TECHNICAL MEMORANDUM

MODSIM modeling of Henrys Fork basin alternatives

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Purpose: The analyses presented in this report are in support of the Henrys Fork Basin Study[1] that was initiated to identify opportunities for developing new water supplies (e.g., above-ground storage, aquifer storage) and improving water management (e.g., conservation measures, optimization of resources) while sustaining environmental quality.

The Henrys Fork of the Snake River (Henrys Fork River) basin in eastern Idaho is experiencing population growth, urban development, irrigation needs, climate changes, and drought conditions that are depleting water resources. The Henrys Fork watershed provides irrigation for over 280,000 acres and sustains a world-class trout fishery. Located in the upper reaches of the Snake River, the Henrys Fork River basin also contributes approximately one-third of the Snake River's flow in eastern Idaho and supplies groundwater recharge to regional aquifers and, to a lesser extent, the Eastern Snake Plain Aquifer (ESPA), all of which are tapped for municipal, industrial, and irrigation water.

A MODSIM-DSS[2] (Modsim) model of the Snake River system was used to explore system impacts and benefits to new water supply and water management alternatives.

Methods: Reclamation's Modified Flows Modsim model[3] of the Snake River basin above Brownlee Reservoir was used to simulate the basin study alternatives. This model simulates 2010 level surface irrigation diversion, 2010 level groundwater pumping, and

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[1] Bureau of Reclamation, Henrys Fork Basin Study, http://www.usbr.gov/pn/programs/studies/idaho/henrysfork/ (Sep. 23, 2013).

[2] MODSIM-DSS, a generalized river basin decision support system and network flow model, developed at Colorado State University in the 1970's and from 1992 through 2009 under joint agreement with the U.S. Bureau of Reclamation Pacific Northwest Region (PNRO).

[3] Bureau of Reclamation, *Modified and Naturalized Flows of the Snake River Basin above Brownlee Reservoir*. Prepared by the U.S. Department of the Interior, Bureau of Reclamation, Pacific Northwest Regional Office, Boise, Idaho. May 2010.

current reservoir operational logic applied to historical inflows for water years (WY) 1928 to 2008. The results from this configuration define the baseline condition for the basin. All alternatives are compared against this model configuration, that we term the "baseline" model. The model runs at a monthly timestep and includes full water right accounting for the legal delivery and storage of water. A reservoir's right to store water is based on its water right priority date in relation to all the other water rights in the basin, thus it competes for the natural flow along with all other rights. The volume that could have been stored based on the reservoirs water right priority date is what is termed the reservoir's "accrual". The water right accounting controls reservoir releases during the irrigation season. However, during the non-irrigation season the system is operated, as much as possible, to physically store water in the most upstream reservoirs within the system. This increases the reliability of filling all reservoirs in the system, by decreasing the chance that water might leave the basin that could have been stored. It also means the physical reservoir storage may not coincide with the reservoir's accrued storage. The Modsim model accounts for this difference and throughout this report the volume that accrued to a reservoir's water right not the reservoir's physical storage will be discussed.

The baseline model was configured to simulate four alternatives: canal automation (CA), raising Island Park reservoir (ISL2), a new off-stream reservoir Lane Lake (LL) near the Teton River, and a new in-stream reservoir Teton Dam (TET).

The CA alternative simulated the automation of irrigation canals within the Fremont-Madison irrigation district in the Henrys Fork basin. This alternative was modeled with an analytical model (R-Model) developed by Dr. Rob Van Kirk[4] in combination with the Modsim model. Historical daily irrigation diversions from 1979 to 2008 were adjusted in the R-Model based on the theoretical crop consumptive use derived from historical evapotranspiration (ET). Based on this adjusted diversion assumption the R-Model output new streamflow estimates at key locations within the basin. The monthly mean percent change in streamflow from the historical R-Model output to this altered irrigation diversion scenario was applied to the historical gains within the Modsim model. The gains in the Modsim model represent natural flows, so the adjustment effectively mimicked a flow regime change in the river due to canal automation. In general, the adjustment increased streamflow through the summer because historical diversion was reduced, and decreased streamflow in the late fall/early winter due to a decrease in groundwater returns from the reduced diversions.

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[4] Rob Van Kirk, "Teton Valley Groundwater – Surface Water Model", http://www.humboldt.edu/henrysfork/Documents_Presentations/TV%20GW-SW%20model.pdf (Sep. 23, 2013)

The ISL2 alternative was modeled by adding a new storage reservoir downstream of Island Park Reservoir that simulated a dam raise at Island Park Reservoir. The new reservoir was modeled with a capacity of 50,000 acre-feet and a junior water right priority of 1/1/1980. This priority date is junior to all other water rights in the basin thus will only accrue water when flows are in excess of the senior water rights demands. A storage contract to use any new storage was modeled as a new demand just downstream of Minidoka Dam. The demand requested the full reservoir capacity of 50,000 acre-feet distributed equally from June through September or 12,500 acre-feet per month.

The LL alternative investigated adding new storage off-stream from the Teton River near Hydromet gage TEAI (Teton River near St. Anthony). The alternative was configured to be able to capture historical natural inflows to TEAI. This alternative added a new reservoir with a capacity of 120,000 acre-feet. The new reservoir was configured with two storage rights, one right to divert up to 60,000 acre-feet from the Teton River just above the crosscut canal confluence and a second right to divert up to 60,000 acre-feet from the Falls River near Squirrel, ID. A max flow rate of 1,018 cfs was applied to each of these diversion rights as estimated by CH2MHILL[5]. The Falls River storage right was given a priority of 1/2/1980 and the Teton River storage right a priority of 1/3/1980; junior to all water rights in the basin. Releases from the new reservoir return to the Teton River just above the crosscut canal confluence. Two new storage contracts were applied to a new demand just downstream of Minidoka Dam. The new demand requested water from its Falls River accrual first then from its Teton River accrual. The demand requested the full reservoir capacity of 120,000 acre-feet distributed equally from June through September or 30,000 acre-feet per month. The same minimum flow requirements were applied to both the Falls River and the Teton River. After discussion with the Native Trout subcommittee of the Henrys Fork Watershed Council, the minimum flow requirements were modeled as 200 cfs from September to November, 400 cfs from December to February, and 300 cfs otherwise. The baseline model run did not have these minimum flow requirements. Hence, the streamflow hydrographs presented in the Results section for this alternative show a shift in low flows for this alternative due to the new minimum flow requirements imposed in this alternative. The max outflow from the proposed new reservoir was unconstrained; this may overestimate the water that could realistically be delivered. However, given that the Modsim model runs at a monthly timestep it is unlikely that a max outflow constraint would affect the currently modeled reservoir releases.

The TET alternative investigated adding new storage on the Teton River just above the crosscut canal confluence. This new reservoir was modeled with a capacity of

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[5] CH2MHILL, *Henrys Fork Basin Study New Surface Storage Alternatives, Addendum 1*. Technical Series No. PN-HFS-002, November 2012.

265,000 acre-feet and given a junior water right priority of 1/3/1980. This priority date is junior to all other water rights in the basin thus will only accrue water when flows are in excess of the senior water rights demands. A storage contract to use any new storage was modeled as a new demand just downstream of Minidoka Dam. The demand requested the full reservoir capacity of 265,000 acre-feet distributed equally from June through September or 66,250 acre-feet per month.

Results: This section discusses the results from the three alternatives modeled as compared to the baseline or current conditions model. The baseline model represents the current system operations and structure. The next section will discuss the climate change work that was done and present results for each of these alternatives. Many of the figures below present summary hydrographs by exceedance level. The exceedance is the percent of time a value is equaled or exceeded throughout the modeled period of record, or the likelihood of a value being exceeded in a given year. The 20 percent, 50 percent, and 80 percent exceedance levels represent high, median, and low flow conditions, respectively.

Canal Automation (CA) alternative

Figure 1 shows the change in streamflow on the Henrys Fork near Rexburg, ID. The CA alternative showed a slight increase in flow in June due to the decreased diversion. A very slight decrease in winter flows occurred because the decreased summer diversions resulted in a decrease in winter groundwater returns. As a result of the minor change in flow from this alternative, canal automation combined with any of the other alternatives was not evaluated. Changes to storage were also minor and are not presented.

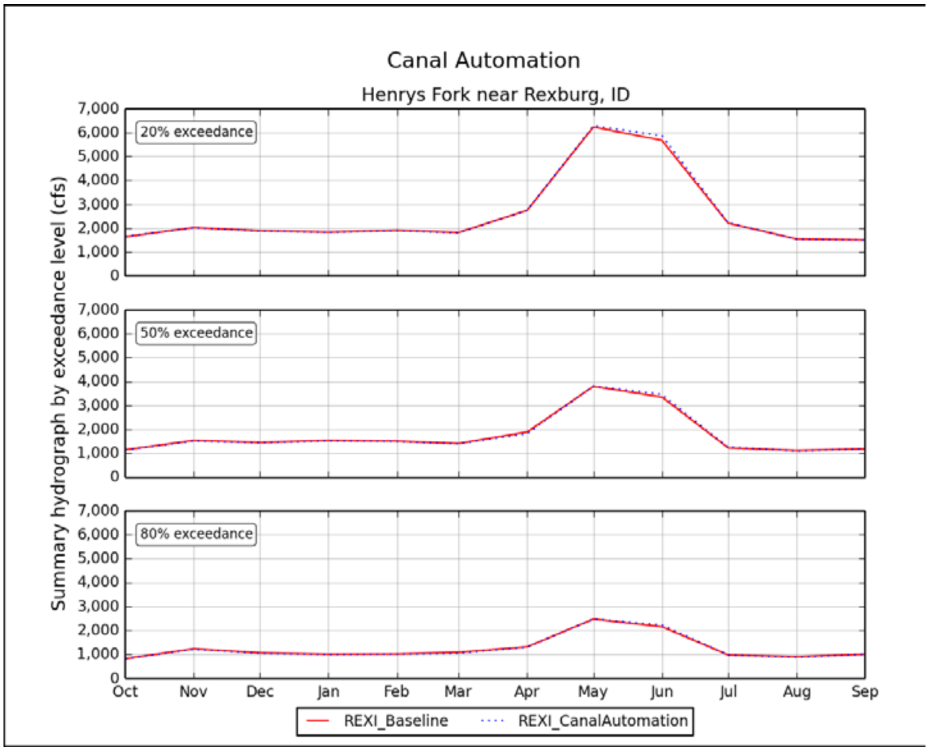

Figure 1: Change in baseline flows due to canal automation. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. An increase in flow was seen in June due to decreased diversion. A very slight decrease in flow in the winter was seen because the decreased diversion caused a decrease in groundwater returns.

Island Park Dam Raise (ISL2) alternative

The ISL2 alternative showed that 75 percent of the time approximately 35,000 acre-feet per water year accrued to the new reservoir water right (Figure 2). In contrast, 20 percent of the time no water accrued to the new reservoir right, most likely in the drier years when senior water right requests equaled or exceeded the natural flow. Figure 3 shows exceedance plots of the change in flow below Island Park reservoir. The 50 percent exceedance hydrograph shows a decrease in flow in the spring as excess flows are captured in the reservoir and an increase in flow in July as the stored water was released. In wet years (20 percent exceedance) the full 50,000 acre-feet was captured and delivered to the new demand hence the increase in flow from June through September. In dry years (80 percent exceedance) less water was captured in the spring and less was delivered.

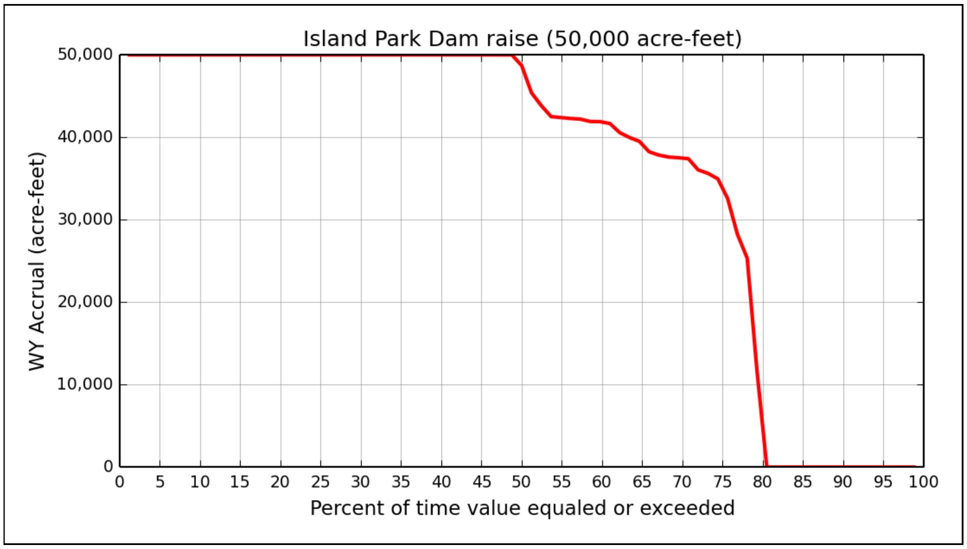

Figure 2: Water year volume accrued by the new reservoir water right. For example, 75% of the time approximately 35,000 acre-feet or more accrued and 20% of the time no water accrued.

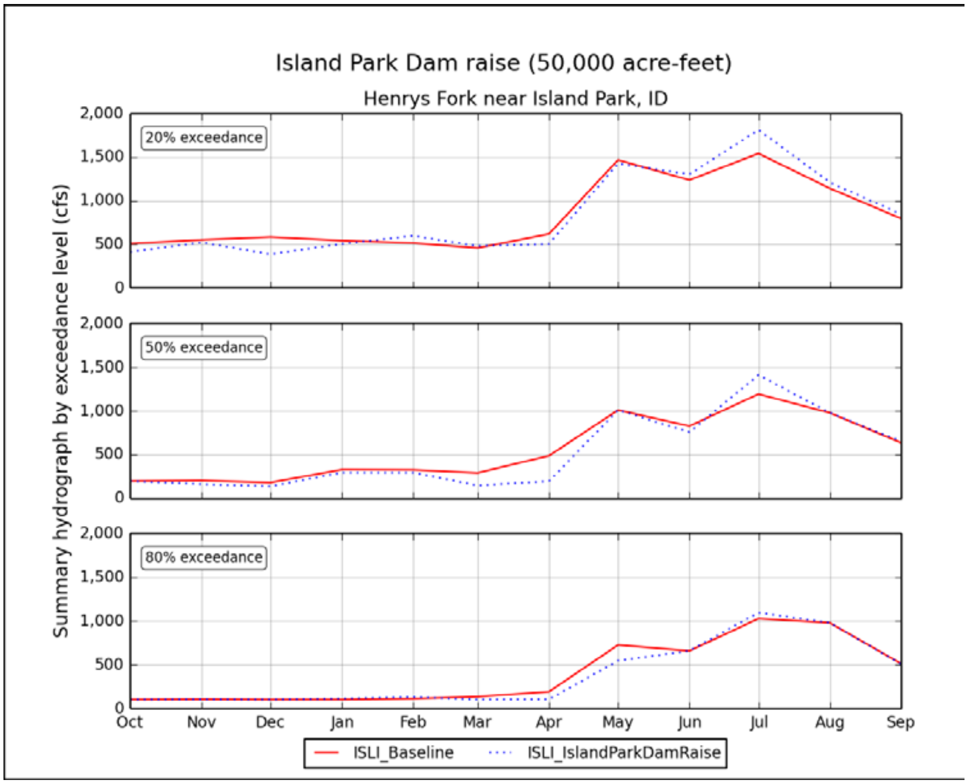

Figure 3: Change in baseline flows due to the Island Park Dam raise below the reservoir. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 50% exceedance hydrograph shows a decrease in flow in the spring as excess flows are captured in the reservoir and an increase in flow in July as the stored water was released. In wet years (20% exceedance) the full 50,000 acre-feet was captured and delivered to the new demand hence the increase in flow from Jun-Sep.

Lane Lake (LL) alternative

For the LL alternative new minimum flow requirements were applied to minimize streamflow impacts on the Falls River and Teton River due to Lane Lake storage. The minimum flow requirements also provide a more accurate reflection of the accrual that might occur to Lane Lake, understanding that reservoir diversions could not negatively affect instream flows. The LL alternative showed that approximately 75 percent of the time 90,000 acre-feet per water year accrued to the new reservoir water right (Figure 4). In contrast, 15 percent of the time no water accrued to the new reservoir right, most likely in the drier years when senior water right requests equaled or exceeded the natural flow.

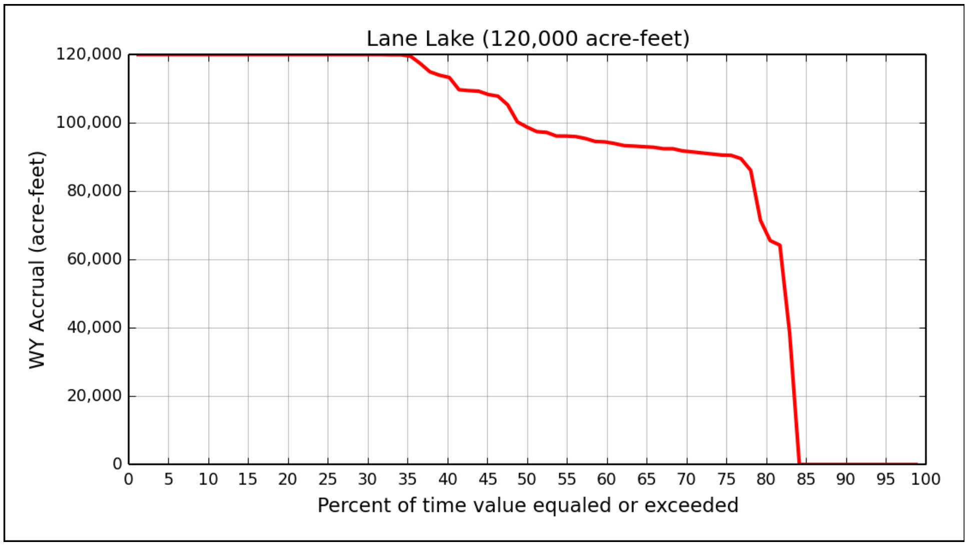

Figure 4: Water year volume accrued by the new reservoir water rights from the Falls River and Teton River. For example, 75% of the time approximately 90,000 acre-feet or more accrued and approximately 15% of the time no water accrued.

The portion of accrual attributable to the Falls River and the Teton River is shown in Figure 5. On average more water accrued to the new reservoir from the Falls River than the Teton River. The mean annual WY accrual volume was approximately 41,000 acre-feet from the Teton River compared with 47,000 acre-feet from the Falls River.

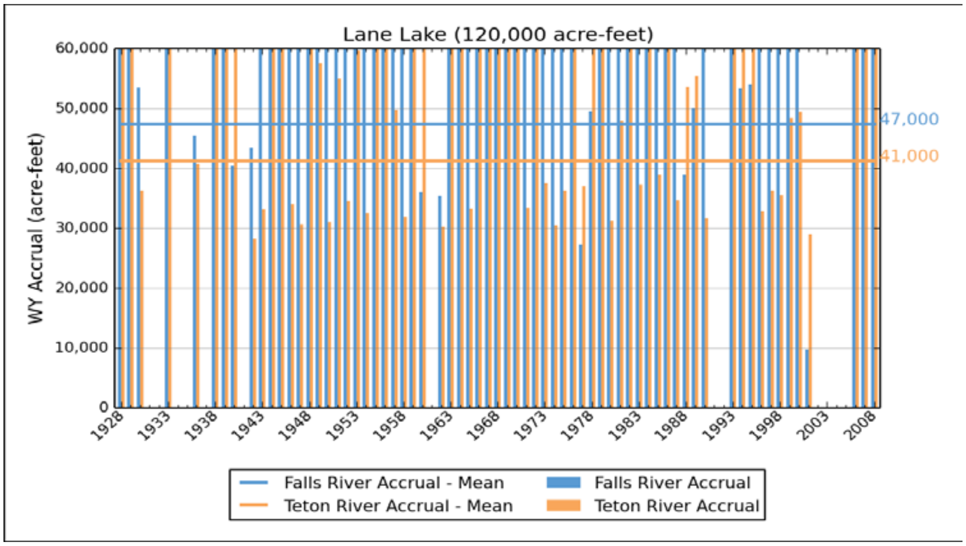

Figure 5: Water year volume accrued by the new reservoir for the Falls River water right and the Teton River water right. In general, more water was stored from the Falls River, the mean annual WY accrual was approximately 41,000 acre-feet from the Teton River compared to 47,000 acre-feet from the Falls River.

Figure 6 displays exceedance plots of the change in flow on the Teton River at St. Anthony, ID due to the Lane Lake diversion and release of stored water. The 50 percent exceedance hydrograph shows a decrease in flow in the late spring as excess flows are captured in the reservoir and an increase in flow from May through July as stored water was released. The 50 percent exceedance flow increase in May and the 20 percent exceedance flow increase in November and May was due to the new reservoir physically storing and delivering water that may belong to another water user, as discussed in the Methods section. Under low flows (80 percent exceedance) from December through February the flows are higher in the LL alternative because of the new Teton River minimum flow requirements imposed on this alternative that were not imposed on the baseline model.

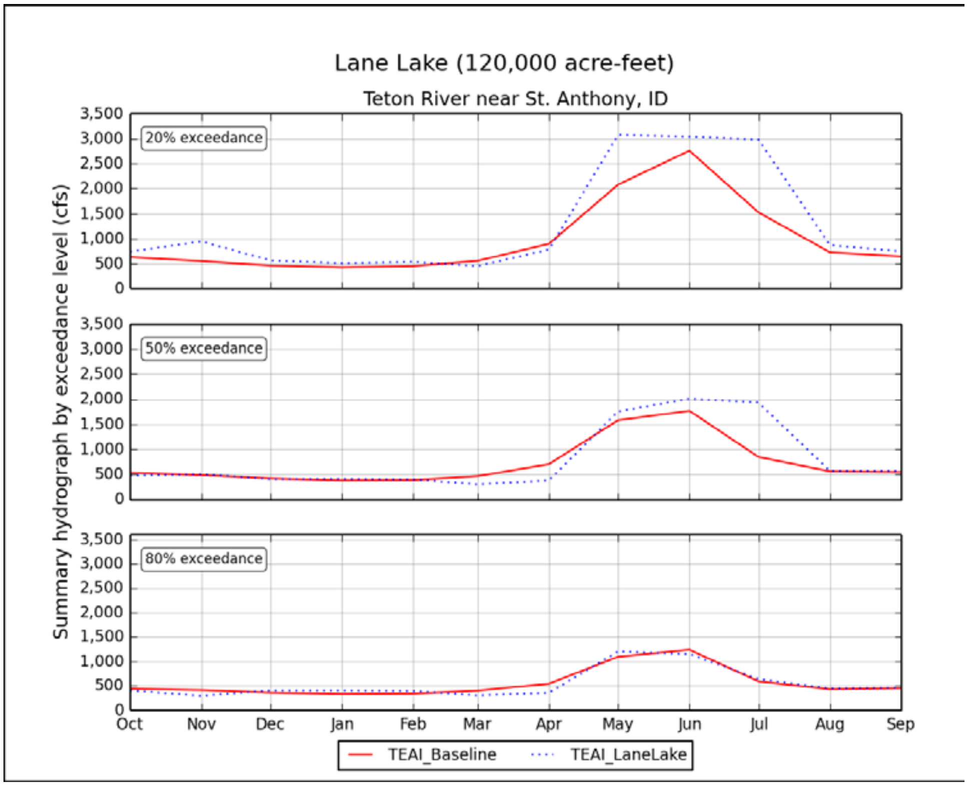

Figure 6: Change in baseline flows due to Lane Lake on the Teton River near St. Anthony, ID. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 50% exceedance hydrograph shows a decrease in flow in the late spring as excess flows are captured in the reservoir and an increase in flow from May-Jul as stored water was released.

Figure 7 shows exceedance plots of the change in flow on the Falls River near Chester, ID due to the Lane Lake diversion. The 50 percent exceedance hydrograph shows a decrease in flow year-round as excess flows are diverted from the Falls River and stored in Lane Lake. As with the Teton River, changes in low flow (80 percent exceedance) were seen from the baseline due to the new Falls River minimum flow requirements applied to the LL alternative.

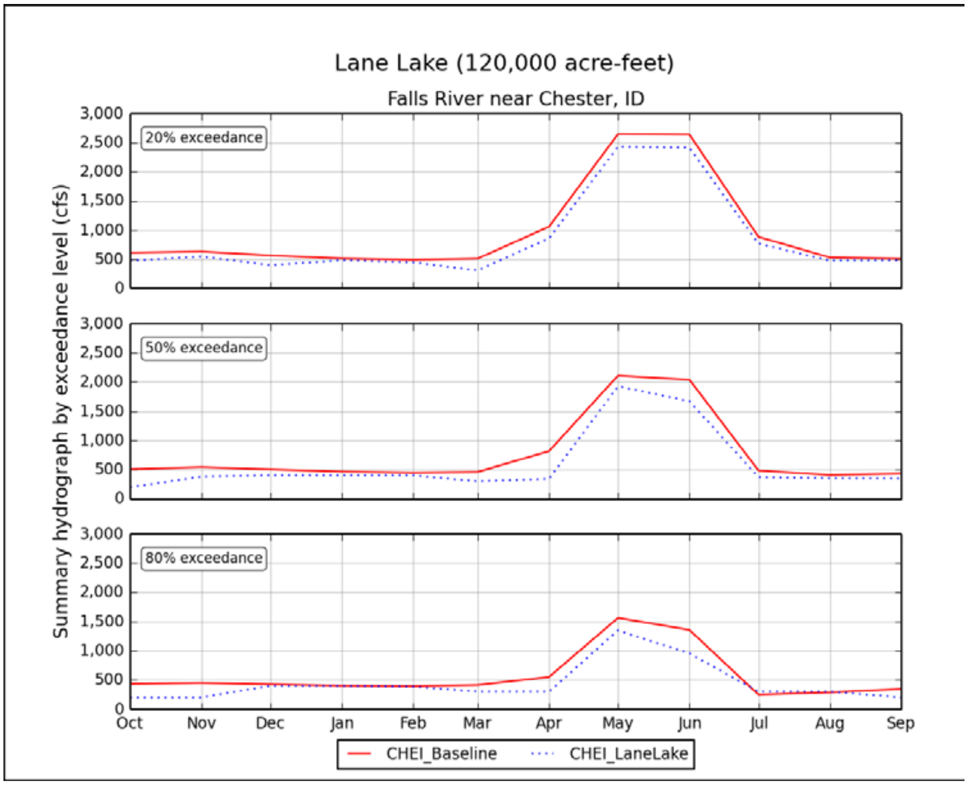

Figure 7: Change in baseline flows due to Lane Lake on the Falls River near Chester, ID. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 50% exceedance hydrograph shows a decrease in flow year-round as excess flows are captured in the reservoir.

Teton Dam (TET) alternative

The TET alternative showed that 70 percent of the time approximately 100,000 acre-feet per water year accrued to the new reservoir water right (Figure 8). In contrast, 15 percent of the time no water accrued to the new reservoir right, most likely in the drier years when senior water right requests equaled or exceeded the natural flow. Figure 9 shows exceedance plots of the change in flow below Teton Dam. The 50 percent exceedance hydrograph shows a decrease in flow in the spring as excess flows are captured in the reservoir and an increase in flow in July as the stored water was released.

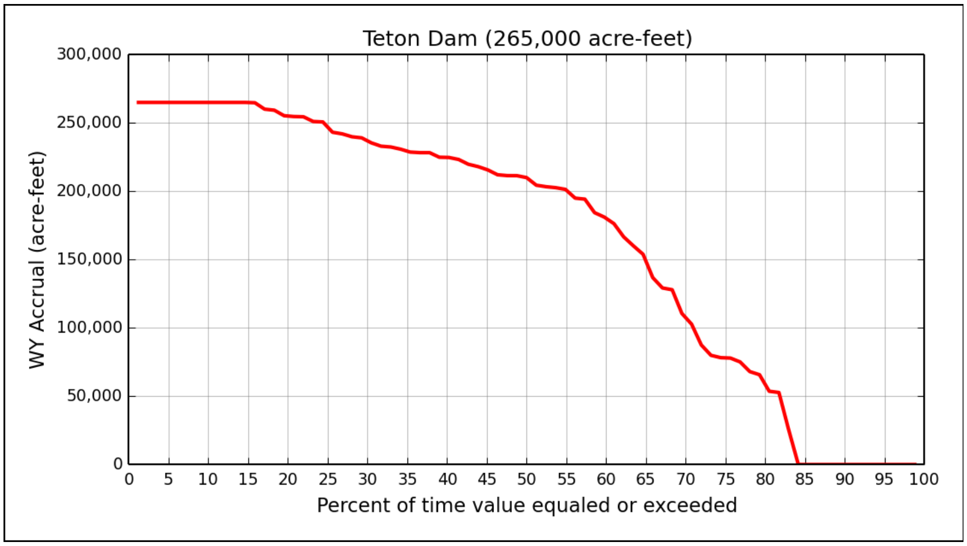

Figure 8: Water year volume accrued by the new reservoir water right. For example, 70% of the time approximately 100,000 acre-feet or more accrued and approximately 15% of the time no water accrued.

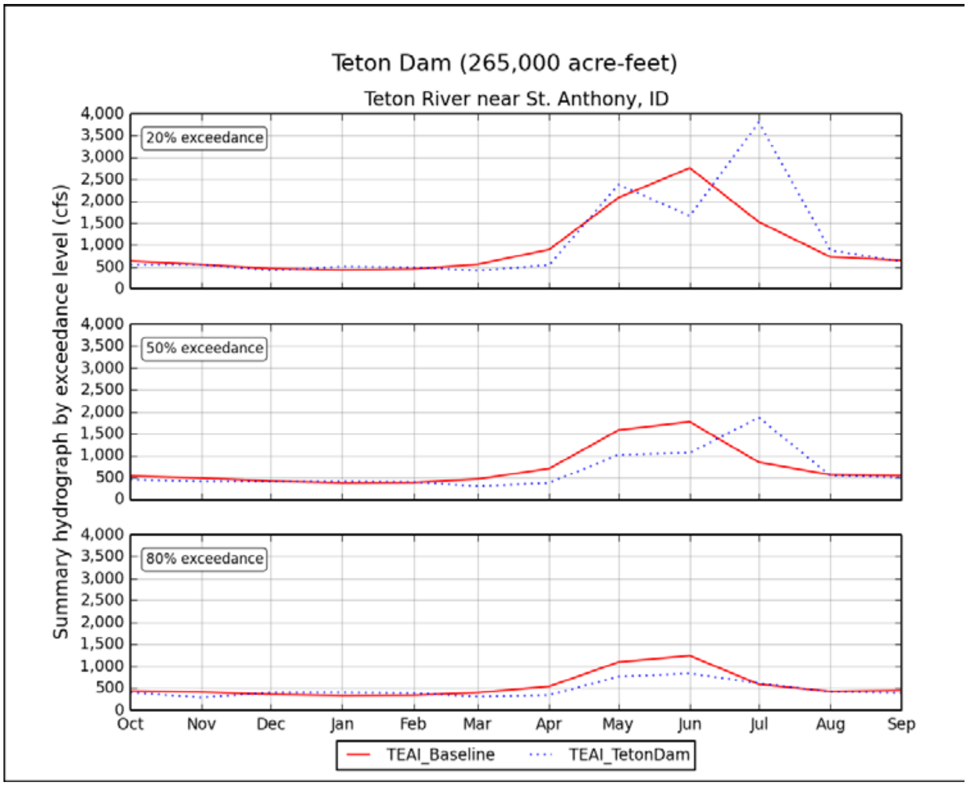

Figure 9: Change in baseline flows due to the Teton Dam below the reservoir. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 50% exceedance hydrograph shows a decrease in flow in the spring as excess flows are captured in the reservoir and an increase in flow in July as the stored water was released.

Climate Change: The potential impacts of climate change in the Henrys Fork Basin Study were evaluated using climate change and hydrology datasets that were adopted by Bonneville Power Administration (BPA), U.S. Army Corps of Engineers (USACE), and the Bureau of Reclamation (Reclamation). These agencies collaborated to develop climate change and hydrology datasets to be used in their longer-term planning activities in the Columbia River Basin. The datasets development was coordinated through the River Management Joint Operating Committee (RMJOC), a subcommittee of the Joint Operating Committee.

Methodology

Climate change simulations were conducted using global climate (circulation) models (GCMs) selected under the direction of the RMJOC. During this process, future climate change and hydrologic datasets were selected based on GCM type, emission forcing scenario, area of interest, and timescale. In addition, both the Hybrid-Delta (step change) and Transient (time evolving) techniques were used.[6] The data were downscaled (from a large coarse scale GCM resolution to a finer resolution scale that was better representative of the geographic area of study i.e. the Columbia Basin) and bias-corrected. Bias-correction is a process in which each GCM's tendencies to simulate past conditions that are statistically different from historical observations (e.g., too wet or too warm) are adjusted to statistically match. This process is referred to as Bias Correction Spatial Disaggregation (BCSD).

For the RMJOC study, future climate change Hybrid-Delta datasets were selected for two future periods from 2010 to 2039 and 2030 to 2059. These 30-year periods are also referred to as "centered around" the 2020s and 2040s, respectively. Six ranges of future temperature and precipitation conditions were selected to characterize the future climate to be evaluated relative to a simulated historical period from 1950 to 1999[7]. These ranges selected included:

- Central (C) or the future projection closest to the 50th percentile temperature and 50th percentile precipitation;
- Minor Change (MC) roughly targeting less warming and 50th percentile precipitation;
- More Warming and Wetter (MW/W) or the future projection closest to the 90th percentile temperature and 90th percentile precipitation;

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[6] U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration, 2010. Climate and Hydrology Datasets for Use in the RMJOC Agencies' Longer-Term Planning Studies: Part 1 – Future Climate and Hydrology Datasets.

[7] The ranges were developed by selecting the scenario that was closest to the 90th, 50th and 10th percentile coordinates for change in mean annual temperature and mean annual precipitation over the Columbia River Basin. This enabled 'bracketing' the ranges so a broad range of future projections could be analyzed.

- Less Warming and Wetter (LW/W) or the future projection closest to the 10th percentile temperature and 90th percentile precipitation;
- More Warming and Drier (MW/D) or the future projection closest to the 90th percentile temperature and 10th percentile precipitation; and,
- Less Warming and Drier (LW/D) or the future projection closest to the 10th percentile temperature and 10th percentile precipitation.

These ranges of temperature and precipitation were generated using two of several future emission forcings available. Emission forcings make assumptions about future emissions based on different economic, technical, environmental, and social developments. The selected emission forcings included A1B, which assumes an average or medium emissions future and B1, which assumes a low emissions future. A more detailed description of the emission forcings can be found in the Special Report on Emissions Scenarios.[8]

Only the data results from the Hybrid-Delta 2040s were selected and incorporated into the Modsim model used for this analysis as part of the Henrys Fork Basin Study. In addition, rather than choosing all six ranges of temperature and precipitation, only three were used in these analyses, which include:

- LW/W - CGCM3.1.t47 with emissions scenario B1, lower emissions
- MC - ECHAM5 with emissions scenario A1B, higher emissions than B1
- LW/D - ECHOG with emission scenario B1, lower emissions

These three projections were chosen as they are representative of wet, average, and dry conditions as compared to all six ranges of temperature and precipitation.

Results

This study uses climate change data that reflects the best available datasets and data development methodologies. However, the best available science includes a number of analytical uncertainties that are not reflected in this report's characterization of future hydroclimate possibilities. These uncertainties range from the emission forcings used in the GCM to the quality of the hydrologic model that generates flow for use in an agency's reservoir model. The reader is encouraged to the Part I Report[6] from the RMJOC Climate Change Study to fully understand the uncertainties associated with the data development and methodologies.

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[8] IPCC (2000). *IPCC Special Report on Emissions Scenarios (Nakicenovic, N. and R. Swart, Eds.)*. Print version: Cambridge University Press, UK. This version: IPCC website. http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=27#anc1. Retrieved 2011-08-18.

It is important to note as the modeling results are presented, during the RMJOC Climate Change Study it was found that four of the six Hybrid-Delta projections chosen over the Columbia River basin were actually wetter than historical when evaluated over the Snake River basin. Even the Central (C) and Minor Change (MC) projections that should have minimal change from the historical condition showed a 10 percent to 15 percent increase in mean-annual runoff for the Hybrid-Delta 2040s projections, Part I Report[6]. Although the results presented in this report show a bias toward a “wet” future, this should not be interpreted as the expected climate change likely to occur in the Snake River basin, but simply a geographic artifact of the projections chosen for the Columbia River basin as a whole. Projections that represented an appropriate range of potential future climates for the entire Columbia River basin happened to be generally biased to a wet future in the upper Snake River basin. Thus the full range of climate variability and uncertainty may not have been captured for the upper Snake River basin. This will be addressed in future studies.

Natural streamflow estimates were generated using Reclamation’s naturalized flow Modsim model[3]. These streamflows represent the flow that would have occurred without reservoir regulation, irrigation diversions, short-term irrigation surface return flow, or the long-term groundwater effects from surface irrigation and groundwater pumping. Figure 10 shows the monthly mean historical natural streamflow near Rexburg, ID as compared to the natural streamflow for each climate change projection used for this study.

The monthly mean streamflow, top graph of Figure 10, shows a shift in runoff timing for all projections from the May through June timeframe to a peak in May and subsequent flow decrease in June. This indicates a combination of changing conditions, most notably a shift in the timing of snowpack melt, but could also indicate increased spring precipitation at lower elevations and potentially a decrease in snowpack.

The middle graph of Figure 10 is the percent change in the monthly mean of each climate change projection from the historical monthly mean. It demonstrates significant shifts in runoff by month. For example, in February, streamflow increased for every projection from approximately 30 percent to as much as 95 percent. Streamflow then decreased from June through September; in July, from approximately 10 percent to as much as 40 percent.

The bottom graph of Figure 10 is the percent change from the historical annual mean WY volume. This was calculated by dividing the monthly mean volume by the historical annual mean WY runoff volume. It represents the change from the mean annual water supply volume. For example, the MC projection shows a 3 percent increase in mean annual runoff volume in February.

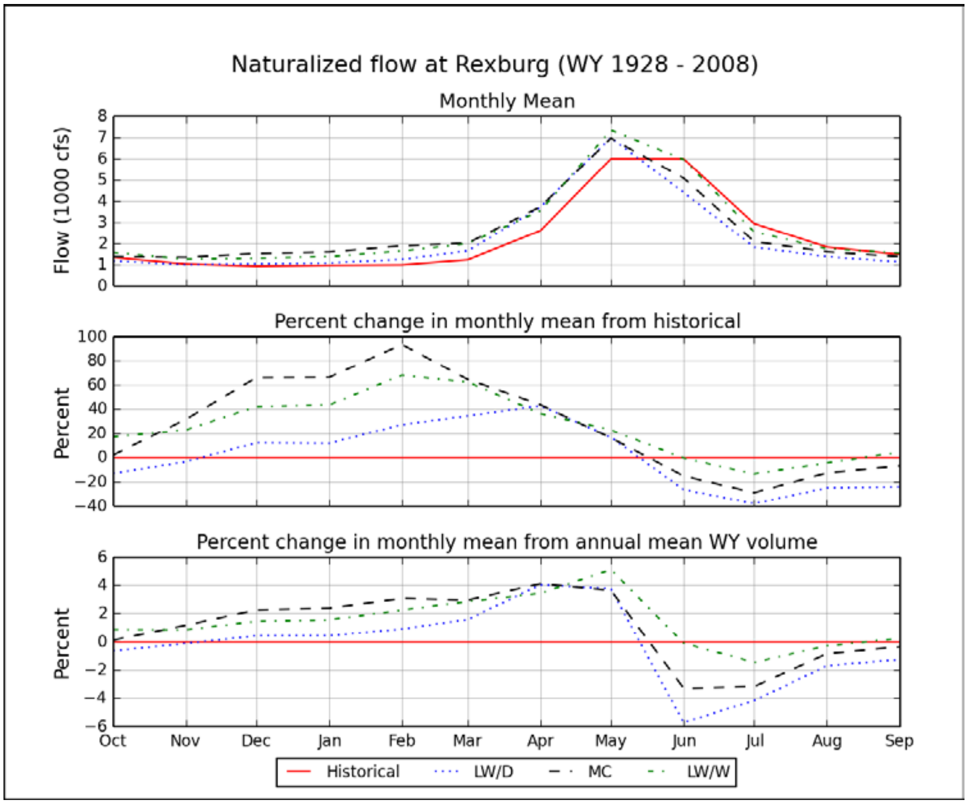

Figure 10: Streamflow on the Henrys Fork at Rexburg, ID from a naturalized Modsim model for the historical condition and the three climate change projections. This represents the flow that would have occurred without reservoir regulation, irrigation diversions, or the long-term groundwater effects from surface irrigation and groundwater pumping. The top graph, monthly mean streamflow, most notably shows a shift in runoff timing. The middle graph demonstrates how significant the flow shift might be by month. The bottom graph shows the percent change to the historical annual mean WY volume. For example, the MC projection shows approximately a 95% increase in streamflow in February (middle graph), this corresponds to a 3% increase in the historical annual mean water supply (bottom graph).

It is interesting to note from the middle graph and bottom graph of Figure 10 the difference between a shift in flow and its impact on the annual mean WY volume. For example, the MC projection on the middle graph shows a 40 percent decrease in monthly mean flow in July, or a four percent decrease in annual mean runoff in the bottom graph. Whereas, the 25 percent decrease in monthly mean flow in June was a six percent decrease in annual mean runoff. The larger impact to water supply occurred in June rather than July even though July experienced a larger percent difference in streamflow.

In general, the graphs in Figure 10 demonstrate a need to capture and deliver more stored water. The bulk of the runoff appears to occur by May rather than through June and the decrease in natural flow through the summer months will likely require additional stored water to maintain current demand levels.

Canal Automation (CA) alternative

As the baseline model run with CA showed (Figure 1), little difference was seen with CA in any of the climate change projections. Figure 11 shows the flow change on the Henrys Fork near Rexburg, ID for the LW/D projection as compared to the LW/D baseline run. Due to the minor change in streamflow reflected here, the results from the other two projections and changes to storage are not presented.

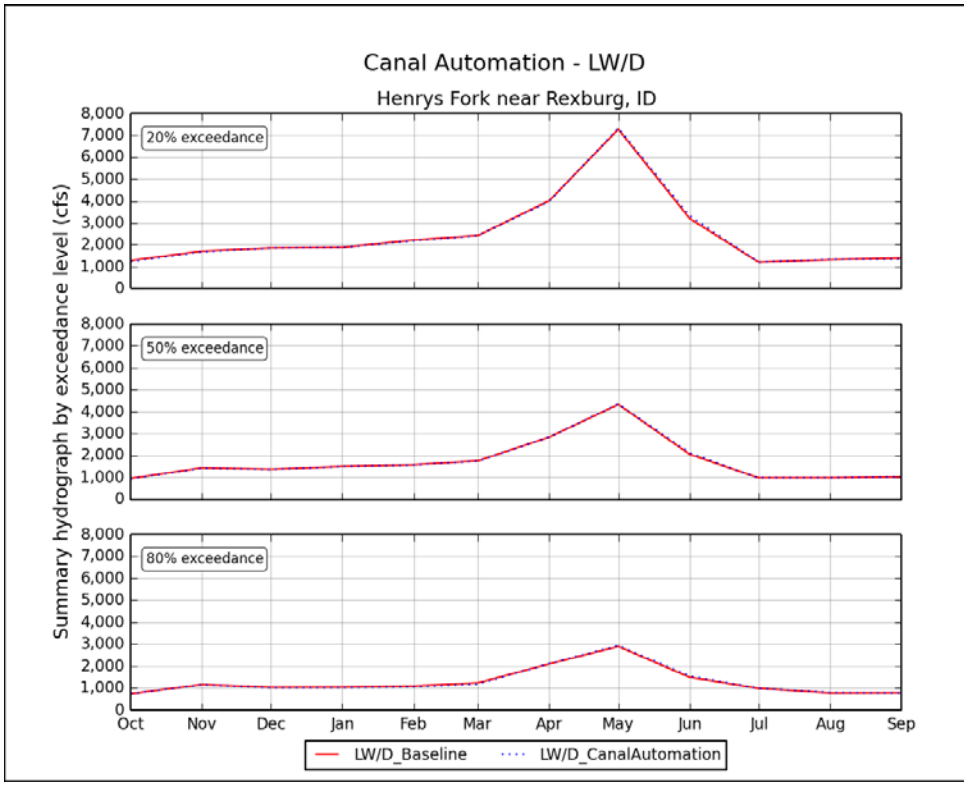

Figure 11: Change in LW/D baseline flows due to canal automation. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. A slight increase in flow was seen in June due to decreased diversion and a slight decrease in flow in the winter as the decreased diversion cause a decrease in groundwater returns.

Island Park Dam raise alternative

Due to the general bias to “wet” conditions in the modeled climate projections, an increase in water year accrual was seen under all projections, Figure 12. This is attributable to the increased winter runoff as previously discussed in the climate change “Results” section, Figure 10.

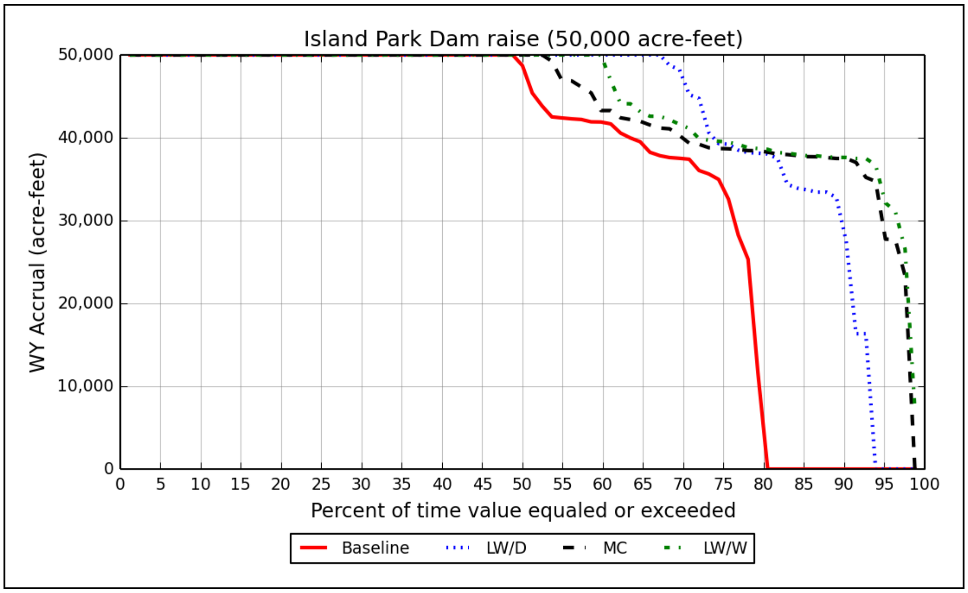

Figure 12: Water year volume accrued by the new reservoir water right. An increase in water year accrual was seen for all climate change projects.

Figure 13 shows the change in flow below Island Park reservoir. The 50 percent and 80 percent exceedance hydrographs show reduced streamflow from October through December that resulted in increased storage. The reservoirs then fill and pass inflow downstream from January through May. Because more water accrued to the reservoir storage right, additional water was released downstream from July through September to satisfy the new demand. Even in the drier years (80 percent exceedance) enough additional water was captured to increase July flows to satisfy the new demand.

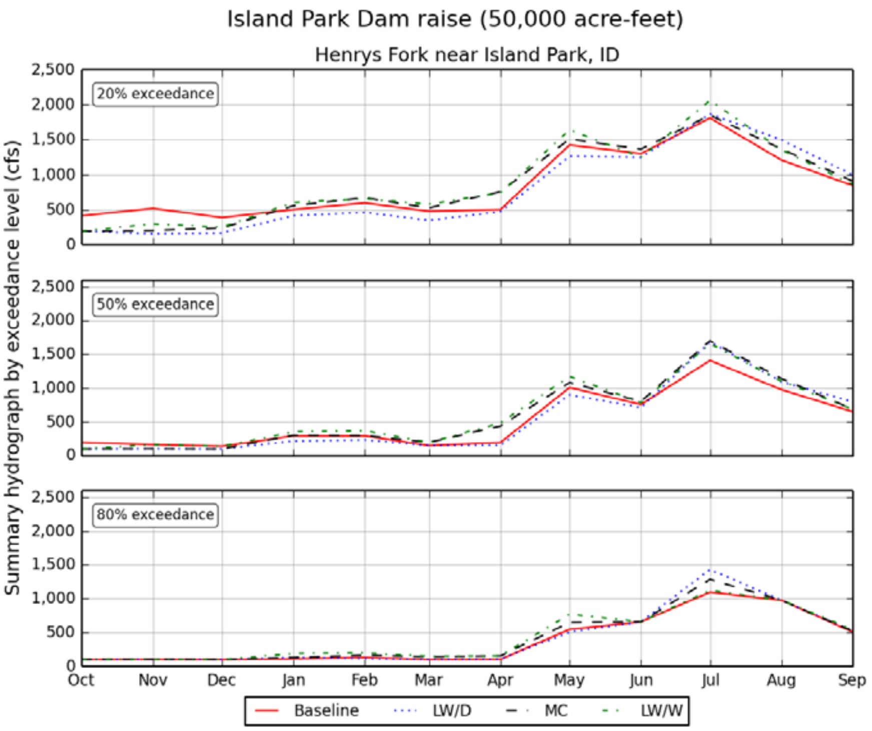

Figure 13: Change in Island Park Dam raise alternative's baseline flow below the reservoir due to the climate change projections. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 20% and 50% exceedance hydrographs show increased storage or reduced streamflow from Oct-Dec, the reservoirs then fill and pass inflow downstream from Jan-May. Because more water accrued to the reservoir storage right, additional water was released downstream from Jul-Sep to satisfy the new demand.

Lane Lake alternative

Similar trends, although visually different, to the ISL2 alternative were seen for the LL alternative. That is, additional water accrued to the reservoir due to wetter winter conditions (Figure 14) and additional water was delivered downstream in the summer to meet the new demand (Figure 15). However, in this alternative as opposed to the ISL2 alternative, the decline in natural flow from June through September was visible for the plotted river locations. Because the volume of stored water delivery was lower on the Teton River than the mainstem Henrys Fork the natural flow decline was more pronounced. The 80 percent exceedance graph of Figure 16 indicates that the minimum flow requirements on the Falls River are not satisfied (climate projections fall below the baseline) with the current model constraints or priorities. The model restricted irrigation diversion on the Falls River to meet the minimum flow requirement first. So, the minimum flow requirement was not met either because other higher priority demands downstream requested the water or there was simply insufficient natural flow in the river.

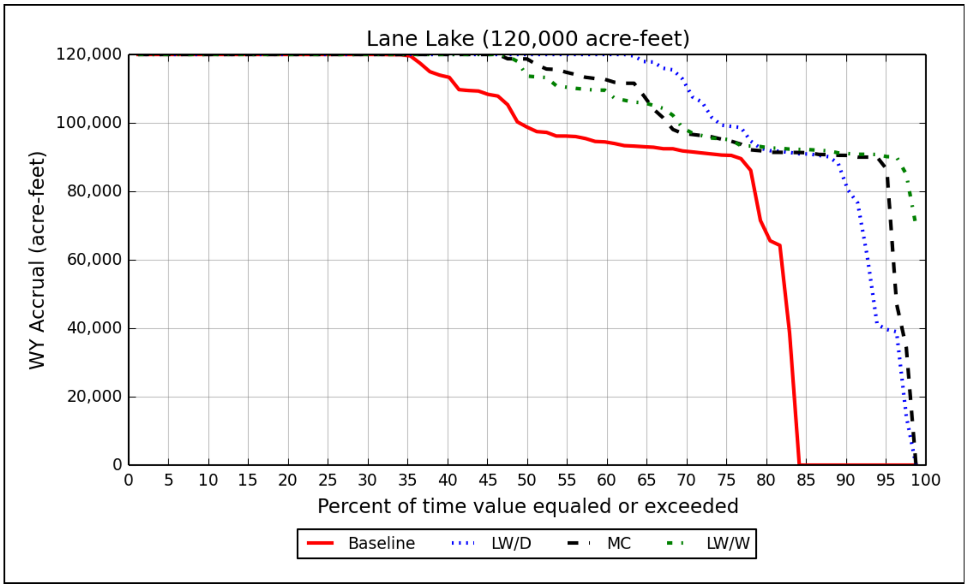

Figure 14: Water year volume accrued by the new reservoir water right. An increase in water year accrual was seen for all climate change projects.

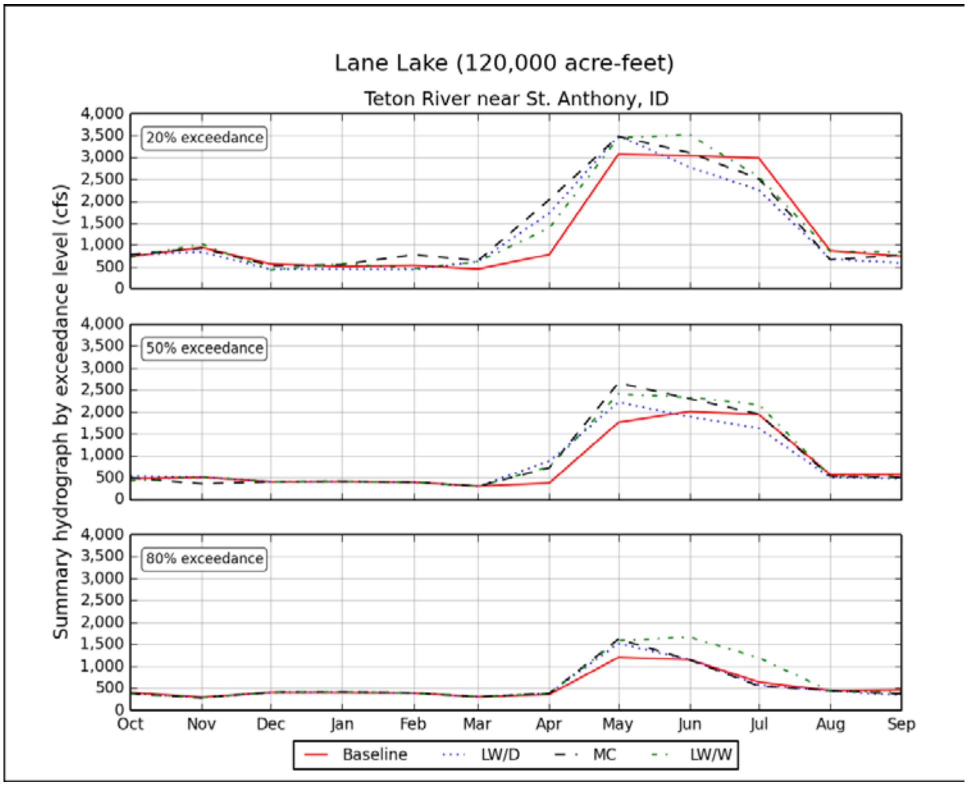

Figure 15: Change in the Lane Lake alternative's baseline flows on the Teton River near St. Anthony, ID compared to the climate change projections. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. Although not as visually apparent, additional water was stored in the winter, in April and May the reservoir was full and we see the change in natural flow from the climate change projections. Additional water was then delivered downstream but due to the climate change projections reduction in natural streamflow from Jul-Sep the additional delivery was not visible when compared to the baseline.

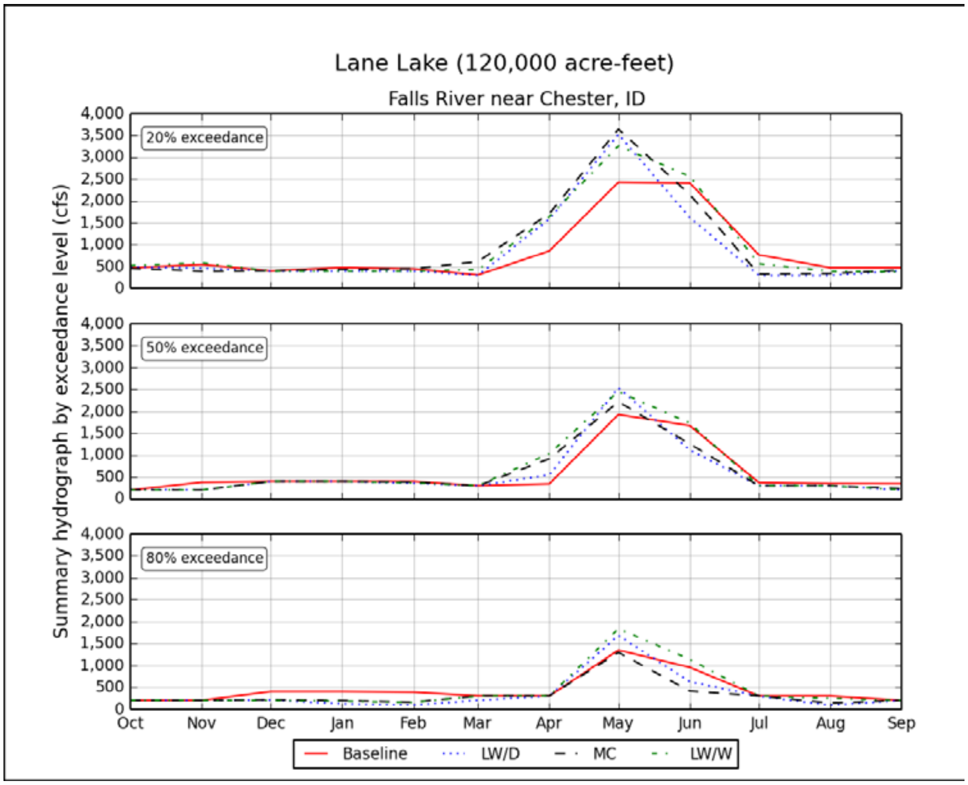

Figure 16: Change in the Lane Lake alternative's baseline flows on the Falls River near Chester, ID compared to the climate change projections. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The 20% and 50% exceedance hydrographs show similar flows through the spring until April when it's likely that diversion to Lane Lake ceases as the reservoir was full. The natural flow peaks in May a recedes quicker than the baseline. The 80% exceedance shows that the minimum flow requirements are not satisfied from Dec-Mar, either because downstream demands have priority for the water or simply that the natural flow was insufficient.

Teton Dam alternative

Due to the general bias to "wet" conditions in the modeled climate projections, an increase in water year accrual was seen under all projections, Figure 17. This was attributable to the increased winter runoff as previously discussed in the climate change "Results" section, Figure 10.

Figure 18 shows the change in flow below Teton Dam. In contrast to the LL alternative where accrual to the reservoir had a flow rate constraint and a volume constraint from the Teton River, the TET alternative was unconstrained by any flow rate and with a higher volume constraint to store water was able to capture nearly all excess flows. This is shown in Figure 18 at all three exceedance levels; the flow from August through April is nearly identical to the baseline. The additional water accruing to the new reservoir right, Figure 17, is being delivered in June and July as seen in the 50% and 20% exceedance plots.

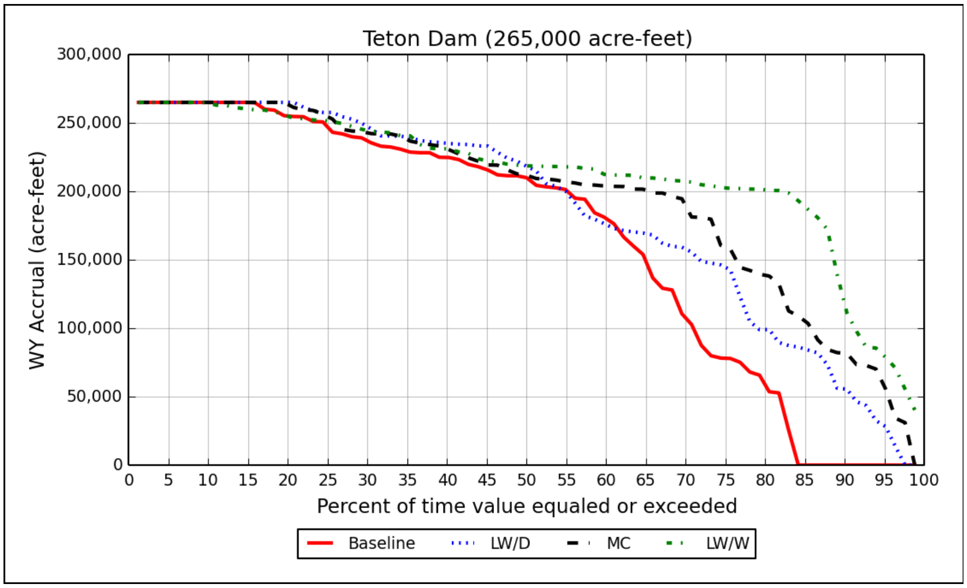

Figure 17: Water year volume accrued by the new reservoir water right. An increase in water year accrual was seen for all climate change projects.

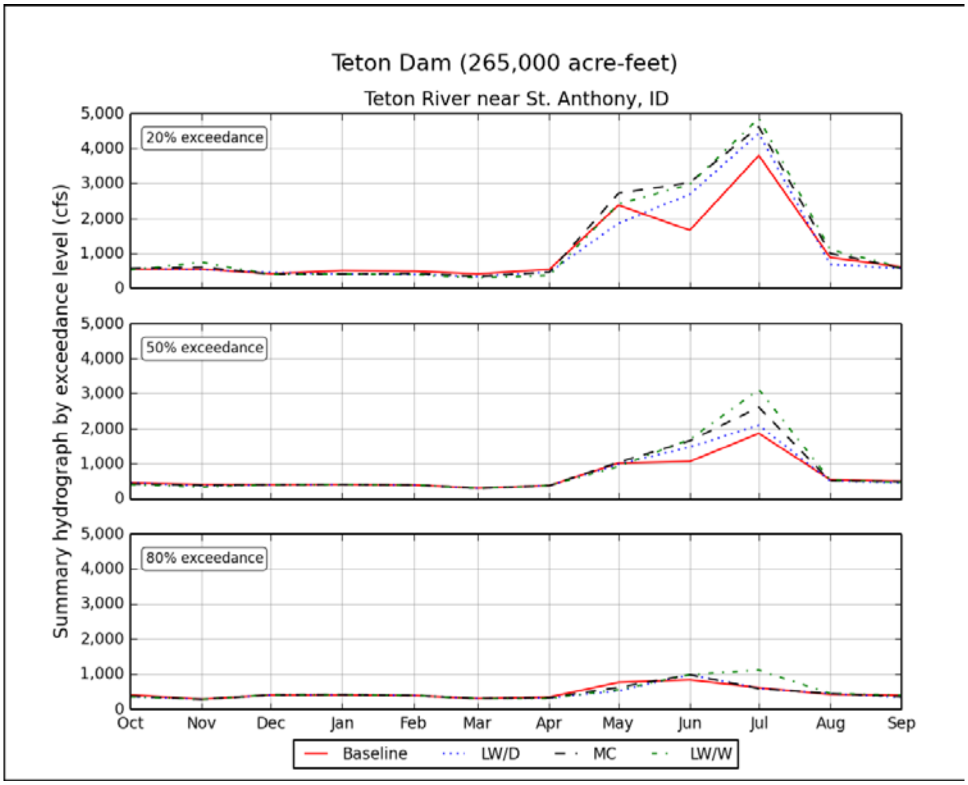

Figure 18: Change in the Teton Dam alternative's baseline flow below the reservoir due to the climate change projections. The 20%, 50%, and 80% exceedance levels represent high, median, and low flow conditions, respectively. The additional accrual, Figure 17, is not released until June and July to meet the new demand.

Climate Change Conclusions

The general bias to “wet” conditions with the modeled climate change projections allowed additional reservoir accrual and delivery of stored water to satisfy the new demand in this study. However, the impact of higher winter flow and lower summer flow was not summarized in this report. It was summarized in the RMJOC Part II Report[9]. The RMJOC study found that water users with both natural flow and storage water rights experienced a shift in water use. That is, water users were more dependent on their stored water because of the decline in summer time natural flow.

Additional analyses will be required in future studies to fully understand the potential impacts to storage and other metrics evaluated in the upper Snake River basin due to climate change. Because future climate is unknown it is important to evaluate the full range of potential change in climate, including the potential effect of a dry future climate when compared to historical conditions.

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[9] U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration, 2010. Climate and Hydrology Datasets for Use in the RMJOC Agencies’ Longer-Term Planning Studies: Part II – Reservoir Operations Assessment for Reclamation Tributary Basins.