Flow (cfs)	Volume (af)	Duration (days)	Median Flow (cfs)
85 cfs 4/01 - 4/30, 100 cfs 5/01 - 5/31, 125 cfs 6/1 - 8/31, 100 cfs 9/01 - 9/30, 75 cfs 10/01 - 10/30, 60 cfs 11/01 - 3/31	965	21	18	8080	59	68	16872	106	100
325 cfs 4/15 - 6/14, 170 cfs 6/15 - 7/31, 115 cfs 10/1 - 4/30	3243	69	32	13851	166	39	32285	263	49

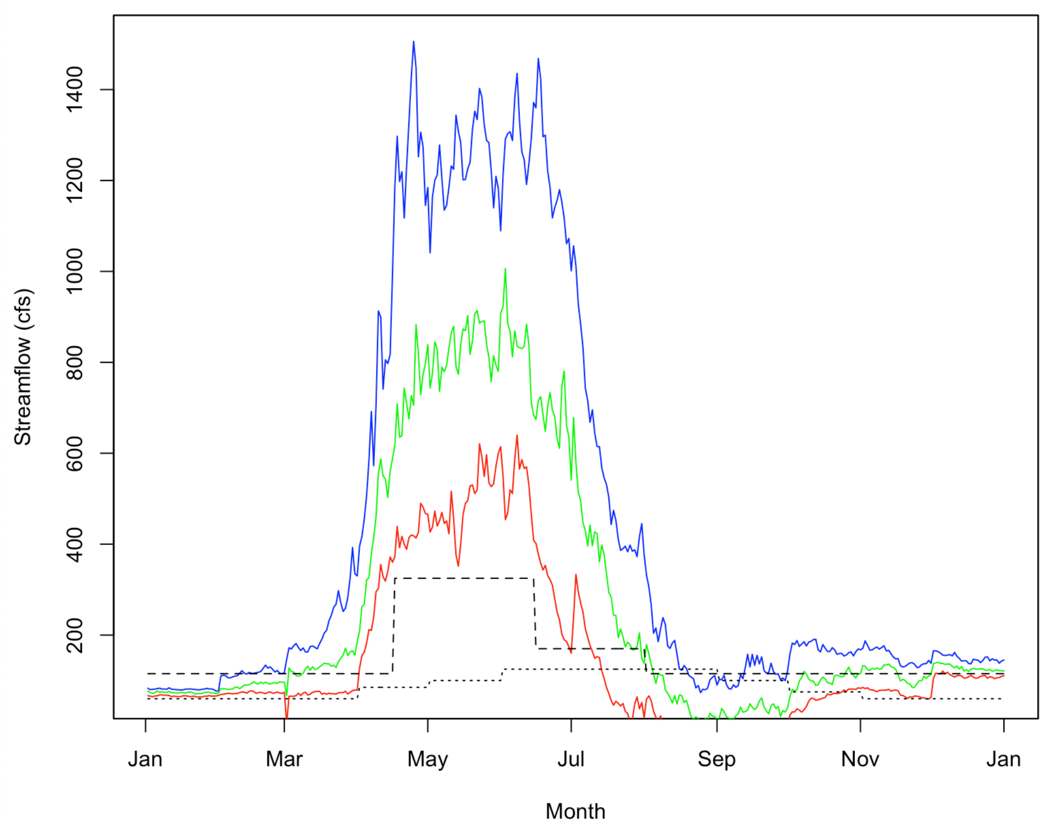
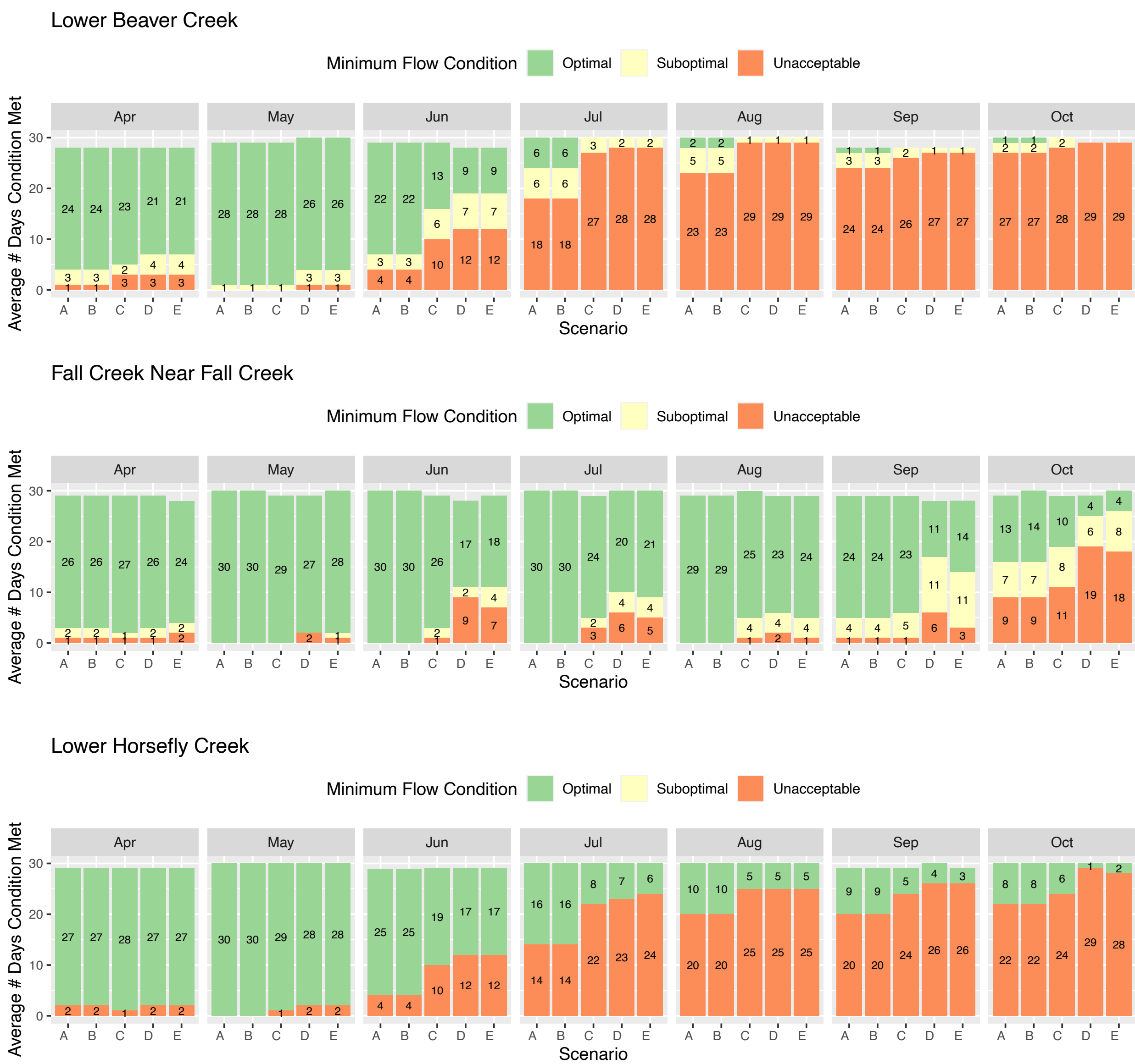


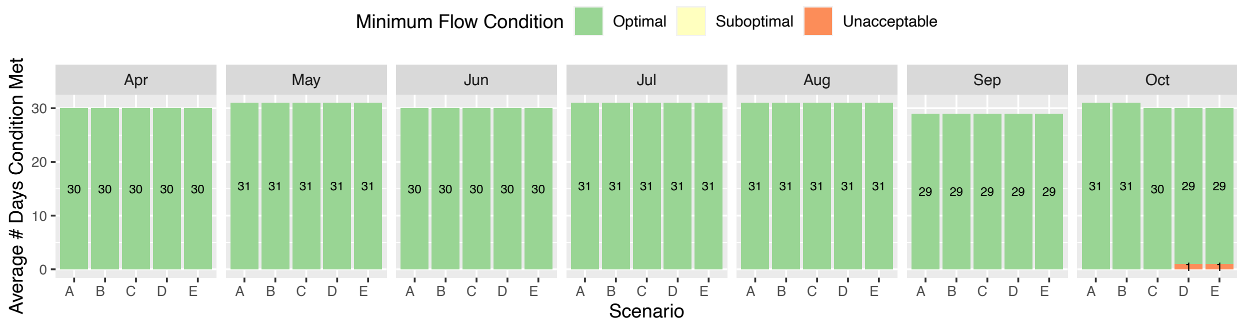
Figure 5. Simulated streamflow time series representing wet (blue), average (green), and dry (red) year types compared to biologically recommended flows for the San Miguel River near Placerville (dotted black line) and near Uravan (dashed black line).

2.7 Scenario Modeling

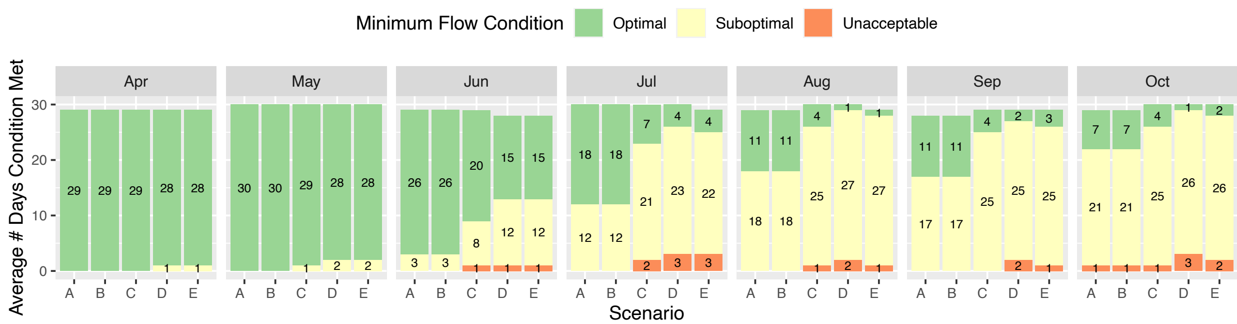
Outputs from hydrological simulations models described in Appendix C were used to understand how the number of days that meet R2Cross criteria change across months in a year and between scenarios at locations across the San Miguel Watershed. Where R2Cross modeling results and/or biological opinions were available, simulation models were used to assess the frequency and magnitude of flows falling above and below minimum flow thresholds defined as optimal (e.g. 3-of-3 R2Cross criteria satisfied), suboptimal (e.g. 2-of-3 R2Cross criteria satisfied), or unacceptable (e.g. < 2 R2Cross criteria satisfied) (Figure 6).



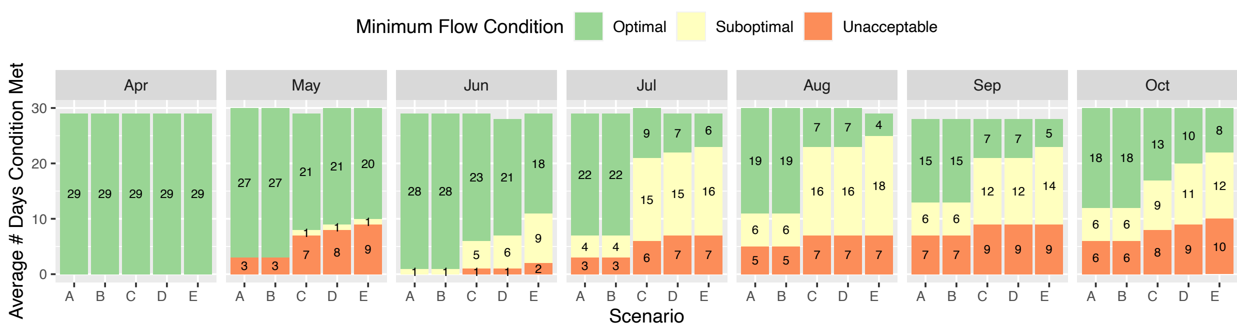
Lower South Fork San Miguel



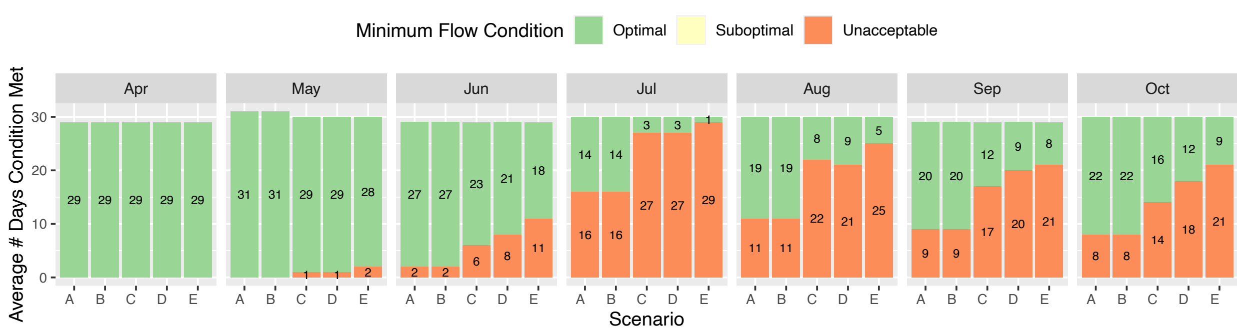
Naturita Creek Below Maverick Draw Ditch



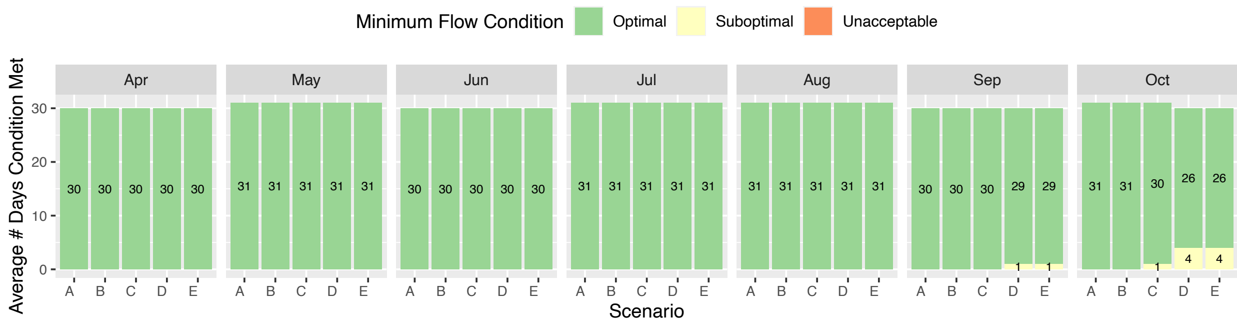
Lower Leopard Creek



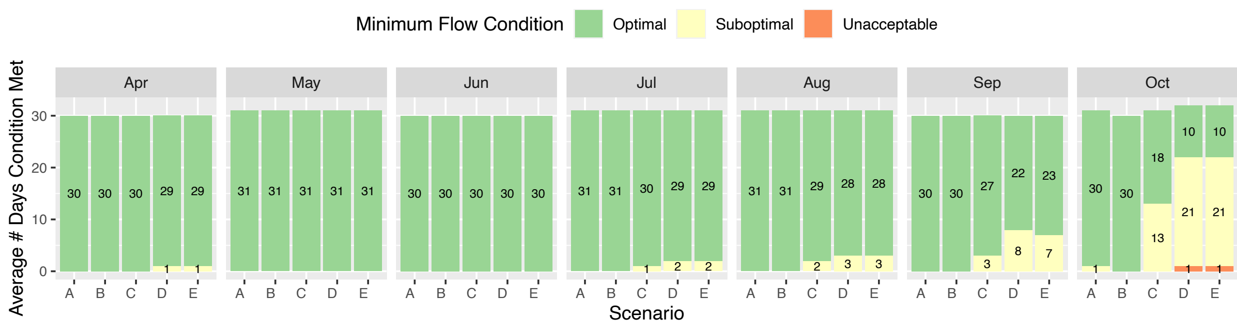
Lower Tabeguache Creek



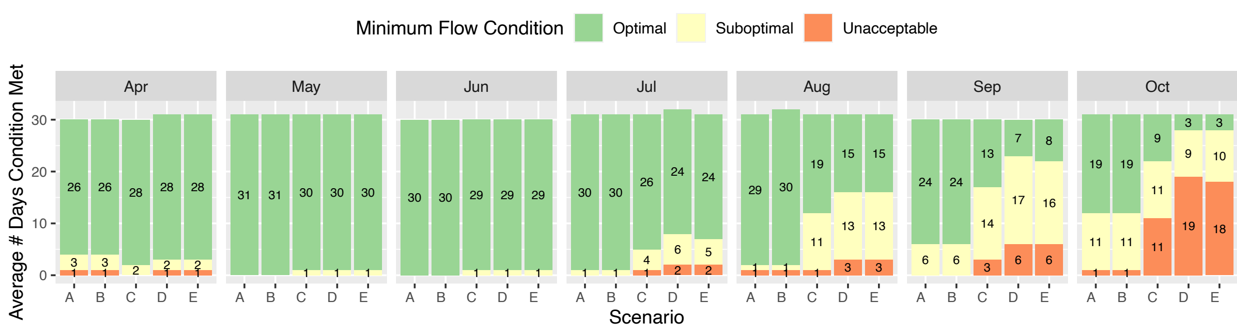
San Miguel River Near Telluride



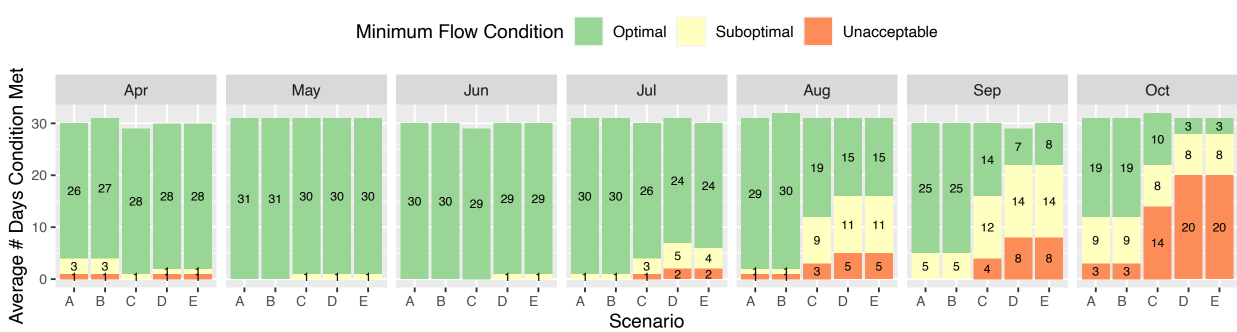
San Miguel below Deep Creek



San Miguel River Near Placerville



San Miguel below Saltado Creek



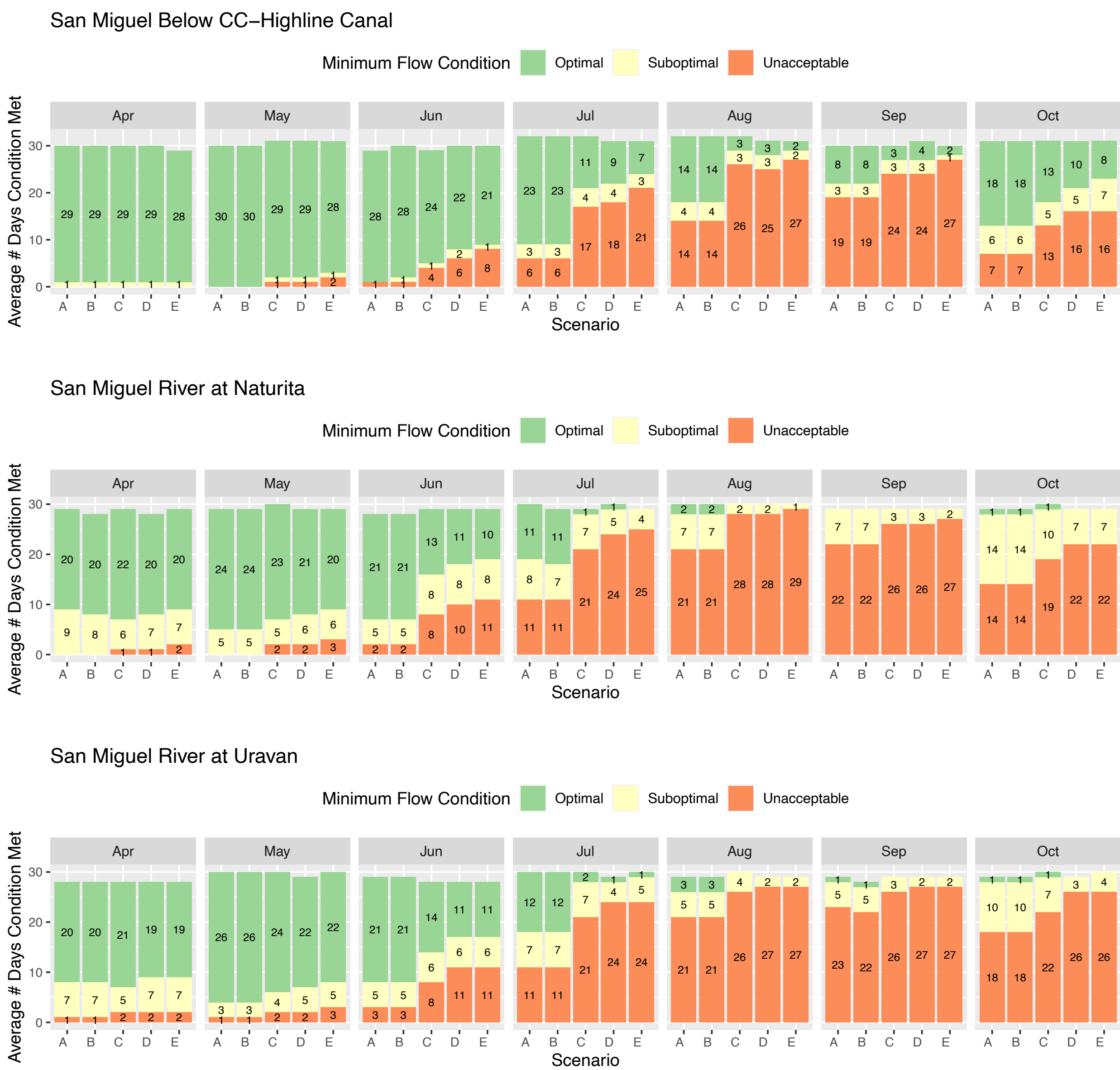


Figure 6. Changing aquatic habitat conditions predicted for stream reaches across the San Miguel watershed during summer months under several hydrological scenarios. Optimal flow conditions (green) correspond to periods when flows exceed 3-of-3 R2Cross criteria. Suboptimal flow conditions (yellow) correspond to periods when flows exceed 2-of-3 R2Cross criteria. Unacceptable flow conditions (orange) correspond to periods when flows are lower than 2-of-3 R2Cross criteria. Note that not all monthly totals sum to the correct number of days in each month. This is an unavoidable artifact of rounding errors incurred when summarizing the 40-year time series from each scenario.

Results of the scenario planning analysis indicate a typical progression toward increasing numbers of suboptimal or unacceptable days in the late summer and fall at most locations in the watershed. The same pattern is observed at most locations across scenarios with the greatest number of unacceptable conditions appearing under scenarios that include climate change (i.e. C, D, and E). This pattern is strongest on the lower reaches of tributary streams and on the San Miguel mainstem below Placerville.

3 Discussion and Conclusions

The health of San Miguel watershed fisheries is mediated by several conditions. All fisheries -- including native warmwater, native coldwater, and sport -- are negatively impacted by loss of high-quality habitat and/or reduction of historic range. While streamflows are generally sufficient for maintaining high quality aquatic habitat high in tributary streams, competition with non-native species perpetuates isolation of Colorado cutthroat trout populations to fragmented habitats above waterfalls high in the watershed. Habitat fragmentation and reductions in stream network connectivity due to surface water diversion structures and road drainage structures (i.e. culverts) in headwaters streams simultaneously represent significant threats to long-term species resilience and important characteristics for maintaining genetic purity among cutthroat populations. Loss of genetic purity is of particular importance for Colorado cutthroat trout populations, of which there are only seven genetically pure populations in the San Miguel watershed [1]. Future management decision-making processes should carefully consider the benefits and drawbacks of improved habitat connectivity for native trout populations.

On the mainstem San Miguel River and along tributaries in the lower watershed, large surface water diversion infrastructure and road networks similarly limit connectivity. The mainstem is most impacted in the vicinity of Nucla and Naturita by several channel spanning diversion structures (e.g. CC-Highline Ditch, Goulding Ditch, Reed Chatfield Ditch, and the BCD Ditch). Connectivity in the lower watershed may be somewhat limited on tributary streams that may be important refugia and spawning habitat for trout and native warmwater fish. Increased connectivity within tributary basin stream networks and between these networks and the mainstem San Miguel may help native fish populations occupy a greater fraction of their historic range. Importantly, in the San Miguel watershed, *temporal barriers* to longitudinal connectivity may also occur when water use significantly depletes flows in the river.

When and where large water depletions occur, aquatic habitat quality may be degraded and aquatic organism passage may be impossible. These changes in habitat quality and network connectivity may produce population-level impacts. Flow reductions on the mainstem San Miguel River are most significant in the lower watershed. Annual flow reductions and corresponding increases in water temperature between Horsefly Creek and Calamity Draw are noted for their potential to limit fishery health by CPW. Chronic reductions in flow are also observed or predicted on Beaver Creek, Leopard Creek, the San Miguel River between Horsefly Creek and Calamity Draw, and on several other small tributary streams. Comparison of observed and simulated streamflow time series to low-flow streamflow thresholds provided a means for estimating environmental water supply gaps. Water supply gaps, as assessed by this investigation, exist on numerous stream reaches throughout the watershed. These gaps vary in magnitude and duration depending on hydrological year type. Water supply gaps are most apparent in dry years on the San Miguel River mainstem below Fall Creek and on small tributary streams like Deep Creek and Bilk Creek. Closing these gaps or limiting their expansion in the future may be an important strategy for maintaining the well-being of local fisheries.

3.1 Notable Findings and Recommendations

Most limitations to native fish survival and recovery are common among species, with some exceptions. Many are hydrological: reduced seasonal connectivity to spawning and rearing habitat, reduced spring flood flows, and reduced late summer baseflows. Others are physical: entrainment in diversion ditches and canals; modification of backwaters, side channels, and other off-channel habitat; and fragmentation of habitat by dams and other in-channel structures. Water quality impairment (including temperature), non-native fish competition and predation, and hybridization round out the top challenges these fishes face. The effects of climate change are predicted to exacerbate many of these limitations. Conservation opportunities for native fishes in the San Miguel arise from addressing limitations: increasing or protecting flood and summer streamflows; protecting and restoring off-channel habitat; installing fish screens in diversions and providing for fish passage around diversions and low-head dams; managing non-native species; improving water quality; controlling or eliminating invasive fish species, and supporting stocking efforts, to name a few. Specific findings regarding the fishery include:

- Fish habitat quality, as assessed by R2Cross analysis, exists in a suboptimal state in many locations across the watershed during certain portions of the year. The duration and magnitude of these suboptimal conditions tend to increase under increasingly dry climate change predictions (e.g. scenarios C, D, and E).
- Water supply gaps for fisheries are most persistent across year types on the San Miguel River mainstem below the Highline Canal, and on tributaries in the lower watershed. The most significant gaps on the San Miguel River occur in the area where the fishery is expected to transition from warm-water to cold-water species.
- The ability for local aquatic biota to respond and adapt to changing climate conditions may be constrained by limited stream network connectivity in some parts of the watershed. Two low-head dams on the San Miguel mainstem between Cottonwood Creek and Naturita and diversion structures or culverts on the lower reaches of tributary streams within 1.0 mile of the San Miguel River appear to be most limiting to aquatic organisms ability to access diverse habitats/refugia across different times of year.
- Entrainment of native trout, native warm-water fish and managed sport fish in surface water diversions may reduce the number individuals able to reproduce in any given year.
- The range of native cutthroat trout populations is limited to relatively short tributary reaches at high elevations. These populations may be particularly susceptible to reductions in streamflow brought about by a warming and drying climate.

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