# Ecological Streamflow Needs in the Henry's Fork Watershed

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## Introduction and Purpose

This document has been prepared in part to meet objectives of the project "Conservation of surface and ground water in a Western watershed experiencing rapid loss of irrigated agricultural land to development," funded by U.S. Department of Agriculture (USDA) Cooperative State Research Education and Extension Service grant 2008-51130-19555 to Humboldt State University. Dr. Rob Van Kirk of Humboldt State University is project director; Fremont-Madison Irrigation District, Friends of the Teton River, and the Henry's Fork Foundation are project partners. One of the five project objectives is to develop strategies to increase water availability for agriculture while enhancing ecological benefits in key stream reaches. After the USDA project was underway, the U.S. Bureau of Reclamation, with partial funding from the Idaho Water Resources Board, initiated a special study of water resources in the Henry's Fork watershed. The Henry's Fork Watershed Council has provided much input to both projects and has facilitated collaboration and synergy between the two projects. Through formal and informal discussions, the Bureau of Reclamation, the USDA project team, the Watershed Council, and smaller subgroups of watershed stakeholders have identified the need to summarize ecological streamflow needs in the watershed. This document attempts to meet that need as well as the USDA grant objective related to ecological flow needs. Although the three individuals listed above co-authored this document, the information contained in it has resulted from many years of research and discussion. Almost all of the streamflow issues presented here have arisen in previous meetings involving the Watershed Council, its formal subcommittees, Fremont-Madison Irrigation District, specific canal companies, hydroelectric power companies, and other watershed stakeholders. The authors take full responsibility for the content of this document but at the same time acknowledge the substantial contributions of many other individuals.

This document presents major streamflow needs for maintenance of fisheries and other ecological functions in the Henry's Fork watershed. Some general observations are presented first, followed by a list of seven sets of specific stream reaches in the Henry's Fork watershed in which flow alteration can negatively affect fisheries and/or ecological functionality. Other than cursory listing in the summary table, this document does not consider issues such as entrainment of fish in diversions, barriers to fish migration, changes in sediment supply, channel modification, and habitat alteration, which, although often associated with water use infrastructure and water management, are not streamflow considerations per se.

## General Observations

The hydrologic regime of a stream is the primary physical driver of geomorphic and ecological processes in the stream channel and floodplain, which in turn determine the types and abundances of aquatic species that inhabit the stream/riparian system (reviewed in Van Kirk and Burnett 2004). Hydrologic regime is defined as magnitude, timing, duration, frequency, and rate of change of streamflow and intra- and inter-annual variability in these attributes (Poff et al. 1997). Thus, hydrologic regime in a particular stream reach cannot be reduced to a single target flow. Furthermore, the hydrologic regime of a particular stream reach is determined by the integration of climate, geology, watershed processes and human uses throughout the entire catchment upstream of that reach, so any management actions taken to meet a flow or water use objective in one part of the watershed affect flow in all downstream reaches. Effects associated with operation of large dams and diversions are relatively obvious and easily quantified, but effects due to a combination of small diversions, irrigation seepage, and groundwater return flow over large areas can be just as large in magnitude and ecological importance but much more difficult to recognize and quantify.

The natural hydrologic regime can be considered as the hydrologic regime present in a stream in absence of substantial anthropogenic effects, which, in the Henry's Fork watershed, consist primarily of storage, delivery, diversion and return of water for irrigation and hydroelectric power generation. These activities affect to some extent almost all stream reaches in the Henry's Fork watershed except headwater springs and streams. Because native aquatic and riparian species have evolved life histories around the natural hydrologic regime, alterations to the natural regime can have negative consequences on these species, and maintaining important components of the natural regime can be critical to conservation of native species, particularly in the presence of nonnative species (Fausch et al. 2001, Moller and Van Kirk 2003, Van Kirk and Jenkins 2005). In the Henrys' Fork watershed, the primary native fish species of concern is Yellowstone cutthroat trout (YCT, *Oncorhynchus clarkii bouveri*), of which viable, wild populations exist primarily in the Teton River drainage, a few Henry's Lake tributaries, and a few isolated headwater tributaries elsewhere in the watershed. In the absence of competition from nonnative species, native cutthroat trout can persist under a variety hydrologic conditions, including under regimes that are substantially altered from the natural regime. For example, the hydrologic regime of the upper Snake River has been altered by storage and delivery operations at Jackson Lake for over a century, yet cutthroat trout still dominate there. On the other hand, there are many examples of rivers in the Greater Yellowstone region (e.g., upper reaches of the Gallatin and Madison rivers) in which hydrologic regimes have been altered very little, yet native trout are essentially absent (Van Kirk and Benjamin 2001). The headwaters of nearly all streams in the Henry's Fork watershed are relatively unaltered, yet viable populations of YCT are found in very few of these streams. Thus, maintaining the natural hydrologic regime is neither necessary nor sufficient to maintain populations of native trout in the presence of nonnative species, and hydrologic regime is only one of numerous factors that affect long-term viability of native trout.

On the other hand, the most popular, economically important, and widespread fisheries in the watershed are supported primarily by wild populations of nonnative rainbow (*O. mykiss*), cutthroat x rainbow hybrid, brown (*Salmo trutta*) and brook (*Salvelinus fontinalis*) trout (Van Kirk and Gamblin 2000, Loomis 2006). Optimal hydrologic regimes for maintenance of these populations may differ substantially from the natural regime. In general, the primary flow limitations for these fisheries are low flows downstream of Henry's Lake and Island Park Reservoir during winter storage season and low flows downstream of large diversions late in the summer.

Maintenance of riparian and wetland vegetation depends on certain critical components of the hydrologic regime (reviewed by Jankovsky-Jones and Bezzerides 2000). Recruitment and growth of woody riparian species such as cottonwoods and willows require springtime peak flows of appropriate magnitude, timing and recession rate, along with a supply of sediment. In the Henry's Fork watershed, extensive volcanic geology and a large amount of groundwater influence in the Henry's Fork headwaters naturally limit the extent of hydro-geomorphic conditions suitable for creation and maintenance of extensive floodplain riparian systems, thereby reducing the importance of peak flow characteristics in many stream reaches (Jankovsky-Jones and Bezzerides 2000, Van Kirk and Burnett 2004, Bayrd 2006). The stream reaches in which peak flow characteristics are potentially important for maintaining floodplain riparian ecosystems include Henry's Lake Outlet, the lower few miles of Fall River, the Henry's Fork downstream from St. Anthony, and most of the Teton River drainage. Peak flow characteristics are also important in headwater streams such as Robinson Creek, Conant Creek, and tributaries draining the Centennial Mountains. Maintenance of wetland ecosystem processes depends on high water tables and groundwater-dominated hydrologic regimes. Extensive wetland areas exist naturally in the Island Park Caldera, associated with headwater springs (Big Springs, Warm River, Buffalo River, etc.; see Benjamin 2000). Large wetland areas also occur in areas of spring emergence southwest of Ashton, along the Henry's Fork downstream of St. Anthony, in Teton Valley, and along the lower Teton River forks downstream of Highway 20. Although it is not known with certainty the degree to which these wetland areas are enhanced and/or maintained by groundwater flow resulting from irrigation seepage, hydrologic modeling suggests that irrigation seepage is an important component of the current hydrology in these wetland areas (Van Kirk and Jenkins 2005, Peterson 2011). Quantifying the contribution of irrigation seepage to these ecologically important wetland areas is a major objective of current modeling efforts.

## Specific Sets of Stream Reaches of Concern

Although there are other stream reaches in which flow alteration can have localized, primarily seasonal, effects on fish populations and other aspects of stream and riparian ecology, the seven sets of stream reaches listed in this document comprise the reaches that arise most frequently in discussions of flow needs for fish and aquatic/riparian species in the watershed (see accompanying map and summary table). The nature, timing, magnitude and potential ecological effects of alterations in most of these reaches have been quantified and presented in previous and recently completed work (Benjamin and Van Kirk 1999, Van Kirk and Burnett 2004, Van Kirk and Jenkins 2005, Bayrd 2006, Peterson 2011).

## 1. Henry's Lake Outlet

### *Flow issues*

The flow regime in Henry's Lake Outlet is determined primarily by releases from Henry's Lake Dam, although the effects of dam releases decrease gradually as the stream gains water from largely unregulated tributaries and springs as it flows from the dam to its confluence with Big Springs. The primary flow alterations in this reach are decreased winter flows during storage season and greatly increased flows during late summer of dry years when storage water is released for irrigation use in the lower watershed (Van Kirk and Burnett 2004). The delivery of water during late summer has shifted the mean timing of peak flow from June to July and increased within-year and between-year variability in peak flows. Henry's Lake stores twice its mean annual inflow, so that in order to refill the reservoir, low storage-season flows are required for several years following large drawdown of Henry's Lake

### *Affected resources*

Yellowstone cutthroat trout, rainbow trout, cutthroat x rainbow hybrid trout, and brook trout are found in Henry's Lake Outlet and support recreational fisheries (Van Kirk 1999). Of these species, only the YCT is native. Most of the YCT and hybrid trout found in the Outlet are individuals from Henry's Lake that migrate downstream over the dam during the spring spawning season. Fish that down-migrate from Henry's Lake cannot return to the lake as they may have done prior to construction of the dam in the 1920s. Some of these individuals may be produced by wild reproduction in Henry's Lake tributaries, but most are probably produced by hatchery operations (see Garren et al. 2009 for a recent description of the Henry's Lake fishery). Most of the rainbow and brook trout are wild. Sterile brook trout stocked into Henry's Lake may migrate downstream into the Outlet, and hatchery rainbow trout stocked into Island Park Reservoir and Snake River fine-spotted cutthroat trout stocked in the Mack's Inn reach of the Henry's Fork may migrate upstream into the Outlet. The fine-spotted cutthroat trout support a put-and-take recreational fishery and do not constitute a conservation population of the large-spotted form of cutthroat trout native to the watershed. Gregory (2000) observed 111 rainbow trout redds, 25 cutthroat trout redds, and 556 brook trout redds in the Outlet over the course of one year but very little apparent survival of age 0 fish. He concluded that low numbers of age 0 trout indicated either low survival of eggs in the redds or mortality/emigration of young trout soon after emergence, potentially because of lack of sufficient rearing habitat or possibly because of warm summer water temperatures. Habitat conditions in the Outlet are generally better in the upper reaches (Stumph 1995), where the effect of low flows is most pronounced. It is not known what role and function the Outlet played in maintaining fisheries in the watershed prior to construction of the dam, but it probably served primarily as a spawning and rearing stream for cutthroat trout that migrated seasonally between the Outlet and Henry's Lake or the Henry's Fork. Historical literature and recent hydrologic analysis suggest that the Outlet can dry up completely during the late summer of dry years even under natural conditions.

Low winter flows, when they occur, probably limit the number of fish that can over-winter in the Outlet. However, the primary effect of Henry's Lake Dam operations on the Outlet has been to alter geomorphic processes and riparian vegetation dynamics in the channel and floodplain. The shift in timing of peak flows from late spring/early summer to mid-summer is likely to affect riparian vegetation recruitment.

Accelerated erosion in the Outlet due to high flows and channel/floodplain alterations has been identified as a source of fine sediment that deposits in the Henry's Fork and in Island Park Reservoir downstream (YSCD 1995, HabiTech 1997, 1998).

### *Current management*

Although Henry's Lake is owned and operated by North Fork Reservoir Company, a private entity, the storage water rights held in Henry's Lake fit into the larger accounting and priority scheme of storage rights that exist throughout the upper Snake system, the vast majority of which are held in Bureau of Reclamation facilities. Thus, the management of physical water stored in and released from Henry's Lake is conducted within the context of the entire upper Snake system and its multi-facility and multiple-use criteria and objectives. Because Henry's Lake is located far upstream in the system, current operations seek to minimize the amount of storage delivered from Henry's Lake, and thus large amounts of storage are released from Henry's Lake only during very dry years. These operations incidentally minimize the effects of flow alteration in the Outlet and also minimize the effects of reservoir drawdown on the world-class fishery in Henry's Lake itself. During sequences of normal to wet years, outflow closely matches inflow during most of the year, resulting in relatively little hydrologic alteration (Van Kirk and Burnett 2004).

### *Possible future management*

Minimizing the amount of storage water required to meet irrigation and other flow needs downstream (and throughout the system) late in the summer is the primary option available for limiting the effects of flow alteration in Henry's Lake Outlet. This strategy also benefits water rights holders by ensuring that as much storage as possible remains in Henry's Lake, high in the system. Therefore, any water management options in other parts of the Henry's Fork watershed that minimize the need for delivery of storage help minimize the effects of flow alteration in the Outlet. Another option for minimizing effects of flow alteration in the Outlet would be more naturally shaped releases from Henry's Lake during years when delivery of Henry's Lake storage is required. Improved forecasting of system-wide irrigation demand could enable managers to anticipate the need for delivery of Henry's Lake storage water earlier in the season, which could result in release of much of the delivery early in the season when flows would more closely match the timing and magnitude of natural peak flows. Improved forecasting could also allow this water to be stored in Island Park for release later in the summer, thereby optimizing management throughout the system.

## 2. Henry's Fork below Island Park Dam

### *Flow issues*

Flow in the Henry's Fork immediately downstream of Island Park Dam is controlled exclusively by operation of the dam, although the effects of dam operations are mediated less than one mile downstream at the confluence of the Buffalo River. The Buffalo is a spring-fed tributary that provides year-round flow that ranges from about 200 to 600 cfs. For comparison, median natural flows in the Henry's Fork at the location of the dam range from about 550 cfs during the winter to about 1200 cfs during runoff. Operation of Island Park Reservoir for storage and delivery of irrigation water have, on average, reduced winter flow by about 50% and increased late-summer flow by about 70%. Irrigation delivery has introduced a second peak into the annual hydrograph at the end of July, in addition to the natural runoff peak that occurs largely at its unregulated magnitude in late May (Van Kirk and Burnett 2004).

### *Affected resources*

The reach of the Henry's Fork from Island Park Dam to Mesa Falls supports one of the most popular rainbow trout fisheries in the world (Van Kirk and Gamblin 2000). Although rainbow trout are not native to the Henry's Fork, the fishery below Island Park Dam is currently supported solely by natural reproduction. Brook trout (nonnative) are also found in the Henry's Fork downstream of Island Park Dam but do not constitute an important component of the fishery. Trumpeter swans and other waterfowl use the Henry's Fork seasonally at Last Chance and Harriman State Park, a few miles downstream. The fish and wildlife resources of this reach of the Henry's Fork and their interrelations with flow at Island Park are well understood and documented (Gregory 2000, Van Kirk and Gamblin 2000, Van Kirk and Martin 2000). Low winter flow has been identified as the primary flow issue in this river reach. There is a strong relationship between winter flow and the number of juvenile rainbow trout that survive to enter the fishable population (Meyer 1995, Mitro et al. 2003, Garren et al. 2006). In particular, higher flows later in the winter are directly related to higher survival and recruitment of rainbow trout. In turn, the ability to release higher winter flows from Island Park Reservoir while also meeting system-wide water management objectives and filling storage water rights, is nearly completely dependent upon the amount of storage remaining in the reservoir at the end of the irrigation season (Benjamin and Van Kirk 1999). Because inflow to Island Park Reservoir is provided largely by springs fed by deep groundwater, reservoir fill and hence winter flow releases are relatively insensitive to snowpack.

### *Current management*

Many years of collaborative work among irrigators, state and federal agencies, hydropower companies, university researchers, and nongovernmental organizations have resulted in near-optimal management of Island Park Reservoir to meet system-wide water supply objectives while maximizing rainbow trout recruitment. This management strategy is outlined in the Henry's Fork Drought Management Plan, prepared and implemented by a committee of representatives from Fremont-Madison Irrigation District, Henry's Fork Foundation, North Fork Reservoir Company, Trout Unlimited, The Nature Conservancy, and the U.S. Bureau of Reclamation (HFAG/JPC 2005). The current operation distributes the flow required to fill the reservoir nonuniformly over the storage period, which is usually October 1 to April 1. Water is stored at a higher rate during the fall and early winter (less water released) so that more water can be released during the late winter, when it has the greatest benefit per unit of discharge to the fish population. In addition, Island Park Reservoir is also managed to minimize the amount of water that must be delivered from Henry's Lake. Senior storage rights held in Henry's Lake can be physically delivered from Island Park. When water must be delivered from Henry's Lake, it can be delivered to Island Park at different times and magnitudes than actually required to meet irrigation demand, while Island Park deliveries supply the immediate demand.

### *Possible future management*

Minimizing the amount of storage water required to meet irrigation and other flow needs downstream (and throughout the system) late in the summer is the primary option available for increasing winter flows at Island Park Dam. This strategy also benefits water rights holders, by ensuring that as much storage as possible remains in Island Park Reservoir, which is located relatively high in the system. Therefore, any water management options in other parts of the Henry's Fork watershed that minimize the need for delivery of storage help minimize the effects of flow alteration downstream of both Island Park Reservoir and Henry's Lake. As mentioned in the Henry's Lake section above, Island Park Reservoir would play an important role in future scenarios in which improved demand forecasting would allow more optimal timing and magnitude of Henry's Lake releases.

## 3. Lower Fall River (downstream of Fall River Canal diversion)

### *Flow issues*

Flow in the lowest three miles of Fall River (from the Fall River Canal diversion downstream to the Henry's Fork confluence) is seasonally affected by withdrawals from numerous diversions, the largest of which are the Enterprise Canal and Fall River Canal. Late-summer flow in this reach averages about 50% less than natural flow and can be as low as 75 cfs in a channel that would carry an average of 800 cfs under natural conditions. The magnitude of late-summer flow alteration is low in wet years and high in dry years (Van Kirk and Burnett 2004). The wide, shallow geomorphology of the channel makes this reach more sensitive to low flows than it might otherwise be. However, the middle portion of the reach is braided into numerous smaller channels that contain a large amount of woody debris and other structure and receive some irrigation return flow through shallow groundwater pathways.

### *Affected resources*

Fall River contains a modest population of wild rainbow trout that supports some recreational fishing. Fall River also serves as a spawning and rearing tributary for rainbow trout from the Henry's Fork. Once the new fish ladder at Chester Dam (on the Henry's Fork, immediately downstream of the Fall River confluence) is operational, brown trout and rainbow trout from the Henry's Fork downstream of Chester Dam will have access to Fall River, and its use as a spawning and rearing tributary may increase. However, low flows in the lower three miles of Fall River during July and August are not likely to affect this use. Adult migrations occur during fall and spring, and out-migration of juveniles is likely to occur primarily during peak flow, which occurs on Fall River prior to the season of peak irrigation demand and remains largely unregulated. Thus, the primary effect of seasonal low flows in lower Fall River is to reduce the number of trout that can remain in this reach during late summer, thereby reducing some recreational fishing opportunities. The channel has never been documented to completely dry, which likely allows aquatic invertebrate populations to persist throughout the summer and also allows fish to migrate out of the affected reach as flow decreases. There has been little formal study of trout use in this river reach and of the direct ecological effects of flow alteration.

### *Current management*

No formal water management arrangements are in place to address seasonal low flows in lower Fall River.

### *Possible future management*

Increasing late-summer flow in lower Fall River would require some combination of building new storage capacity upstream on the Fall River system, managing existing storage (Grassy Lake) more optimally, reducing diversion into Enterprise and Fall River canals, or reducing diversion into the North Fremont canal system (Yellowstone, Marysville, and Farmers Own canals) upstream. Of these options, the one with the largest benefit-to-cost ratio is reducing diversion into the North Fremont system, which would have the additional benefit of providing more water to the Marysville Hydroelectric plant during the late summer. The North Fremont system contributes a relatively small amount of the total groundwater recharge supplied by the Fall River/Henry's Fork/lower Teton canal system, so continuing to convert this system from earthen canals to pipelines could potentially provide a tangible increase in lower Fall River flows during irrigation season with relatively little negative effect on groundwater resources. Any increases in flow through the lower portion of Fall River could be delivered through the Crosscut Canal to the lower Teton River to help address low-flow concerns there, without negatively affecting flows on the Henry's Fork downstream of Chester Dam. By contrast, the Enterprise and Fall River canal systems are very extensive and supply large amounts of incidental recharge, much of which probably returns to the surface system in the lower Teton River. Thus, reducing diversion into the Enterprise or Fall River canals is likely to exacerbate low flows on the lower Teton River. Although Grassy Lake is small (15,000 acre-feet at the headwaters of a river system with an annual mean discharge of 700,000 acre-feet), during years when Grassy Lake storage is not needed to supply irrigation demand, about 50 cfs are released over a 30-day period in the fall. As with Henry's Lake, better forecasting of demand early in the season could allow this release, when required, to occur earlier in the summer and be delivered to the Teton River through the Crosscut Canal. Hydrologic models currently under development can be used to investigate the potential to increase flows in lower Fall River late in the summer by increasing irrigation efficiency, reducing diversion into the various Fall River canals, and/or operating Grassy Lake slightly differently.

## 4. Henry's Fork downstream of St. Anthony

### *Flow issues*

Although the shape of the managed hydrologic regime in this reach very closely resembles that of the natural regime, the entire hydrograph is shifted down to lower overall flows year-round (Van Kirk and Burnett 2004, Bayrd 2006). Late in the irrigation season, low flows can result in locally high water temperatures, although these are mediated by substantial groundwater input. There are no continuous, long-term water-temperature records for this reach, but data collected by the Henry's Fork Foundation and the USDA project over the past few years suggest that during relatively cool summers such as 2010, water temperatures are not high enough to have negative effects on trout. On the other hand, during warmer summers, water temperatures in certain locations may be high enough to negatively affect trout.

### *Affected resources*

Relatively abundant wild rainbow and brown trout and the occasional cutthroat trout support an increasingly popular recreational fishery in this reach, and seasonal low flows and high temperatures could affect this fishery. Idaho Department of Fish and Game has recently increased the frequency of trout population data collection in this reach, and results indicate much higher numbers of trout in this reach in the fall than in the spring and an overall increasing trend over the past few years. Higher trout abundance in the fall could reflect migration into this reach later in the irrigation season, when flows and water temperatures are less suitable further downstream in the Henry's Fork and in the lower Teton River. Water temperature data from 2010 suggest that groundwater inputs to the reach downstream of St. Anthony maintain cooler late-summer and fall temperatures than those observed in adjacent reaches. The St. Anthony reach also supports extensive riparian and wetland areas, which appear to be thriving under the current, irrigation-influenced hydrologic regime.

### *Current management*

In coordination with Fremont-Madison Irrigation District, the Bureau of Reclamation manages releases at Island Park Dam to meet irrigation demand in the St. Anthony area while attempting to maintain a minimum of 1200 cfs at the St. Anthony gage. For a variety of reasons (e.g., timing of releases, river flow travel time, activities at the Ashton hydroelectric project), flow can sometimes drop below 1200 cfs, despite the 1200 cfs objective. Diversions downstream of the gage can equal or exceed 1200 cfs, but a large amount of groundwater return largely compensates for these diversions. The absence of any flow measurement between the St. Anthony and Rexburg gages precludes analysis of flow conditions on the finer spatial scale that would be required to assess specific effects of low flows on trout behavior and survival in this reach.

### *Possible future management*

Collection and analysis of more flow, temperature, trout population, and macroinvertebrate data is needed to quantify specific effects of low flows on fish and other aquatic life in this reach before any changes to the current management are warranted.

## 5. Lower Teton River (North and South forks)

### *Flow issues*

During at least some period of late summer of almost every year, both forks of the lower Teton River are completely dry downstream of the lowest large diversion (Teton Island Feeder on the North Fork and Rexburg Irrigation on the South Fork). The North Fork generally remains dry for several miles downstream, where groundwater return provides surface flow. The South Fork remains dry for only a short distance downstream to the point at which the City of Rexburg wastewater treatment plant discharge provides surface flow in the stream channel. Additional flow is provided by groundwater input and surface return further downstream.

### *Affected resources*

Both forks of the Teton River support wild populations of native YCT, in addition to some wild rainbow and brown trout. The timing of low flow and/or desiccation in these reaches is such that up-migration of adult spawners is not disrupted, but low flows certainly limit the numbers of trout of all ages that can persist through the summer in the lower Teton River.

### *Current management*

Low flows on the lower Teton River during late summer have been a concern to irrigators for a century. The earliest water rights (1879 priority dates) in the Henry's Fork watershed were claimed on the lower Teton River, but subsequent claims upstream eventually resulted in physical difficulty supplying these senior rights holders with water late in the summer, creating conflict among water rights holders in different parts of the watershed. In the 1930s, the Crosscut Canal was built in conjunction with Island Park Reservoir specifically to address this issue; the Crosscut is used to deliver Island Park storage water to the Teton River. Teton Dam was also built in part to address late-summer water shortages on the lower Teton River. After the failure of Teton Dam, several individuals who were planning on a water supply from the dam developed exchange wells on the lower Teton to replace their lost supply. During very dry years this pumped groundwater provides flow to the lower Teton water rights holders. The current system of storage reservoirs, Crosscut Canal, North/South Fork splitter, and exchange wells is managed to provide just enough water in the lower Teton River late in the summer to meet demand down to the Teton Island Feeder canal on the North Fork and Rexburg Irrigation canal on the South Fork. Return flow of irrigation seepage is generally sufficient to meet demand at several smaller diversions downstream on the North Fork. Rexburg Irrigation is the lowest diversion on the South Fork. No specific management actions are currently taken to provide water for fisheries on the lower Teton River.

### *Possible future management*

One could argue that the primary water shortage issue that motivated the current basin study is the difficulty in meeting irrigation demand late in the summer on the lower Teton River. Any actions taken to increase streamflow in the lower Teton River stand to benefit both fisheries and irrigators. However, because of the extremely complex nature of surface and groundwater hydrology in the Teton River watershed, including the role of the Crosscut Canal in deliberately delivering Henry's Fork and Fall River surface water to the lower Teton and the role of canal seepage in incidentally delivering additional Henry's Fork and Fall River water to the lower Teton, identifying solutions to the lower Teton problem without creating new problems elsewhere in the watershed will require creative thinking and detailed hydrologic modeling. One idea that has already been proposed is to deliver savings from irrigation efficiency in the North Fremont area through the Crosscut to the lower Teton. There may also be possibilities for increasing late-summer flow in the Teton River through managed groundwater recharge in Teton Valley.

## 6. Teton Valley tributaries (alluvial fan reaches)

### *Flow issues*

During late summer, no surface flow remains in the alluvial fan reaches of (from north to south) Badger, North Leigh, South Leigh, Teton, Darby, and Fox creeks. Hydrologic modeling has shown that these stream channels would naturally become dry at some point during the summer during most, but potentially not all, years. However, irrigation diversion has decreased the period of continuous flow between the mountain flanks and spring emergence on the valley floor (Van Kirk and Jenkins 2005, Peterson 2011). Trail Creek, the most upstream tributary to the upper Teton River, can also experience periods of desiccation during the late summer. Modeling suggests that in contrast to the other six tributaries, Trail Creek would flow continuously across the alluvial fan reach throughout the entire year in all but the driest years. In addition, large increases in groundwater recharge due to irrigation seepage have greatly increased the groundwater component of the Teton River hydrologic regime, which has potential negative effects on the persistence of native cutthroat trout but positive effects on nonnative trout, wetland resources, and downstream irrigators.

### *Affected resources*

Although distribution and abundance of YCT have decreased in many locations throughout Teton Valley, YCT are found in nearly every major Teton River tributary and exist in isolation from nonnative trout in the headwater reaches of Bitch, Badger, South Leigh, and Darby creeks. Nonnative brook and rainbow trout are found throughout the Teton River, in the valley-bottom spring creeks, and in headwater areas of some of the tributary streams. Cutthroat x rainbow hybrid trout have recently been observed in the lower and middle reaches of Bitch Creek, which is not hydrogeologically connected to the Teton Valley alluvial aquifer but is mentioned here because it supports the largest population of YCT of any Teton River tributary. Across its range, YCT life histories are very closely tied to hydrologic regimes (Kiefling 1978, Gresswell et al. 1994, Gresswell et al. 1997). Where such hydrologic regimes—either naturally or through alteration—have low snowmelt peaks relative to baseflows (i.e., are or have characteristics of groundwater-dominated systems), nonnative rainbow trout are more successful at invading and ultimately displacing cutthroat trout through competition and hybridization (Fausch et al. 2001, Moller and Van Kirk 2003, Van Kirk and Jenkins 2005, Fausch 2008, Van Kirk et al. 2010). The migratory nature of YCT has also been thoroughly documented in the scientific literature, and successful reproduction in many systems requires sufficient streamflow (hydrologic connectivity between spawning/rearing areas and the main river) through the May-September period that encompasses YCT spawning up-migration, spawning, egg incubation, fry emergence, and fry out-migration (Thurow et al. 1988, Varley and Gresswell 1988, Roulson 2001, 2002, Koenig 2006). Although long-term (e.g., decades to centuries) fish population and hydrologic data are not available to definitively tie trends in YCT abundance and distribution to hydrologic conditions in Teton Valley, it is likely that YCT populations have been affected by hydrologic alteration due to water management, including both seasonal dewatering on the alluvial-fan stream reaches and increased groundwater influence in valley-bottom stream reaches, and possibly also by climate shifts and variability. Therefore, restoration of important components of the natural hydrologic regime in key tributaries is an important component of YCT restoration and recovery in Teton Valley.

At the same time, the current hydrologic regime in Teton Valley has been shaped in very large part by irrigation, particularly seepage into the alluvial aquifer from irrigation canals (Van Kirk and Jenkins 2005, Peterson 2011). This increased groundwater input has enhanced fish, wildlife, and wetland resources throughout the valley. Wetland ecosystems and the fish (nonnative species in many cases) and wildlife they support are important components of the ecological and cultural landscape in Teton Valley.

Groundwater recharge incidental to irrigation has acted as a storage mechanism that provides a readily available source for domestic wells and slows the travel time of water through the Teton River system, providing additional supplies of late-season irrigation water for down-gradient and downstream irrigators without the high ecological and economic costs of constructed storage infrastructure. Therefore, it is critical that actions taken to restore components of the natural hydrologic regime to benefit native species be evaluated in the context of effects on existing water and related resources dependent on groundwater recharged by irrigation systems.

In some cases, it is possible that nonnative trout have failed to invade certain headwater stream reaches in part because of lack of connectivity between these headwater reaches and the main river. Increasing hydrologic connectivity in these streams might not be desirable unless also accompanied by weirs that prevent upstream invasion of nonnative trout and/or by programs aimed at eradicating non-native species from the system. The approach of increasing hydrologic connectivity while using weirs to prevent nonnative invasion has proven successful on the South Fork Snake River at maintaining a pure YCT population in the presence of a large, self-sustaining rainbow trout population (Van Kirk et al. 2010). Thus, it is also important that any actions taken to increase hydrologic connectivity not increase the probability of nonnative trout invasions into stream reaches currently occupied only by native YCT.

### *Current management*
Friends of the Teton River is currently working with irrigation companies and water rights holders in Teton Valley to find creative ways to return water to the alluvial fan reaches of the Teton Valley tributaries late in the summer. The goals of these efforts are to 1) restore important components of the natural hydrologic regime (particularly relative magnitude and timing of peak flows and seasonal duration of connectivity) where such restoration has a high potential of benefiting cutthroat trout and 2) maintain recharge to the local aquifer that will sustain resources dependent on this groundwater over the long term.

### *Possible future management*
Given the complexity of the hydrologic, ecological, legal, and institutional systems surrounding water management in the Teton River watershed, it is imperative that management actions be designed on a site- and resource-specific basis but with complete information regarding the effects of these actions on other, inter-related resources. Furthermore, if actions in one part of Teton Valley have the potential to negatively affect resources in other locations in the watershed, it is desirable to identify concurrent actions that will mitigate these negative effects. For example, if re-watering a particular stream reach by reducing diversions into a canal system reduces groundwater recharge, managed recharge at different times and places could mitigate this reduction, producing no net change in groundwater recharge over larger spatial and temporal scales. Because groundwater flow is much less sensitive than surface flow to fine-scale spatial and temporal patterns of recharge and discharge, it is likely that fine-scale adjustments to the current hydrologic system could produce substantial benefits to surface flow in key tributary reaches at key times of the year with little or no long-term effect on groundwater-dependent resources. Additionally, to enhance native fishery populations it is critical that future water supply solutions be evaluated with an eye for avoiding instances which may result in increased stream

dewatering. For example, current water management practices allow Teton Valley irrigators to purchase water from storage facilities out of the basin (most commonly out of Island Park Reservoir) to provide water for downstream senior users when the State curtails surface water usage. This practice, resulting in out-of-basin water exchanges, tends to exacerbate tributary dewatering issues.

### 7. Small Streams

#### *Flow issues*

Numerous small streams throughout the watershed experience low flows downstream of irrigation diversions or pumps during the irrigation season. These include Sheridan Creek (reach 7a on the map), Conant and Squirrel creeks (7b), Moody Creek (7c), and Canyon Creek (7d). Unlike the Teton Valley tributaries and the mainstem Teton and Henry's Fork, these streams generally receive little return flow downstream of the points of diversion. This is due to a variety of factors, including use of pump/pipeline systems instead of canals on these smaller streams, application of diverted water to areas that do not drain back to the stream, and local hydrogeologic conditions. Low flows are seasonal in nature and vary from year to year depending on water supply.

#### *Affected resources*

Because of limited access and the small size of these streams, none support major recreational fisheries. However, all them potentially contribute to the trout populations of larger water bodies to which they are tributaries through provision of spawning and rearing habitat. The primary effect of low flows is to force seasonal migration of trout out of the affected reaches, potentially decreasing the total number of juvenile fish that can be produced in the stream. Specific population-level effects of reduced recruitment in tributary streams are difficult to quantify, but Van Kirk and Gamblin (2000) provide some evidence for the role of decreased tributary production (including that in Sheridan Creek) in reducing the population of wild rainbow trout in Island Park Reservoir. In streams such as Canyon Creek, where native YCT are the dominant trout species, the effects of seasonal low flows also include disruption of migration patterns evolved in response to the natural hydrologic regime (see Teton Valley tributaries, above). Native YCT are the primary trout species of concern on lower Moody Creek. Conant and Squirrel creeks contain nonnative brook and rainbow trout, but native YCT are also found there.

#### *Current management*

Site-specific flow restoration projects have been undertaken on numerous small stream reaches in the watershed, sometimes in conjunction with fish passage and habitat restoration. In the mid-1990s, the Henry's Fork Watershed Council endorsed, partially funded, and/or facilitated solicitation of external funding of such projects on Conant, Squirrel, and Sheridan creeks. Some of these projects have improved flow conditions on these streams. However, because irrigation diversions from these small streams are generally much smaller than those from the main rivers in the watershed, most are not included in the Idaho Department of Water Resources accounting model and are not measured on a daily basis as are the mainstem diversions. Thus, long-term flow data sufficient to document improvements is generally lacking.

### *Possible future management*

Because these small streams and the diversions from them have little if any interaction with the substantial groundwater resources critical in other parts of the watershed, there is generally little hydrologic downside to “standard” approaches to improving irrigation-season flow in these streams. Such approaches include improving irrigation conveyance efficiency (e.g., many small canals have been converted to pipeline systems in the Conant Creek drainage), consolidating points of diversion to single points and moving them downstream of inflows from other tributaries (e.g., as has been done on Squirrel Creek), and using leasing or exchange mechanisms to reduce demand and diversion late in the summer. These actions are best motivated by site-specific data that clearly identify a need and potential solution and best implemented on a local, case-by-case basis with individual landowners and canal companies.

## Conclusions

Despite extensive management of water resources to provide water for irrigation and hydroelectric power generation, the major rivers and streams in the Henry’s Fork watershed support world-renowned wild trout fisheries and extensive wetland and riparian areas. Ecologically important effects of altered streamflow regimes are generally limited to reaches immediately downstream of the two largest dams in the watershed and downstream of diversions that are large relative to streamflow. These effects are largely seasonal in nature, occurring during the winter storage season in some reaches and during peak irrigation demand in others. Return of irrigation seepage through groundwater pathways mitigates effects of diversion on late-summer low flows at several spatial scales, and hydrologic modeling suggests that this return flow contributes to maintenance of wetland areas, although possibly at the expense of hydrologic conditions that benefit native trout.

As exemplified by collaborative winter flow management at Island Park Dam to fill irrigation storage rights while maximizing benefits to fisheries and hydropower generation, addressing streamflow challenges in the watershed is most productive when research has clearly identified the relationships among streamflow and ecological variables and when the effects of potential changes in management actions on downstream resources are fully explored and understood. Current research in the watershed is greatly increasing our understanding of the complexity of the human-influenced hydrologic system, the importance of irrigation seepage to that system, and the life history and streamflow needs of Yellowstone cutthroat trout. New modeling tools can help assess the effects of management actions on groundwater resources and on flow in downstream reaches. As highlighted above, the greatest water management challenges in the watershed occur in the Teton River and its tributaries, which support the majority of the native trout populations remaining in the watershed. Accordingly, the greatest needs for increased understanding of relationships among hydrology and fish-population attributes occur in the Teton watershed, particularly in Teton Valley and on the lower Teton forks. Because of both intentional (via the Crosscut Canal) and incidental (via irrigation seepage and groundwater flow) delivery of water from lower Fall River and the Henry’s Fork to the lower Teton River, more detailed information on flows and fisheries in lower Fall River and lower Henry’s Fork will be required to solve streamflow problems on the lower Teton River without exacerbating existing problems or creating new ones elsewhere. Meeting future water needs in the Henry's Fork watershed and throughout the upper Snake system will require collaboration, new information, and creative ideas.

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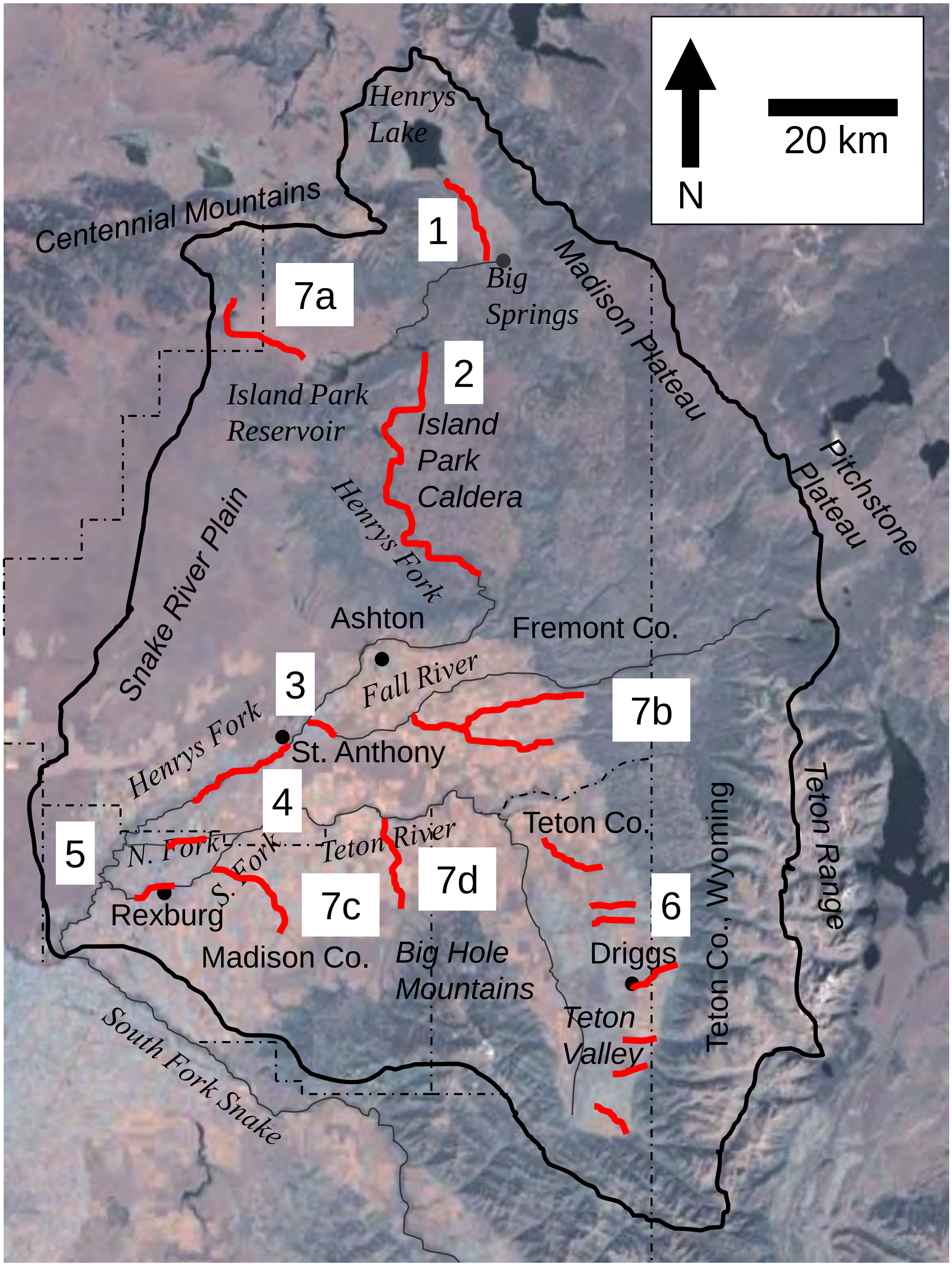


Watershed map showing major stream reaches of concern. Identification numbers are those used in the text and table.

Summary of major stream reaches of concern. Identification numbers refer to those on the map.

| ID | Stream | Reach Description | Season | Ecological or fishery concerns; other issues |
|---|---|---|---|---|
| 1. | Henry's Lake Outlet | Henry's Lake Dam to confluence | Spring | Spring flow peaks diminished for stream channel and floodplain processes |
| | | | Summer | Low flows/high water temperatures during some years, high flows during irrigation delivery exacerbate erosion in others |
| | | | Winter | Low flows |
| 2. | Henry's Fork | Island Park Dam to Mesa Falls | Winter | Low flows limit juvenile rainbow trout survival |
| 3. | Fall River | Lower diversions downstream to confluence | Summer | Low flows below diversions |
| 4. | Henry's Fork | Below Egin Canal Diversion | Summer | Low flows; potential for high water temperatures, although cooling occurs because of groundwater return from St. Anthony to Parker-Salem Road Bridge |
| 5. | Teton Forks | From diversions below splitter to confluences | Summer | Dewatering below diversions downstream to near confluences. Trout migration, spawning, and rearing; native Yellowstone cutthroat dominate, but other species present |
| 6. | Teton Valley Tributaries | Alluvial fan reaches | Summer | General decrease in flows and increase in duration of natural no-flow period, but specific numbers vary widely. Also, diversions have greatly increased groundwater flows, so restoring surface flow has effects on groundwater. Please read text above! |
| | Badger Creek | From diversions below splitter to confluences | Summer | Dewatering or low flows below diversions; cutthroat trout migration, spawning, and rearing. Also, fish entrainment issues. NOTE: this is the only tributary in which flow has not been thoroughly studied; dewatered reach is estimated. |

| ID | Stream | Reach Description | Season | Ecological or fishery concerns; other issues |
|---|---|---|---|---|
| | N. Leigh Creek | State Line to Spring Creek area | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing |
| | S. Leigh Creek | State Line to Spring Creek area | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing. However, increase in flow might result in non-native trout invasion. |
| | Teton Creek | Grand Teton Canal Company Diversion to HWY 33 | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing |
| | Darby Creek | State Line to Confluence | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing |
| | Fox Creek | State Line to Confluence | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing. Also fish passage/barrier issues. |
| | Trail Creek | Trail Creek Sprinkler & Irrigation Co. Main Diversion to confluence | Summer | Dewatered or low flows; cutthroat trout migration, spawning, and rearing; juvenile YCT outmigration severely impaired |
| 7. | Small Streams | Below diversions | Generally summer | General concerns: low flows, potential high water temperatures, trout migration/spawning/rearing |
| 7a. | Sheridan Creek | Below Sheridan Ranch diversions to confluence | Summer | Low flows, potential high water temperatures, trout migration/spawning/rearing; cutthroat trout not present |
| 7b. | Conant/Squirrel creeks | Lower Squirrel Creek, Conant Creek from Squirrel Creek to confluence | Summer | Low flows, potential high water temperatures, trout migration/spawning/rearing; cutthroat trout present but not dominant |
| 7c. | Moody Creek | Lower creek below diversions | Spring,sSummer | Low flows, potential high water temperatures, trout migration/spawning/rearing; cutthroat trout dominant |

| ID | Stream | Reach Description | Season | Ecological or fishery concerns; other issues |
|---|---|---|---|---|
| 7d. | Canyon Creek | From diversions below splitter to confluence | Summer | Low flows, potential high water temperatures, trout migration/spawning/rearing; native Yellowstone cutthroat trout dominant. Potential migration barriers and canal entrainment are also issues. |
| NA | Other (not shown on map) | | | |
| | Fall River | Marysville Diversion to Marysville Hydro return | Summer, winter | Low flows, but with minimums established by hydropower license. Irrigation management has no effect on the minimum flow requirement. |
| | Bitch Creek | Entire length | Year-round | Maintain natural hydrograph for core cutthroat population. There are currently no storage or diversion facilities on the entire length of Bitch Creek. |