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MEMORANDUM

Date: August 22, 2011

To: Will Tully, USBR
From: William J. Miller, PhD, Miller Ecological Consultants, Inc.
CC:
Subject: WGFP EPA Aquatics Issues

EPA provided verbal comments during several telephone conferences and meetings on aquatic issues for the Windy Gap Firming Project DEIS and Aquatic Resource Technical Report. The major issues addressed in this memorandum are: 1) Additional discussion of past actions that affected current baseline conditions in the Colorado River and aquatic resources; 2) a qualitative discussion of cumulative effects of past diversion on aquatic resources; 3) better integration of information on changes in stream morphology, water quality including results of dynamic water temperature modeling, and hydrology to assess effects to aquatic life; 4) a discussion of projected changes in stream temperature in relation to current water temperature standards and the potential effect on fish populations; and 5) a qualitative assessment of how climate change could contribute to the cumulative effects on the aquatic community.

1) Past Actions that affected current baseline conditions in the Colorado River and Cumulative effects of past diversions on aquatic resources.

The current conditions in the Colorado River near Windy Gap are the result of a variety of past actions over the last century and longer. The actions include changes to the hydrologic regime from water diversions for agriculture, municipal and industrial uses, alterations to the watershed from changes in land use due to agriculture, municipal growth, resort and second home development; and changes to the aquatic fauna from commercial harvest, introduction of non-native species, management for sport fishing, and whirling disease.

1a) Biology

Joseph et al. (1977) report that the native fish community in the upper Colorado River consisted of four species: Colorado River cutthroat trout (Onchoryncus clarki pleuriticus), speckled dace (Rhinichthys osculus), mottled sculpin (Cottus bairdi), and mountain whitefish (Prosopium williamsoni). This number of species is typical of many of the headwater trout streams in the central Rocky Mountains (Moyle and Herbold 1987). Behnke (1992) notes that the native Colorado River cutthroat trout were reported to achieve weights of up to 22 pounds. He does not state if these were lake dwelling or riverine specimens. In other areas with both lake dwelling and stream dwelling forms, the lake forms attain larger sizes.

Non-native species introductions began in the late 1800s as game management agencies stocked species for sport fishing opportunities for both residents and tourists. The earliest documented stocking of game species in the upper Colorado River basin occurred 1882 (Wiltzius 1985) when both brook trout and rainbow trout were stocked. Brown trout were first stocked in the upper Colorado River basin in 1888. The first introductions of non-game non-native species occurred in the early 20th century. All of these non-native species would have increased the competition with and possibly predation on the native species, including Colorado River cutthroat trout. Fathead minnow were stocked in the Colorado River near Hot Sulphur Springs in 1938. White sucker were stocked into a lake in the Colorado River headwaters in 1926 (Wiltzius 1985). In addition, both unintentional and intentional introductions of other game and non-game species have occurred over the past century. Over time, the native species, especially cutthroat trout have declined and the non native trout increased. The result is the current fish community in the upper Colorado River basin.

There were commercial fisheries in the early 1900s in Colorado that may have contributed to changes in the fish populations in the state. The fishery locations included both public and private waters. A report from the US Fish Commission in 1903 stated that 290,390 pounds of "black-spotted" trout (the common name for the native cutthroat) and native suckers were caught in the state. In addition, a total of 1,069,776 pounds of non-native fish were caught statewide (Wiltzius 1985). A total of 19,900 pounds of black-spotted trout were caught in 1900 in Grand County (Wiltzius 1985). These fisheries likely caused a decline in the native cutthroat populations.

Sport fish management has had a major impact on the make up of the fish community in the Colorado River near Windy Gap. Game fish limits have changed over the past 50 years from a "catch and keep" type of approach, which relies on fish stocking to supplement populations, to a "catch and release" type of approach, which relies more on natural reproduction. Most trout stocking in the last 50 years consisted of introducing the desired non-native trout species, rainbow, brown, and cutthroat trout for sport catch rather than stocking native Colorado River cutthroat species. Those stocking efforts resulted in the reduction in the native cutthroat populations due to competition and predation from other species.

Other biotic factors also can impact the fish community. These factors include: changes to the primary and secondary producers upon which the fish community depends and the introduction of parasites, in particular, whirling disease. Whirling disease was present many Colorado Rivers by the mid 1990s including the Colorado River near Windy Gap. Whirling disease resulted in a severe reduction in rainbow trout populations in many of the infected river systems. The Colorado River at Windy Gap, dominated by rainbow trout in the 1980s, is now dominated by brown trout. The decline of rainbow trout provided an opportunity for the increase in brown trout populations. Brown trout are managed for sport fishing by CDOW and in other states. Brown trout are known predators and competitors of other trout species. Brown trout have been shown to reduce native cutthroat populations (Behnke 1992) and to reduce other salmonid populations through predation and competition (Taylor et al. 1984). Brown trout are nominated as one of the top 100 invasive species by the Global Invasive Species database (http://www.invasivespecies.net/database/species/search.asp?st=100ss&fr=1&str=&lang=EN).

The presence of brown trout in the current numbers make re-establishment of other salmonids, either rainbow trout or cutthroat trout, difficult. The re-establishment of other salmonids would require a reduction in the number of brown trout. This could be accomplished through either physical removal of the brown trout or some means to naturally disadvantange brown trout reproduction, survival and recruitment. One example of a removal effort is on the Cache La Poudre River where the Colorado Division of Wildlife has undertaken a large scale brown trout removal effort on a section of the Cache La Poudre River in an effort to re-establish a rainbow trout population (K. Kehmeier, personal communication). The high population of brown trout in the Colorado River provides a sport fishery in that reach of river, however, it may also inhibit the populations of other salmonids.

The trout populations are the consumers of the production from primary and secondary trophic levels. As such, trout populations rely on both terrestrial and aquatic invertebrates as food sources. Fausch et al. (2010) report that aquatic invertebrates provide the majority of the energy inputs for fish in spring and early summer but terrestrial invertebrates are the energy source for fish in late summer when aquatic invertebrates are scarce. This same study showed that lack of terrestrial invertebrates resulted in substantial reduction in benthic macroinvertebrates from feeding fish and a substantial increase in periphyton due to lack of foraging aquatic invertebrates. Aquatic invertebrates in the Colorado River near Windy Gap have a high diversity with numerous species (Miller Ecological Consultants, Inc 2009, Rees 2009). Rees collected invertebrates upstream and downstream of Windy Gap Reservoir and found diverse communities, however, no Pteronarcys stoneflies were collected. CDOW reported a decline in both the stonefly Pteronarcys and mottled sculpin since Windy Gap Reservoir was constructed. Pteronarcys were collected by Miller Ecological Consultants, Inc downstream of Windy Gap in 2004 (Miller Ecological Consultants, Inc 2009). The Colorado Department of Public Health and Environment (CDPHE) has a new metric for evaluating macroinvertebrate communities for impairment, the Multi Metric Index (MMI). For high elevation cold water streams an MMI value of 50 or less indicates impairment. Rees (2009) calculated MMI values of 92 and 89 for the macroinvertebrates upstream and downstream of Windy Gap Reservoir, respectively. Miller Ecological Consultants, Inc data for the Lone Buck and Breeze sites had MMI values of 100. Both of these samples indicate a healthy macroinvertebrate community.

There is a lack of historical information regarding the fish community and abundance at the time the first non-indigenous settlements occurred in the upper Colorado River basin. Unexploited fish population levels would be regulated by the habitat conditions. The current fish community also can be a factor of habitat but may be more directly related to management actions such as harvest limits and stocking. Research in the 1970s by CDOW showed that changing harvest limits could result in much high population numbers and biomass. Many rivers in Colorado now have sections that are catch and release water to provide a quality fishing experience. Recent surveys of fish populations in the Colorado River downstream of Windy Gap show that abundance for fish greater than 6 inches long has ranged from a high of 11255 fish/mile in 2003 to 3441 fish/mile in 2010 (Figure 1) (Ewert 2011). It is undetermined why the highest numbers were collected after one of the driest hydrologic years on record and the lower numbers were collected recently. The conditions for survival may have been better in 2001 and 2002 with lower peak flows. Nehring and Anderson (1993) found a strong correlation between year class strength and peak flows. Other rivers in Colorado have populations in the same range as the Colorado River downstream of Windy Gap. The Gunnison River near Altmont has populations that ranged from approximately 3500 fish/mile in 2004 to 5500 fish/mile in 2008 (Brauch 2011). The majority of the fish population in the Gunnison River is brown trout. The Fryingpan River trout populations are approximately 9000 fish/mile with brown trout approximately three times more numerous than rainbow trout (Bakich 2011).

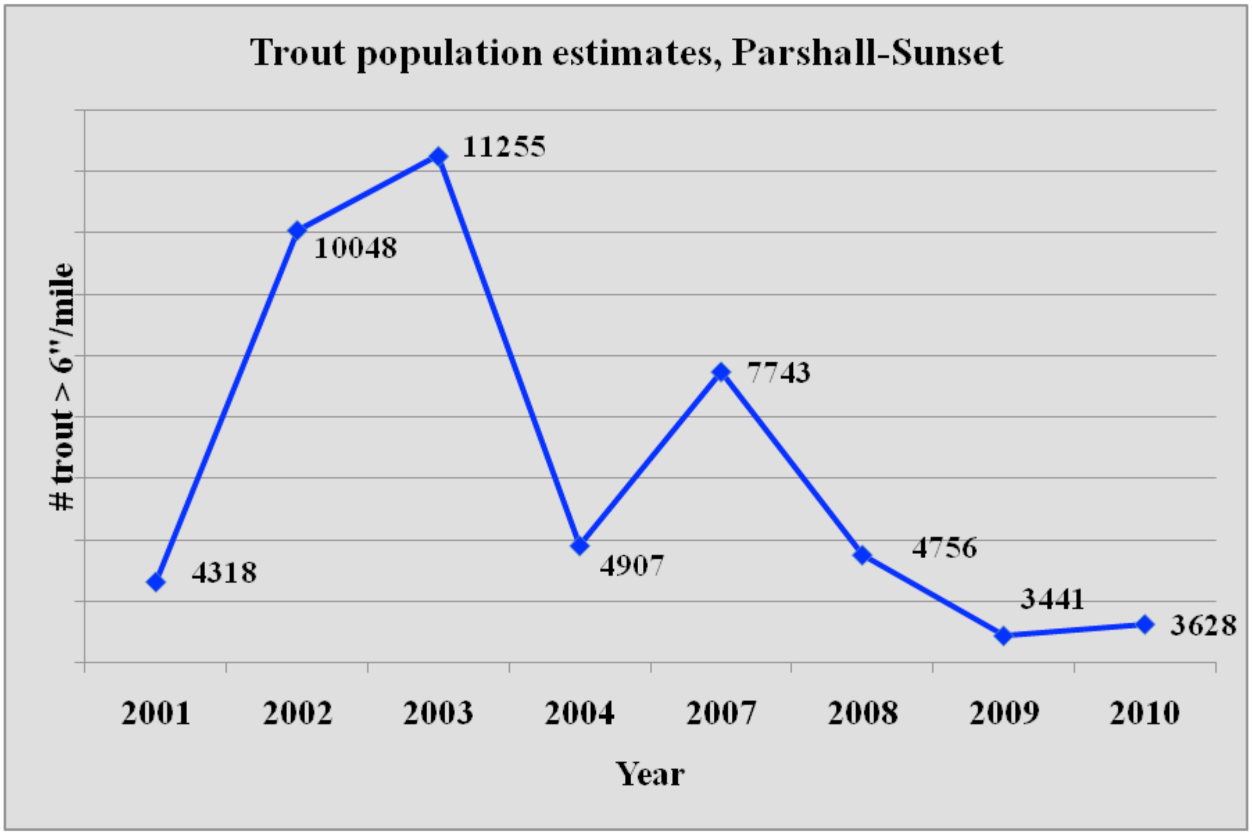

Figure 1. Trout population estimates for the Colorado River downstream of the Williams Fork for 2001 – 2010.

1b) Hydrology

The upper Colorado River and its sub-basins have snowmelt runoff hydrographs with peak flow during late spring and early summer. The highest flows and largest volume of water occurs in June (Hydrology Table 3-1) when approximately 36 % of the annual flow occurs. The first stream flow alterations occurred with diversions for agricultural use and municipal and industrial water supplies. Those alterations have continued for more than 100 years and include trans basin diversions from the Colorado River basin to the South Platte River Basin for use on the Front Range of Colorado. The transbasin diversions began in the 1890s with the Grand River ditch and continued in the 1900s with Moffatt in 1937, C-BT in 1947 and Windy Gap in 1985. Irrigation diversion began in Grand County in the 1890s. These incremental flow diversions have occurred over nearly 100 years. As a result, the native flow volume has been reduced by approximately 70 % by these diversions and off stream uses. The flow pattern is still shaped by snowmelt runoff but at a reduced magnitude and duration. Approximately 33% of the current annual volume occurs in June compared to 36% of the native June annual volume. The large reservoirs and headwater transbasin diversions have the ability to reduce the peak river flows in most years. In years with extremely high snow pack, such as the winter of 2010-2011, long duration, high flows still occur.

The summer and fall low flows also are reduced from native flow conditions. The reduction in stream volume in July, August and September is approximately 65% of native conditions (FEIS Table 3-1). The lower summer flows may result in less area of suitable habitat and elevated stream temperatures than with native conditions.

The overall result of the diversions is a proportionally reduced hydrograph in all months of the year. Since no data on fish populations are available for native conditions, the impact of changes in hydrology to fish populations is unknown. This year round reduction likely has resulted in some changes to stream morphology over the last century. The channel characterized as stable (FEIS Section 3.7) under existing conditions. Further, the flows required to move fine sediment to medium gravels occur under existing conditions and would occur with all alternatives (FEIS Section 3.7). The flows required for ecological function would occur at nearly the same frequency as existing conditions.

1c) Stream morphology, water quality and hydrology

Recently, research has focused on comprehensive ecologically-based management of riverine systems to provide function for both instream aquatic biota as well as near-stream riparian areas (Bunn and Arthington 2002, Chapin et al. 2002,Lytle and Merritt 2004, Lytle and Poff 2004, Poff and Zimmerman 2010, Richter et al. 2003). Natural flow regimes, with both floods and droughts, occurred for many years prior to any river regulation. The biota in these ecosystems have adapted to that flow regime. That adaptation is the response to changes in the physical environment with floods as well as the biological adaptation to withstand floods or prolonged droughts in those systems (Lytle and Poff, 2004). Lytle and Merritt (2004) in their study of riparian forests concluded that a natural flow regime was the best prescription for maintaining near-stream cottonwood riparian areas.

In addition to instream flows, research has focused on river conservation and restoration (Trush et al. 2000). The study of river ecosystems includes all of the riverine components listed by the Instream Flow Council in the context of a functioning system that provides the components necessary for restoring and maintaining a diverse ecosystem similar to natural conditions.

The dynamic character of river systems has been stated as one of the important features in maintaining ecological integrity (Poff et al. 1997, Richter et al. 1997). The natural variability within riverine systems needs to be considered as part of restoration and flow manipulation efforts. Any specified instream flow management should include a strategy for incorporating this natural variability and also the potential uncertainty involved with that in restoration of river systems (Wissmar and Bisson, 2003).

Clipperton et al. (2003) incorporated four ecosystem components into a Instream Flow Needs Determination for the South Saskatchewan River Basin. The four components were: 1) fish habitat; 2) water quality; 3) riparian vegetation; and 4) channel maintenance. The objective of their determination was to provide a high level of protection for the riverine ecosystem that could be achieved by instream flows alone. Further, they wanted to provide for protection of aquatic habitats in the short term while protecting processes that maintained aquatic habitat in the long term.

Clipperton et al. (2003) identified a process for determining the desired protection levels. Their process included the selection of threshold habitat levels for protection of fish habitat. This concept is similar to the Comprehensive Ecologically Based Flow Determination of Annear et al. (2004). Other studies have employed a combination of instream flow methods including the Modified Tennant Method (Tennant 1976), and Tennant with the Tessman Modification (Tessman 1980) as demonstrated in Washington state streams. Habitat changes as a function of flow for the Windy Gap Firming Project was determined using a two dimensional hydraulic and habitat method similar to the current method of USGS. In addition, a habitat time series analysis was used to determine changes in habitat over a range of hydrologic conditions. The latter method incorporates components similar to Clipperton et al. (2003) and Annear et al. (2004).

1c-1) Physical Components of Rocky Mountain Riverine Systems

Physical components of riverine systems that affect the biota both in the riparian and instream areas include hydrology, geomorphology, and water quality. Hydrology within riverine systems, especially in systems with snowmelt-driven hydrographs, usually have spring or early summer peak flows with base flows occurring in fall through winter. The magnitude and duration of the peak flows are variable and dependent on annual snowpack and also rainfall events that occur after snowpack has subsided. These flows affect the stream morphology. Specific flow magnitude and duration are required to move sediment, initiate channel migration, create and maintain habitat, and incorporate organic material in the form of woody debris into the system.

Research has shown that the geomorphic changes occur with peak flows of various return intervals. Hill et al. (1991) discussed the need for large flow events for channel migration and valley form influences. These events are generally large events that occur approximately 1 in 25 years or greater. More frequent flooding occurs on nearly an annual basis. These flows occur at a bankfull or slightly higher than bankfull level and are shown to rework channel features without a lot of channel migration. In general, these flows occur every 1.5 to 2 years in most stream systems. Research has shown that flows that occur during the annual peaks do most of the in-channel reworking of bars and instream habitat to create habitat for the base flow period of the year.

By considering various physical processes that occur in river systems, particularly in alluvial systems with cobble and gravel bedforms, flow regimes can be specified that will modify channel morphology. These modifications can move from a present day condition which may be a detached floodplain and incised channel to a more connected floodplain with a less incised channel which provides function for both instream and near-channel riparian habitat (Trush et al. 2000).

The ecological flows should have a recurrence interval for overbank flooding that is approximately 1.5 to 2 years between flow events, to maintain connectivity with the riparian areas and maintain longevity of riparian forests. In addition the specified bankfull flows, to maintain instream channel habitat and create new habitats, should occur at a frequency that is generally found in the natural system and is suitable for present channel conditions. Habitat flow relationships for baseflow conditions and other seasons of the year can be determined from stream cross-sectional data for riffles, which is an indicator of benthic invertebrates' productivity.

1c-2)_ Biological Components of Riverine Systems

Biological component of riverine systems include instream biota such as primary and secondary producers (e.g. algae, periphyton, benthic invertebrates) and consumers (e.g. invertebrates, fish). Aquatic biota have evolved to survive within the range of flows that occur under natural conditions. For example, benthic invertebrates with annual life cycles are in life stages that avoid high flows impacts. These include adult free flying lifestages and egg life stages.

Fish species also have evolved to minimize impacts from detrimental flows. Timing of spawning, hatching and emergence for salmonids is timed to maximize long term survival under natural flow regimes. The natural flow regimes create habitat that can be used by juvenile and adult fish to avoid detrimental effects of high flows and refuge habitat during low flows.

Riparian corridors also include terrestrial species of plants and animals that depend on instream flows. High flows during runoff inundate riparian which promotes new vegetation growth, maintains existing vegetation, and carry organic material into the stream channel.

1c-3) Physical Processes and Biological Responses Associated with an Annual Hydrograph

The channel geometry and plan form of the channel and the biota within the channel are all affected by the volume and timing of annual discharges. Physical features of the stream channel change as a result of peak flows and the biota respond to those physical changes.

The annual hydrograph can be categorized into several time periods. These include ascending limb of runoff, peak runoff, descending limb of runoff, summer flows, fall, winter and spring baseflows.

The ascending limb of the hydrograph affects the channel configuration and stream sediment in the following ways. As discharge increases, the hydaulics forces within the stream channel correspond to the volume of discharge. Local hydraulic conditions increase the near bed shear stress, which begins fine sediment particle mobilization in areas that exceed shear stress based on particle size. As the flows continue to increase, larger size classes of substrate are moved as the shear stress increases and incipient motion is reached and exceeded for those size classes. In general, maximum bed movement occurs at or near bankfull conditions when the shear stress is highest.

During the peak of the runoff, two factors that affect the physical conditions within the stream are the magnitude and duration of the peak runoff. During the time of peak runoff, flows that are at or near bankfull are producing the maximum amount of work on the channel geometry including erosion on the channel banks, redistribution of sediment and transport of organic debris (large and small) downstream.

Flows that are greater than bankfull discharge expand into the floodplain and riparian areas of the stream. These inundate the floodplain, induce floodplain scour in certain locations where there are sufficient velocities to change the floodplain shape. They also mobilize organic debris in the floodplain and transport that to the stream channel.

The amount of change in physical habitat from year to year is determined during this runoff cycle that shapes new habitats and maintains the current habitat. Without peak flows, streams will generally become narrower with vegetation encroaching on the sides and the ultimate stream size will be determined by the average discharge.

The descending limb of the hydrograph has several physical changes associated with it as well. These include sediment deposition as flows recede and deposition of large organic debris in the form of logs and trees that have been scoured from the overbank or near bank areas.

The terrestrial plant community in the floodplain and riparian areas also respond to peak flows. Over bank flow prepare seed beds for plant establishment and water for initiation of plant growth. The soils become saturated, which benefits wetland and riparian plants.

Aquatic biota responses to peak flows are also apparent in the various biota that inhabit the stream. Benthic macroinvertebrates in snowmelt runoff systems have generally evolved to avoid the detrimental effects of high flows. These include being in locations or in lifestages that avoid those high flow impacts. Many of the macroinvertebrates in western stream systems have evolved so that adults emerge and lay eggs prior to runoff. Therefore the most dominant lifestages that exists in peak flow are the egg or early instars. The small size of these lifestages allows them to avoid many of the detrimental effects of peak flows.

Similarly, the large woody debris and habitat features that are formed during previous years' peak runoff provide refuge habitat for the various lifestages of fish species that inhabit streams. These types of habitat provide lower velocities during peak flow and shelters from the higher velocities normally associated with a peak runoff event.

The baseflow periods beginning after the runoff and extending through fall, winter and into spring are generally times of stable flow for the year. During these times, the physical conditions are influenced more by water quality and in particular water temperature than discharge. The bed and sediment are stable except for fine sediment moved or local movement during runoff events from rainstorms.

Biological activity during summer is usually in response to the water temperature and increased day length. Summer period is the time of greatest growth due to the elevated water temperatures and the increased primary and secondary productivity. Both of these provide food for fish. During fall baseflows, the terrestrial plants in the near stream areas provide leaf litter that is a major energy source for secondary production in the stream.

This organic material is either shredded or decomposes within the stream system and is used as food by various invertebrates. In addition, during decomposition, the bacteria associated with decomposition provide food for invertebrates. These invertebrates then are food sources for the fish species present in the stream.

Adult and juvenile fish of all species are dependent on refuge habitat for shelter during fall and winter. These habitats are created during spring runoff by scouring the stream channel to develop pools and deeper runs. These deeper areas provide sufficient habitat to avoid the harsh winter environments.

Spring spawning species, such as rainbow and cutthroat trout, generally spawn in May and June on the ascending limb of the hydrograph. They also are nest builders and excavate redds. Spring spawning species generally incubate during runoff and begin to emerge in late June and into July as flows recede or have receded.

During summer, maximum water temperatures produce the maximum growth and productivity in the stream. This is a time when fish acquire the greatest amount of weight in preparation for the harsher environments for fall and winter.

Overall stream productivity on average in natural systems is determined by the baseflow conditions that provide for primary and secondary productivity and feeding as well as refuge habitats. Peak flows temper those populations and can influence the year class strength of salmonids if very high discharges occur when the young fish are susceptible to the peak flows (Nehring and Anderson 1993). In general, the peak flow time period has the lowest amount of optimal habitat for fish species but that peak flow provides the work in the channel that shapes, creates and maintains habitat for the majority of the remainder of the year for those species.

1c-4) Summary

The stream biota in the Colorado River near Windy Gap Reservoir are the result of over a century of human induced changes to the ecosystem. These changes include introduction of non-native species, management of fish for commercial harvest, sport fishing harvest and catch and release, diversion of water for human use, and habitat fragmentation caused by dams and diversions. Since the changes have occurred over a long period of time and many occur together, all of these changes in the aggregate have had some level of impact on the ecosystem.

The existing flow regimes in the Colorado River near Windy Gap Reservoir still include the components for stream health but at lower levels that natural flows. There are high peak flows that exceed bank full conditions on a regular basis. The existing flow regimes provide the necessary conditions to create and maintain habitat (FEIS Section 3.7). In addition, these higher flows provide the conditions to maintain riparian conditions. The base flows maintain the benthic invertebrate populations. The sediment transport analysis reports that the transport capacity of the Colorado River exceeds the sediment supply. In addition, flows that move sediment up to medium gravel, which is important for spawning trout, a moved on a regular basis (FEIS Section3.7). Winter flows combined with the habitat created by the high flows provide refuge habitat during winter conditions.

The combination of the above conditions provides the habitat for the fish populations and macroinvertebrate populations in the Colorado River near Windy Gap Reservoir. The trout populations do fluctuate from year to year but the cause for the fluctuations is undetermined and likely a combination of several factors. The trout populations are relatively high and comparable to other Colorado Rivers. As in other Colorado Rivers, the majority of the trout population is brown trout. The macroinvertebrate community is diverse and indicates a healthy stream system. Although one species, *Pteronarcys californica*, has declined in the Colorado River both upstream and downstream of Windy Gap Reservoir.

Another factor that may impact the aquatic biota is stream temperature. The dynamic water temperature model predicts more exceedence of the State Water Temperature standard with the proposed alternatives than with existing conditions (Hydros Consulting 2011). There are times with existing conditions when the thermal conditions in the river exceed the current water temperatures standards for the Chronic Standard of 18.2 C and approach the daily maximums of 23.8 C. at some locations downstream of Windy Gap Reservoir. The consequences of those water temperatures are discussed in the following sections.

Current water temperature standards and effects of Windy Gap Firming Project on current fish populations.

The current water temperature standards include both a numeric and narrative standard. The numeric standard (April though October) is a Mean Weekly Average Temperature (MWAT) of 18.2 C and a Daily Maximum (DM) of 23.8 C. The narrative standard is: "Temperature shall maintain a normal pattern of diel and seasonal fluctuations and spatial diversity with no abrupt changes and shall have no increase in temperature of a magnitude, rate, and duration deleterious to the resident aquatic life." (CDPHE Regulation 33, 33.5 (1))

The Colorado River near Windy Gap is classified as Cold Water Tier II. The water temperature standards are set to be protective of the cold water species in the river. The MWAT is set as a chronic threshold. Water temperatures lower than the MWAT do not impact the species. The DM is set to be protective against lethal conditions.

The current water temperatures downstream of Windy Gap Reservoir have both seasonal and daily variations. Examples from July and August 2009 are provided to show the range of diurnal change and the seasonal variation (Figures 2 and 3). Thermal conditions are a result of several factors that include; solar radiation, air temperature, relative humidity, wind speed, water volume, stream shading, channel geometry and stream orientation (Theurer et al. 1984). Windy Gap did not pump in July and August of 2009. The resulting water temperature were the result of water passing through Windy Gap Reservoir and moving downstream combined with meteorologic conditions. The August 2009 water temperature pattern follows air temperature more closely than it follows discharge. The mid August time period illustrates this pattern (Figure 3).
These daily and seasonal variations in stream temperature provide cues to stream biota for specific aspects of life history such as spawning. In addition, certain temperatures are required for energy assimilation and growth. This is especially important for young salmonids and other young fish that rely on summer growth to prepare for and survive harsher winter conditions. Adult fish rely on summer energy assimilation to prepare for winter and for preparation for reproduction. The best temperatures for growth vary by species.

Water temperature simulations show that diurnal and seasonal water temperature patterns are similar to the existing conditions (Hydros Consulting 2011). The monitored water temperature show a diurnal change of approximately 3° C to 4° C (Figure 2 and Figure 3). The water temperature simulations show a similar magnitude of diurnal change. The highest observed seasonal temperatures occur in July and August. The water temperature simulations show this same seasonal pattern (Hyrdos Consulting 2011).

Daily water temperature simulations were conducted for 1975, 1979, 1986, 1988 and 1989. These years were chosen since they had the highest likelihood of being conditions when water temperatures would change due to project operations. In all of these years except 1986, the simulations predicted exceedence of both the MWAT and DM during July and August for existing conditions. In all of these years except 1986, the simulations predicted an increased number of exceedences of both the MWAT and DM downstream of Windy Gap Reservoir for No Action, Alternative 2 and Alternative 5 (Hydros Consulting 2011).

The additional number of exceedences of the MWAT would likely increase the stress on the aquatic community. The additional exceedance of the DM would add stress above the level of the MWAT. The impacts from the exceedences would be greater if the exceedences were sequential rather than sporadic. The increased stress over a longer period of time may result in less fit individuals, stress to lower trophic levels and potentially mortality. While both MWAT and DM are a concern, the increased number of DM exceedence may have the greatest impact. Mitigation has been designed to minimize or eliminate the exceedance of both the MWAT and DM standards (Windy Gap Firming Project Fish and Wildlife Mitigation Plan 2011). The measures include a reduction or curtailment of pumping when water temperatures are at the thresholds specified in the mitigation plan.

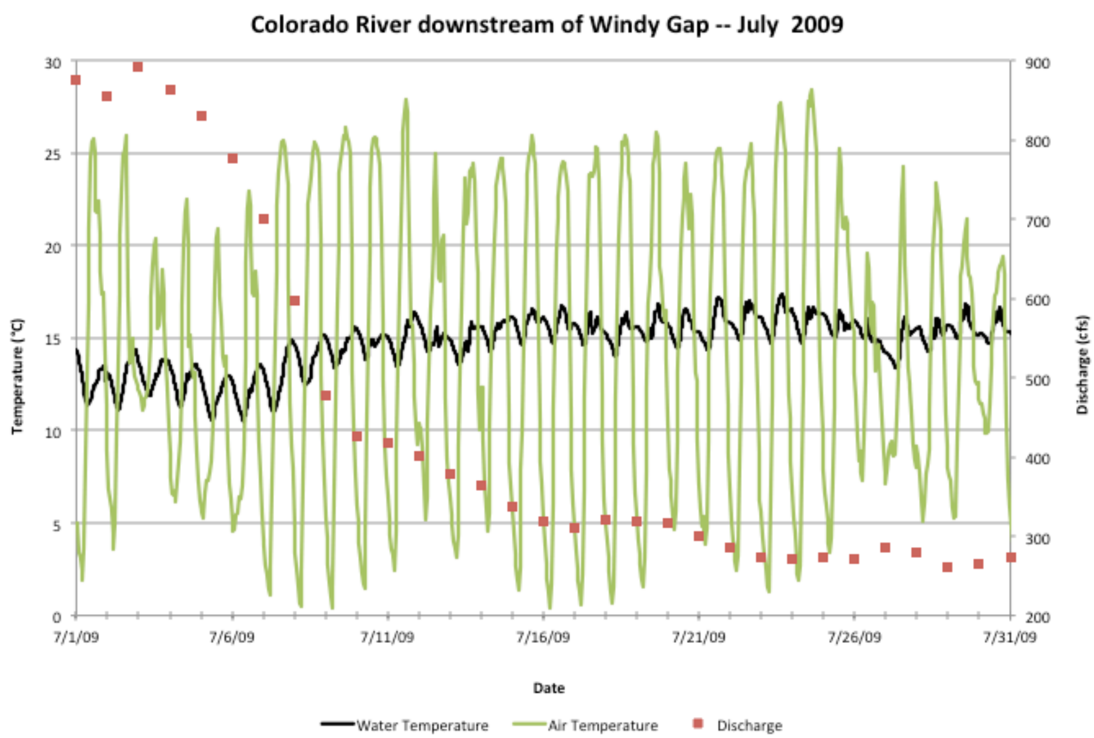

Figure 2. Hourly water temperatures, air temperature (at Granby) and mean daily discharge for the Colorado River downstream of Windy Gap Reservoir, July 2009.

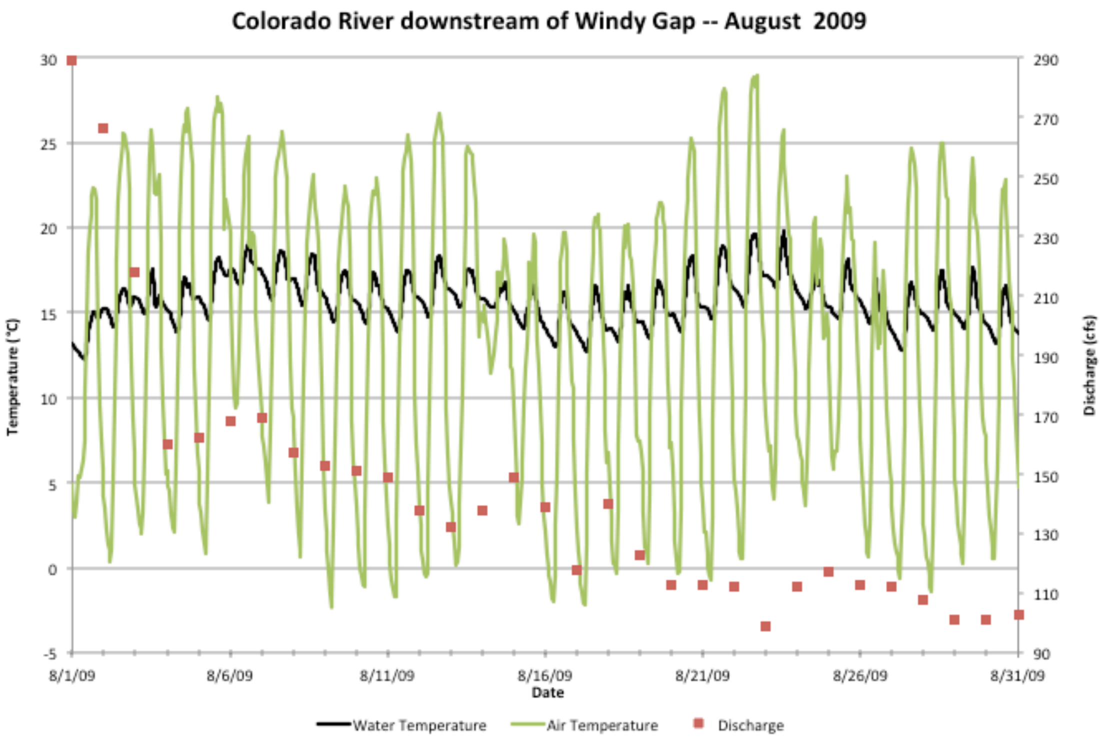

Figure 3. Hourly water temperatures, air temperature (at Granby) and mean daily discharge for the Colorado River downstream of Windy Gap Reservoir, August 2009.

Climate Change

Although differences in model results demonstrate the uncertainty in projecting future climate conditions, the anticipated effects of warmer temperatures in the Colorado River basin upstream of Windy Gap, as identified by the CWCB, 2010), include:

- Average annual runoff increases by about 5%
- More winter precipitation as rain,
- Average year around temperature increase of about 1.8°C;
- Peak runoff in May rather than June as currently happens;
- Higher than current average runoff in April and May
- Lower than current average runoff in the late summer-fall months;
- Decreased baseflow from ground water in late summer;
- Reduced soil moisture in summer and longer growing seasons extended by an estimated 18 days split equally between the spring and fall;
- , A shift from snow to rain in the early and late winter months due to increased temperatures; and
- Greater loss of water by evapotranspiration

Climate change may affect the timing and operation of the WGFP, as well as the water supply and demand for WGFP Participants. Potential environmental impacts from climate change, as described above, are qualitatively assessed as part of the cumulative effects evaluation for applicable resources such as surface water hydrology, ground water, stream morphology and floodplains, surface water quality, aquatic resources, vegetation, wetlands and other waters, threatened and endangered species, and recreation.

Climate change may affect the timing and operation of the WGFP, as well as the water supply and demand for WGFP Participants. The impacts to aquatic resources are difficult to quantify given the uncertainty associated with the future conditions. However, a change in the hydrograph due to earlier snowmelt may result in an impact to both spring and fall spawning species. Earlier high flows may result in lower survival of newly emerged fall spawning salmonids and less successful recruitment for spring spawning species. The decreased base flow in the summer in combination with the elevated air temperatures could result in additional increases to water temperatures. The higher water temperature may stress the cold water species or restrict their downstream range from current conditions. More winter rains may also change water quality, especially fine sediment, due to runoff from soils that are normally snow covered.

The dynamic water temperature model used 2007 air temperatures to predict changes in water temperature due to climate change. The results of that analysis indicates that the MWAT exceedences would increase by up to 4 occurances in one of the five hydrologic conditions modeled in addition to the increases predicted for the Alternatives. The additional exceedences would be further stress to the aquatic system during these events.

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