US Army Corps
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Walla Walla District

LITTLE WOOD RIVER, GOODING, IDAHO

INTEGRATED LETTER REPORT AND ENVIRONMENTAL ASSESSMENT

APPENDIX J, CLIMATE CHANGE ASSESSMENT

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1 ENGINEER CONSTRUCTION BULLETIN 2018-14 ANALYSIS OF POTENTIAL CLIMATE VULNERABILITY

This is an evaluation of potential climate vulnerabilities facing the Gooding Canal Rehabilitation project. The project study area is the Little Wood River in the City of Gooding, Idaho. The city is located near the confluence of the Big Wood River and Little Wood River, which merge a short distance downstream to form the Malad River, which is a tributary to the Snake River. This assessment was performed to highlight existing and future challenges facing the project due to past and future climatic changes, in accordance with the guidance in Engineering Construction Bulletin (ECB) 2018-14, revised 10 Sep 2020. Background information on the project can be found in the main report, and background information on climate-affected risks to projects and assessments thereof can be found in the ECB.

During high flow conditions, there is an increase in localized flood risk and threat to adjacent public infrastructure and private property due to deterioration and failure in the walls of the Gooding Canal. Slumped piles of masonry in the channel reduce its conveyance capacity and allow ice jams to form and debris to accumulate during winter high flow events further reducing channel conveyance, and results in localized overbank flooding. The canal has further restrictions due to multiple bridge crossings that create pinch points during high flow events that also contribute to ice jamming and localized flooding during winter high flow events. The Gooding Canal is heavy used for irrigation during the summer, and water flows into and out of the river at many locations. Irrigation use of the canal has increased steadily since the canal was constructed. The highest flows in the Gooding canal usually occur during the non-irrigation season, when natural flows are high and little water is diverted for irrigation. During low flow periods in the winter, the river may freeze solid. Historically, flooding occurs in the Gooding canal when ice jams form followed by an extreme weather event. Winter high water events are primarily caused by rain on snow, or other melt events. Peak streamflow can be used to represent future trends in increased flood risk through the City of Gooding and is thus the primary focus of this assessment.

1.1 Literature Review

Included in this section are highlights from select publications regarding observed historical climate trends relevant to the inland Pacific Northwest Region and corresponding forecasts of future meteorological and hydrologic conditions. The consensus presented within a wide range of the literature is that observed trends within twentieth century records indicates increased temperature with associated increase in freeze-free season lengths and decreased snowpack or April 1 SWE, with variable hydrologic impacts including variable snowmelt runoff. Delayed runoff of snowmelt is an important process that temporally redistributes winter precipitation to the dries part of the year.

The Little Wood River project area is located within the eastern extents of the Upper Snake River basin (HUC4: 1704). Despite being within the state of Idaho, the hydroclimate of the Little Wood River watershed is hydrologically closer to those of the inland Northwest than either the Idaho Batholith or Northern Rockies ecoregions to the east. Thus, this literature review focused on the Pacific Northwest region (HUC2: 17), more specifically the inland Columbia River basin of southeastern Washington where possible.

The Fourth National Climate Assessment (NCA4) and the USACE Civil Works Technical Report CWTS-2015-23 are the basis for this literature review. The focus of these references is on summarizing trends in historic, observed meteorological and streamflow data, as well as providing an indication of trends in future climate impacted hydrology based on the outputs from Global Climate Models (GCMs). The NCA4 considers climate change research at both a national and regional scale. Civil Works Technical Report CWTS-2015-23 was published as part of a series of regional summary reports covering peer-reviewed climate literature. The 2015 USACE Technical Reports cover 2-digit, United States Geological Survey (USGS), hydrologic unit code (HUC) watersheds in the United States (U.S). Little Wood River is located within 2-digit HUC 17, the Pacific Northwest Region (USACE 2015).

In many areas, temperature, precipitation, and streamflow have been measured since the early 20th century and provide insight into how the hydrology in the region has changed over the past century. Future climate predictions are derived from GCMs loaded with representative concentration pathways (RCPs) reflecting projected radiative forcings through the end of the 21st century. The radiative forcings encompass the change in net radiative flux due to external drivers of climate change, such as changes in carbon dioxide or land use/land cover.

Projected temperature and precipitation results can be transformed to regional and local scales (a process called downscaling) for use as inputs in precipitation-runoff models (Pytlak, et al. 2016). Downscaling is necessary to add local information (such as terrain elevation, aspect, and slope) to the coarse climate model output to create the higher resolution geospatial datasets to support hydrologic modeling at the subbasin scale. All downscaling methods have relative strengths and weaknesses and inherently introduce uncertainty and error that may require subsequent correction via debias or hybrid methods.

Uncertainty is inherent to projections of temperature and precipitation due to the GCMs, RCPs, downscaling methods, and many assumptions needed to create projections (USGCRP 2017). When applied, precipitation- runoff models introduce an additional layer of uncertainty. However, these methods represent the best available science to predict future hydrologic variables (e.g. precipitation, temperature, & streamflow). Many researchers use multiple GCMs and RCPs in their studies to understand how various model assumptions impact results (Gleckler et al., 2008).

For this assessment, background literature on observed and projected temperature, precipitation and streamflow trends are provided as context for the hydrologic regime and the design/implementation requirements to ensure project viability, reduce risk, maintain durability, and extend service life.

1.1.1 Temperature

Baseline Temperature Trends: In the twentieth century, all areas of the Pacific Northwest Region became warmer, and spring temperatures increased 1 to 3°C between 1970 and 1998 (Spears et al. 2013). MacDonald (2010) noted that average annual temperatures in the Pacific Northwest for the 2001 to 2009 period were up to 2 standard deviations above the 20th century average (1895 – 2000).

Based on observed temperature records, the annual, average air temperature between 1986 and 2016 for the Northwest has increased by 1.54°F from the 1901-1960 annual average temperature baseline (Vose, et al. 2017). Temperatures from 1895–2011 averaged warming of about 1.3 °F. The average present-day (1986– 2016) observed coldest daily temperature for the Pacific Northwest Region is 4.78°F warmer than the average for the first half of the last century (1901–1960). The warmest day of this same comparison is 0.17°F cooler. Temperature extremes across the contiguous United States has changed. The frequency of cold waves has decreased since early 1900s, and heat wave frequency has increased since mid-1960s. The number of high temperature records set in past two decades far exceeds the number of low temperature records.

Kunkel et al (2013) reported that temperatures in the Pacific Northwest Region have generally been above the 1901–1960 average for the last 25 years, both annually and for all seasons. The report noted that increases in inland temperature of the northwest US were greater than those near the coast. Freeze-free season lengths during 1991–2010 averaged about 11 days longer than during 1961–1990. Since 1990, freeze temperatures have been occurring later in fall and not occurring in early spring. The freeze-free period across much of the Pacific Northwest Region increased by 25–35 days with larger increases for the inland northwest. Kunkel et al. also reported on the frequent occurrence of heat waves in the Pacific Northwest Region in recent years, with five of the top 10 years for intense heat occurring in the last two decades. Cold waves have been generally more infrequent since 1990, with all the top ten years for intense cold occurring prior to 1991. This study also predicted an increase in the number of days hotter than 95°F in the southeast portion of the Pacific Northwest region within which is the Little Wood River basin. The longest string of days with such high temperatures is simulated to increase by up to 10 days per year.

Future Temperature Trends: For future conditions, Kunkel et al (2013) estimated that increases in temperatures will be greater for the inland northwest that those near the coast. The freeze-free period was estimated to increase by 25–35 days across much of the Pacific Northwest Region, with larger increases on the west of the Cascade Mountains. This study also predicts an increase in the number of days hotter than 95°F in the southeast portion of the region. The longest string of days with such high temperatures was simulated to increase by up to 10 days per year.

Mantua et al (2010) reported that rising water temperatures will thermally stress salmon throughout Washington watersheds, becoming increasingly severe later in the twenty-first century, which is likely to have similar effects in the Little Wood River watershed.

While winter and spring warming may benefit parts of the freshwater life cycle of some salmon populations, the combined effects of warming summertime stream temperatures and altered streamflow will likely reduce the quality and extent of freshwater salmon habitat and increase strain to many salmon populations.

For the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), Mote and Salathé (2010) indicate that climate models which generally reproduce the observed seasonal cycle and twentieth century warming trend of 0.8°C (1.5°F) in the Pacific Northwest Region predict a much greater warming for the next century relative to the average from 1970 to 1999. These models project increases in annual temperature of 1.1°C (2.0°F), on average, by the 2020s, 1.8°C (3.2°F) by the 2040s, and 3.0°C (5.3°F) by the 2080s, averaged across all climate models. Predicted rates of warming range from 0.1°C to 0.6°C (0.2°F to 1.0°F) per decade, with some models projecting an enhanced seasonal cycle trending towards wetter autumns and winters, with drier summers.

Mote and Sharp (2016) indicate that for increasing temperature estimates in the Western United States of 2°– 5° C over the next century, it is likely that losses in snowpack observed up to 2005 will likely continue and even accelerate, with faster losses in milder climates like much of the Cascades and the slowest losses in the higher altitude Rockies and Sierra Nevada.
Pytlak et al. (2018) report that Columbia Basin warming is expected to be greatest (and more locally variable) within the interior, potentially increasing as much as 3 to 6°F over baseline observations by the 2070s if RCP 4.5 emissions pathways are attained.

1.1.2 Precipitation

Baseline Precipitation and Snowpack Trends: Multiple studies have identified increasing trends in average annual precipitation in the Pacific Northwest region for the latter half of the 20th century, especially for the coast areas which are notably distinct from the inland northwest. This precipitation trend is variable depending upon location and season. Within the Little Wood River region, the seasonal hydrologic regime is dominated by winter snowpack with supplemental inputs from “shoulder season” precipitation events that occur primarily in the autumn and spring as the region transitions into and out of winter.

The weighted mean precipitation based on elevation ranges for the Little Wood River Subbasin is 14.66 inches. Most of the precipitation occurs in the winter and spring months. The annual average snow depth for the low elevations of the Little Wood River Subbasin is 1.3 inches, while the annual average snow depths for the middle elevation is 2 inches (WRCC 2001). The estimated annual average total snowfall for the low, middle, and high elevations of the Little Wood River Subbasin is 43.3, 61.4, and 182.8 inches, respectively. Most of the snowfall in the low elevations occurs from November into March. Snowfall occurs mostly from November to April in the middle elevations and from October to April in the high elevations (WRCC 2001).

A precipitation trend analysis by McRoberts et al. (2011) identified widespread positive linear trends of 2-5% for the inland northwest and western Idaho over the 20th century average (1895 – 2009) hydroperiod with a negative trend of 2-5% for southeastern Washington. A similar study by MacDonald (2010) noted a decrease in precipitation within the inland Pacific Northwest Region for the 2001 to 2009 period relative to the 20th century average (1895 – 2000).

Wang et al. (2009) analyzed gridded precipitation data for a historical (1950 – 2000) hydroperiod. Within the inland northwest, slight increasing trends were observed during both the spring and fall and no trend during the summer when precipitation is generally lower.

An analysis of 20th century rainfall data by Pryor et al (2009), identified statistically significant nonlinear trends for the pacific northwest, including: an overall increasing trend in total annual precipitation, a decreasing trend in large precipitation events and intensity (exceeding the 90th percentile) and an increase in the number of precipitation days per year.

Soil moisture is a function of both supply (precipitation) and demand (evapotranspiration). Grundstein (2009) found that soil moisture was slightly decreasing in the eastern portion of the Pacific Northwest based on annual data from 1895 to 2006.

In the twentieth century, some areas of the Pacific Northwest Region received more winter precipitation and experienced a general decline in spring snowpack, reduced snowfall to winter precipitation ratios, and earlier snowmelt runoff between the mid- and late twentieth century (Spears et al. 2013).

In the Western United States, from 1950–1999, there was a general decrease in the fraction of precipitation retained in the spring snowpack. Snow cover extent in North America set record lows in 3 of the 5 years preceding 2012. A study by Kapnick and Hall (2010) found that recent snowpack changes are due to regional- scale warming, which implies a possible future loss of late season snowpack and an earlier melt season. Multiple studies estimated 1°C warmer climate results in a 14.8–20 percent decrease in snow water equivalent (SWE).

Mote and Sharp (2016) reported that both winter and spring temperatures have increased in western North America during the twentieth century, coinciding with spring snowmelt shifting earlier in the year and decreased April 1 snowpack. Carelton and Hsiang (2019) noted that increasing temperatures can accelerate snowmelt and lengthen the frost-free season.

Future Precipitation and Snowpack Trends: Analyses by Beles et al. (2006) suggested both losses in snowpack in lower altitude mountain ranges and high altitude or high latitude cool season will increase during the twenty-first century. Kunkel et al (2013) simulated an increase in seasonal mean precipitation for southeast Washington, except for winter, which was projected to experience a 2–4 percent decrease. There is notable uncertainty however associated with the predicted precipitation changes. While the number of wet days (precipitation > 1 in) was forecasted to increase, the changes were found to be statistically significant for only small areas in central Washington and Oregon.

The Washington Climate Change Impacts Assessment (Little et al 2009) projects that April 1 snowpack will decrease by 28 percent across Washington by the 2020s, 40 percent by the 2040s, and 59 percent by the 2080s (relative to the 1916–2006 historical average).

Because global climate models do not have sufficient spatial resolution to represent the atmospheric and land surface processes comprising the unique regional climate of the state of Washington, the regional climate model study by Salathé et al. (2010) is very relevant. The study reports two 100-year regional climate simulations showing large-scale weather patterns simulated by a global model interacting with local terrain. The mesoscale simulations produced regional changes in snow cover, cloudiness, and circulation patterns, which affected temperature and precipitation trends over the region relative to the statistical downscaling of the global model. To illustrate this effect, this study analyzes the changes from the current climate (1970– 1999) to the mid-twenty-first century (2030–2059). Main findings from this analysis were (1) projected loss of snowpack; (2) reduced snowpack and earlier snowmelt will alter timing and amount of river runoff in the summer, though changes in annual runoff will depend on annual precipitation changes, which differ from one scenario to another; and (3) extreme precipitation frequency increases over the north Cascades and over eastern Washington.

Miles, et al. (2010) assessed regional impacts and adaptation strategies for potential climate change impacts within Washington State. They indicated that the already highly variable water available would be expected to change in the future as temperature increases of 2–3°F by the 2040s and more basins shift towards rain- dominated by mid-century. Summer and fall low flow season would substantially increase in length, exacerbating direct effects of warmer air temperatures on stream temperature. In line with multiple other studies reviewed, this study projects decreasing April 1 SWE.

1.1.3 Streamflow

Streamflow Baseline Trends: The regional summary from the CWTS-2015-23 reported a mixed consensus of statistically significant decrease in streamflow and April 1 SWE data for the latter half of the twentieth century within the Northwest US. A synthesis of historical climate trends (Spears, et al. 2013) found that stream runoff was characterized by earlier freshet peak flows at most stations between 1950 and 1999, with significant trends toward earlier runoff in the Pacific Northwest Region.

Stewart et al. (2005) found that the center of mass of streamflow has shifted earlier by 1 to 4 weeks in many of the records. Other studies found runoff earlier by 1 to 3 weeks over most of the Mountain West. Fritze et al. (2011) found that warmer temperatures in snowpack dependent watersheds cause reduced snowpack during winter, increased winter month runoff, and earlier spring freshet flows associated with an earlier snowmelt, resulting in decreased inflow to lower elevation reservoirs relative to historical conditions.

Future Streamflow Trends: Streamflow for the inland northwest is predicted to decrease in summer, exacerbating increased temperature effect on aquatic habitat. River hydrograph timing is predicted to continue to shift earlier in the year. The combination of increasing temperature and changing hydrology are predicted to result in loss of freshwater habitat and other ecological mismatches.

A study by Elsner et al (2010), notes that the Pacific Northwest Region hydrology is sensitive to temperature change impact on rain/snow balance because of dependency on snowmelt. April 1 SWE is predicted to decrease by 38–46 percent by the 2040s compared with the mean over water years 1917–2006. By the 2080s, seasonal streamflow timing will shift in both snowmelt dominated and rain-snow mixed watersheds. Annual runoff across the state is projected to increase by 2–3 percent by the 2040s, given an increase in winter precipitation.

Hydrologic simulations by Mantua et al (2010) estimated that by the 2080s, the pacific northwest region would experience a complete loss of snowmelt dominant basins within Washington State, with only about ten transient basins (a mix of direct runoff from cold-season rainfall and springtime snowmelt) remaining in the north Cascades. These transient basins were found to be most sensitive to climate change, with historically transient runoff watersheds shifting towards rainfall-dominant behavior, with more severe summer low-flow periods and more frequent days with intense winter flooding.

Modeling by USBR (2011) of two Columbia-Snake River subbasins was used to simulate hydroclimate response from an ensemble of downscaled CMIP3 models that were run through a Variable Infiltration Capacity model (Liang et al., 1994). The project location on the Little Wood River would fall within the study boundary for the Snake River above Brownlee Dam. As enumerated in Table 1-1, the ensemble changes suggest that these basins will experience increasing mean-annual temperature and precipitation during the 21st century, accompanied by decreasing trend in spring SWE, decreasing trend in April - July runoff volume, and increasing trends in December - March and annual runoff volumes.

Table 1-1. Summary of Simulated Changes in Decade-Mean Hydroclimate for Selected Subbasins in the Columbia River Basin

Hydroclimate Metric (Change from 1990s)	2020s	2050s	2070s
Columbia River at The Dalles			
Mean Annual Temperature (°F)	1.4	3.2	4.6
Mean Annual Precipitation (%)	3.4	6.2	8.5
Mean April 1 SWE (%)1	-1.0	-3.1	-6.7
Mean Annual Runoff (%)	2.3	3.7	7.5

Mean December–March Runoff (%)	9.8	18.5	27.3
Mean April–July Runoff (%)	2.2	4.1	2.4
Mean Annual Maximum Week Runoff (%)	3.5	4.0	5.5
Mean Annual Minimum Week Runoff (%)	-1.5	-5.9	-8.5
Snake River at Brownlee Dam			
Mean Annual Temperature (°F)	1.6	3.6	5.0
Mean Annual Precipitation (%)	2.3	3.9	6.6
Mean April 1 SWE (%)1	-5.0	-12.0	-16.0
Mean Annual Runoff (%)	-0.1	1.2	3.4
Mean December–March Runoff (%)	5.6	13.7	21.0
Mean April–July Runoff (%)	-1.3	-2.0	-0.9
Mean Annual Maximum Week Runoff (%)	2.4	3.5	5.8
Mean Annual Minimum Week Runoff (%)	-3.0	-4.3	-5.9

Hydrologic predictions from the River Management Joint Operating Committee (RMJOC) reported by Pytlak et al (2018), indicate that future increases in temperature, with decreases in winter snowpack and summer precipitation will manifest as significantly higher average fall and winter river flows, earlier peak spring runoff, and longer periods of low summer flows starting as early as the 2030s.

1.1.4 Literature Review Summary:

Within the literature reviewed, there is a moderate consensus that air temperatures will increase over the next century in the Pacific Northwest Region, and a strong consensus that the region could experience an increase in maximum temperature extremes on the order of 5–15 °F. A strong consensus is also noted that intensity and frequency of extreme storm events will increase. Future minimum temperature, average annual precipitation, and streamflow show varied trends, which may be due to physiographic variability within the greater Pacific Northwest Region. The 2015 USACE Civil Works Technical Report CWTS-2015-13 provides a visual summary of the trends in observed and projected hydrometeorological variables as shown in Figure 1-1.

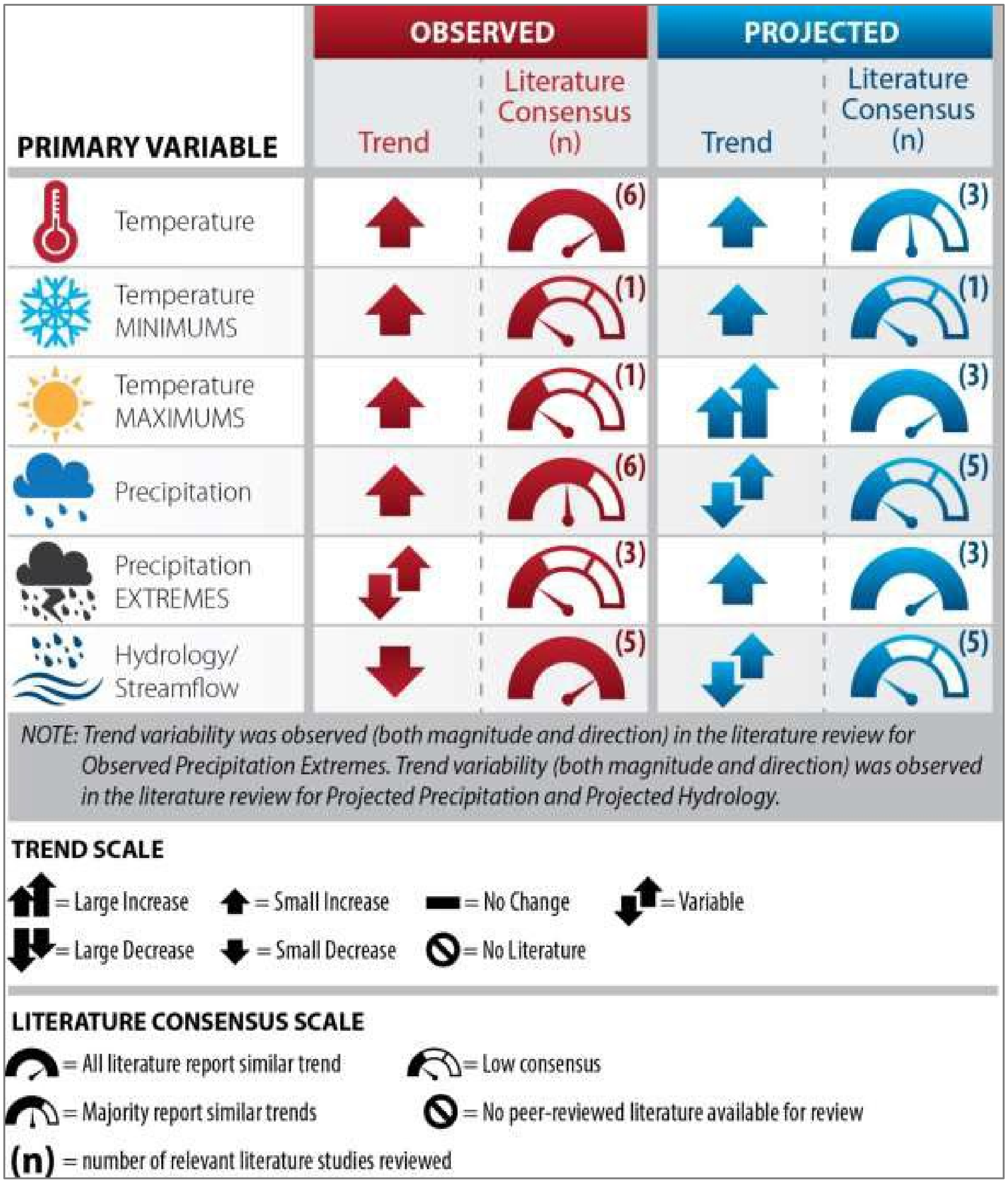


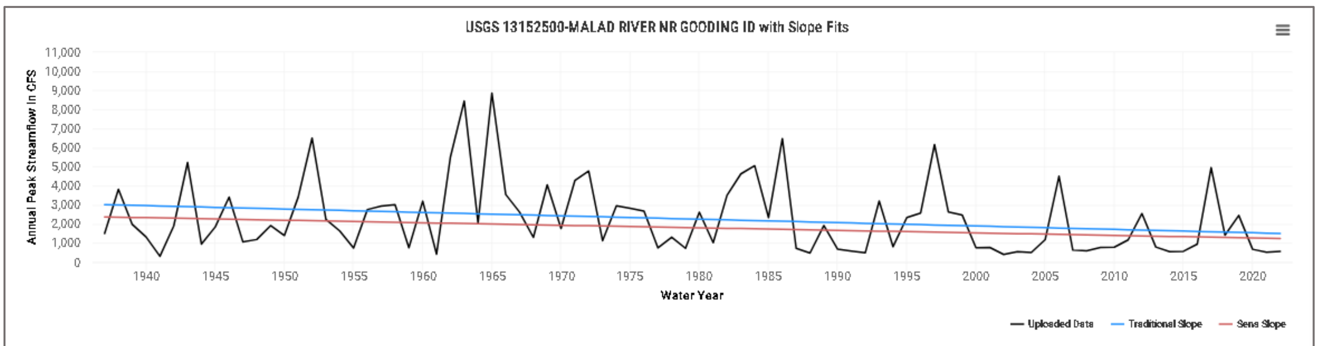
Figure 1-1. Summary Matrix of Observed and Projected Climate Trends
(USACE 2015)

1.2 Trend Analysis and Nonstationarity Detection

The assumption that hydrologic datasets are stationary (their statistical characteristics are unchanging) in time underlies traditional flow frequency analysis. Statistical tests can be used to test this assumption using techniques outlined in Engineering Technical Letter (ETL) 1100-2-3. The Time Series Toolbox is a web-based tool to perform these tests on datasets of annual peak streamflow at U.S. Geological Survey (USGS) stream gages. Linear and monotonic trend analysis is available in both NSD and TST tools by implementing the t-Test (linear), Mann-Kendall (monotonic), and Spearman Rank-Order (monotonic) tests. The p-value for each independent variable tests the null hypothesis that there is or is no correlation with the dependent variable. If the p-value is less than the accepted threshold, than there may be an association with changes in the dependent variable at the population and is deemed statistically significant (Jim Frost, 2022). The accepted USACE threshold for statistical significance is a p-value less than 0.05 and is adopted for annual peak streamflow trend analyses.

For this project, Trend analysis and the NSD tool was applied using annual peak streamflow data from USGS gage 13152500, Malad River Near Gooding, ID. The gage captures 2,990 square miles of drainage area. The USGS water year summary states that flows are regulated by Magic Reservoir and several smaller reservoirs on upstream tributaries and is affected by deliveries from canals diverting from the Snake River at Milner. Diversions upstream of the gage irrigate about 144,000 acres, of which 4,000 acres are irrigated by ground water withdrawals. Annual peak data has been collected since 1916 with a complete record from 1936 to present day. The trend analysis and the NSD tool applies analysis to the period of record from 1936 to 2022.

A linear and monotonic trend analysis using the TST was carried out for the annual peak streamflow. For the period of record, 1936 through 2022, a statistically significant, decreasing monotonic trend was detected by the t-Test (p-value = 0.027), Mann-Kendall (p-value = 0.0047), and Spearman Rank-Order (p-value = 0.0025). See Figure 1-2 for a plot of the data. The decreasing trend has a slope (Traditional and Sen's) of -18 cfs and -13 cfs, respectively.



Trend Line Coefficients

Method	Directionality	Slope	Intercept
Traditional Slope	Negative	-18	37458
Sen's Slope	Negative	-13	28099

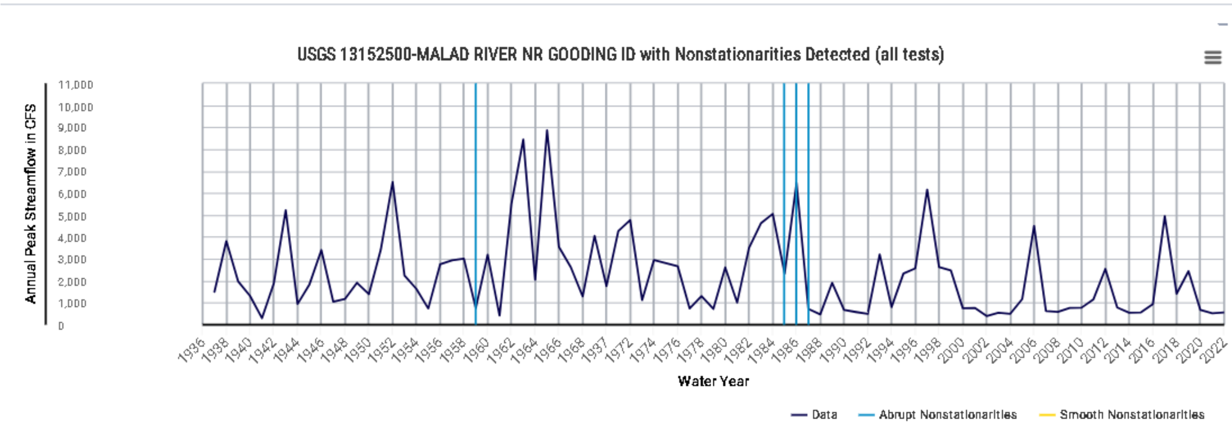
Trend Hypothesis Test

Test	P-Value
t-Test	0.026957
Mann-Kendall	0.0046948
Spearman Rank-Order	0.0025333

- A statistically significant trend (at the alpha = .05 level) was detected by the t-Test.
- A statistically significant trend (at the alpha = .05 level) was detected by the Mann-Kendall Test.
- A statistically significant trend (at the alpha = .05 level) was detected by the Spearman Rank-Order Test.

Figure 1-2. Output of the TST Trend Analysis for USGS Gage 13152500

As shown in Figure 1-3, USGS gage 13152500 has a strong nonstationarity during water year 1986. A strong nonstationarity is one that demonstrates a degree of consensus, robustness, and a significant increase or decrease in the sample mean and/or variance. The 1986 nonstationarity is identified by multiple tests targeted at identifying a change in the overall statistical distribution (see statistical heatmap blue bars in Figure 1-3), indicating consensus. The 1986 nonstationarity can be considered robust because tests targeted at identifying nonstationarities in different statistical properties identify a change in overall distribution (blue bars) and mean (dark blue bar) in Figure 1-3. The magnitude of the mean annual peak flow drops by almost half from 2,700 cfs between 1936 and 1985 to 1,500 cfs between 1986 and 2022. The nonstationarity noted in 1959 lacks consensus and robustness. A strong nonstationarity indicates that it could be beneficial to analyze the data as two subsamples. Analyzing the subset of record from 1986 to 2022 found no statistically significant trends nor additional nonstationarities but this reduces the period of analysis by more than half and is not recommended. The nonstationarity identified in 1986 is most likely due to a change in regulation and irrigation practices caused by additions to the Little Wood River Dam. A one-unit, 3,000 kilowatt powerplant was constructed in 1983 and placed in operation in 1985 at the Little Wood River Dam by the Little Wood River Irrigation District.



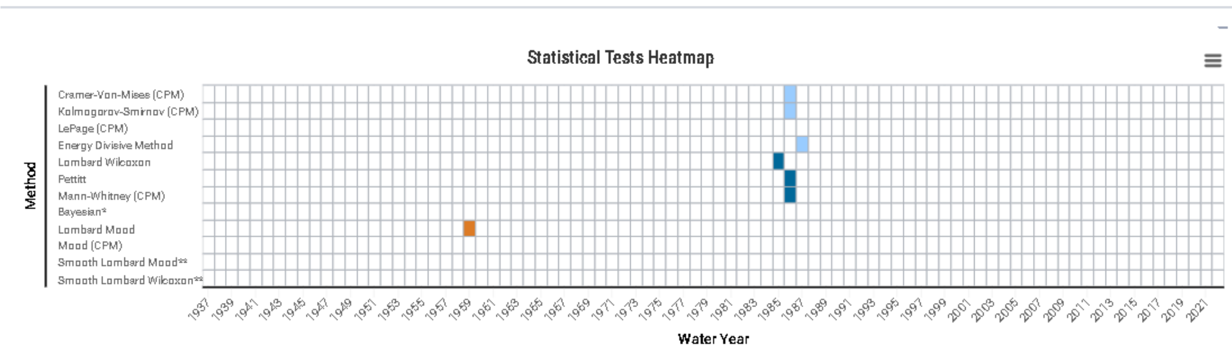


Figure 1-3. Nonstationarity Detection and Statistical Heatmap Results

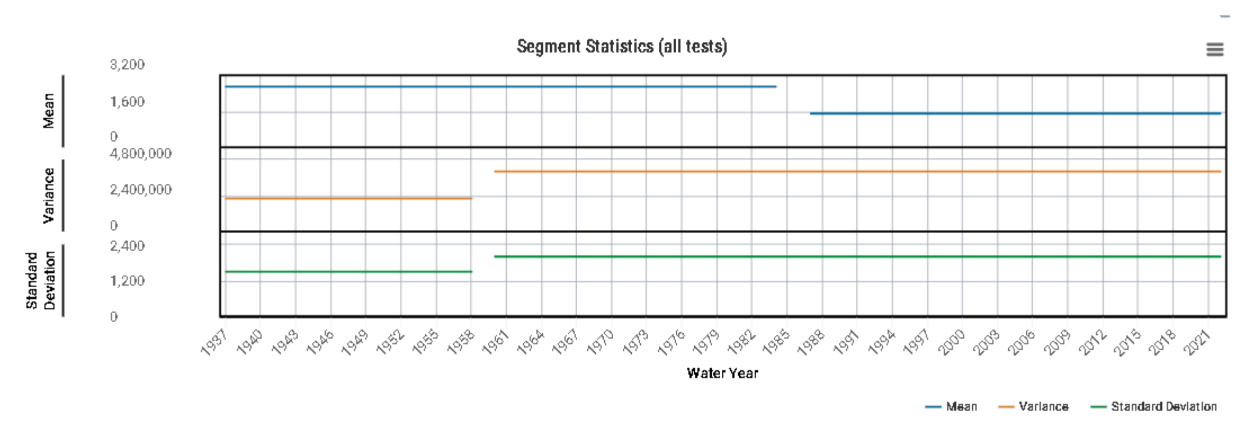


Figure 1-4. Output of the Nonstationarity Detection Tool for USGS Gage 13152500

Since flow data for the project location is highly influenced by upstream irrigation and regulation, the trend analysis and the NSD tool was also applied using annual peak streamflow data from USGS gage 13147900, Little Wood River Above High Five Creek near Carey, ID. The gage is upstream of the project site and is used as a surrogate to evaluate trends and stationarity without the effects of regulation. The gage captures 248 square miles of drainage area, and the water summary indicates it is slightly affected by irrigation of 1,300 acres above the gage. Annual peak data has been collected since 1959 with a complete record for the period of 1980 to present day. The NSD Tool applies analysis to the period of 1959-2022, with an additional review of the data from 1980-2022.

As shown in Figure 1-5, USGS gage 13147900 does not contain any strong nonstationarities for the period of 1959 to 2022. The testing methods used in the TST tool have potential issues when the data has missing values. The peak streamflow data was evaluated for the period of 1980 to 2022 and no nonstationarities or breakpoints were noted in the dataset. No statistically significant trends are detected in the peak streamflow dataset between 1959 and 2022 using the Mann-Kendall and Spearman Rank Order tests applied using a 0.05 level of significance. Analyzing the subset of the record from 1980 to 2022 also found no statistically significant trends.

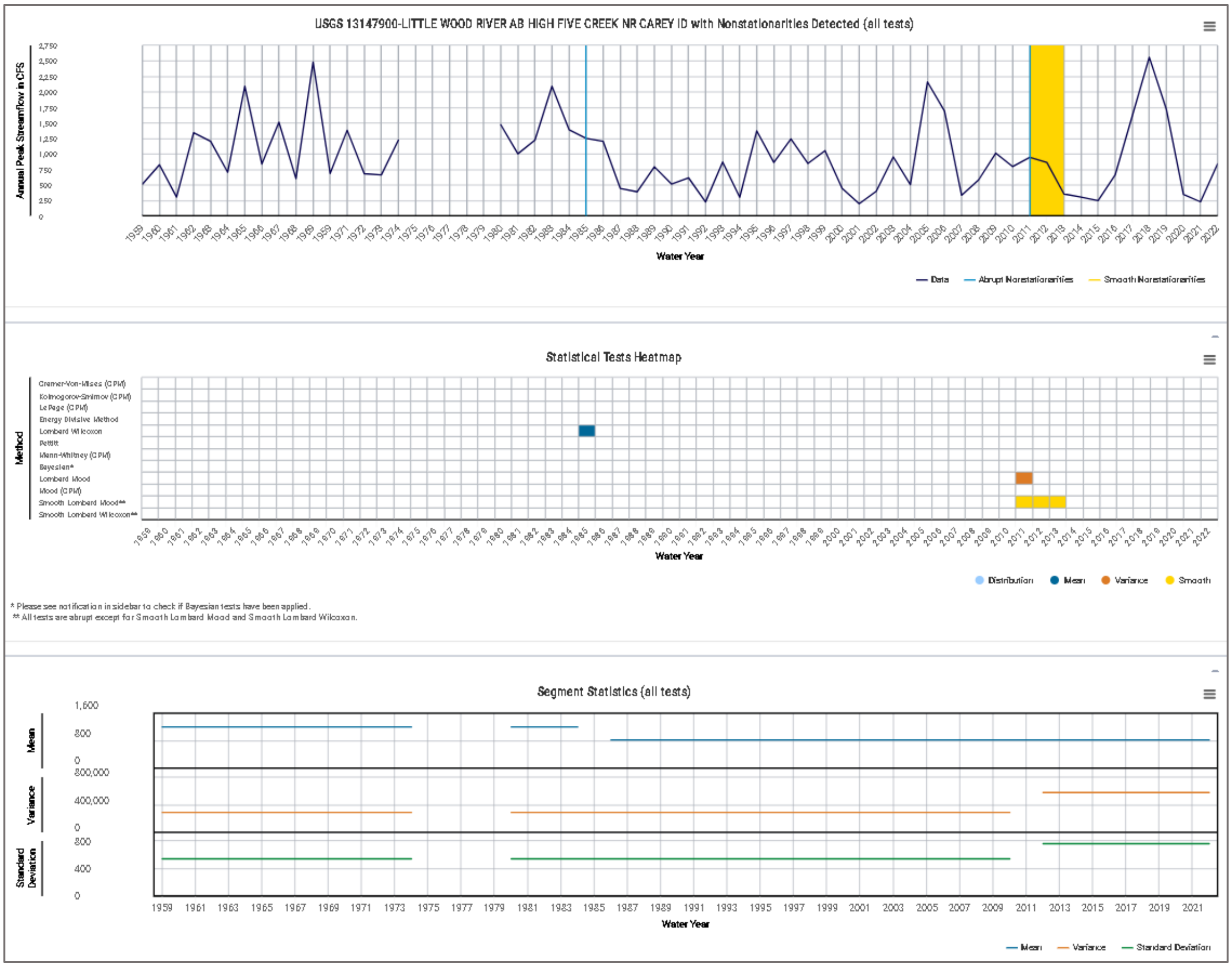


Figure 1-5. Output of the Nonstationarity Detection Tool for USGS Gage 13147900

1.3 Climate Hydrology Assessment Tool

The USACE Climate Hydrology Assessment Tool (CHAT) can be used to assess projected, future changes to streamflow in the watershed. Projections are at the spatial scale of a HUC-4 watershed, with flows generated using a Variable Infiltration Capacity (VIC) model from temperature and precipitation data statistically downscaled from GCMs using the Bias Corrected, Spatially Disaggregated (BCSD) method. The VIC model is setup to simulate unregulated basin conditions. The Gooding Canal is in HUC 1704 (Upper Snake). Figure 1-6 shows the range of output presented in the CHAT using 32 combinations of GCMs and representative concentration pathways (RCP) of greenhouse gas emissions applied to the generate climate-changed hydrology using the VIC model. The range of data is indicative of the uncertainty associated with projected, climate-changed hydrology.

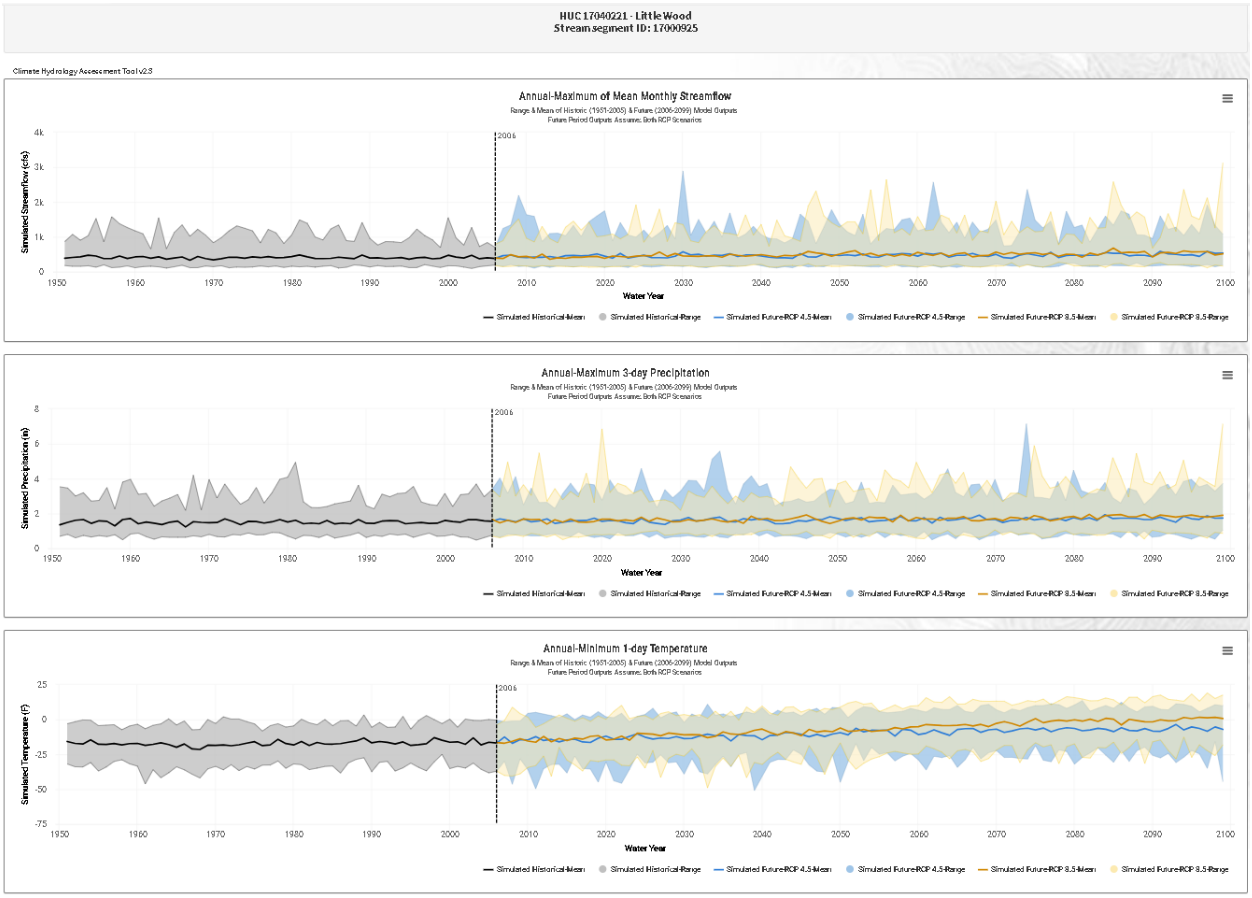


Figure 1-6. Range of 32 Climate-Changed Hydrology Model Output for Upper Snake (HUC 1704)

For the Upper Snake (HUC 1704), there is no statistically significant linear trend for the historic period of 1950 to 2022 for the mean annual maximum monthly streamflow or the maximum 3-day precipitation (p-values <= 0.05). There is a statistically significant linear trend for the historic period for the Annual minimum 1-day temperature with p-values ranging between 0.012 and 0.041. As seen in Figure 1-7 through Figure 1-9 below, the projected trends for the period of 2006 to 2099 for all three variables show statistically significant positive trends with p-values being significantly less than 0.05. The positive trend seen in the annual minimum 1-day temperature could indicate that winter temperatures will increase, which could indicate a decrease in ice jam related flooding events. However, this may be offset by the potential increase in annual peak streamflow indicated by the positive future trend.

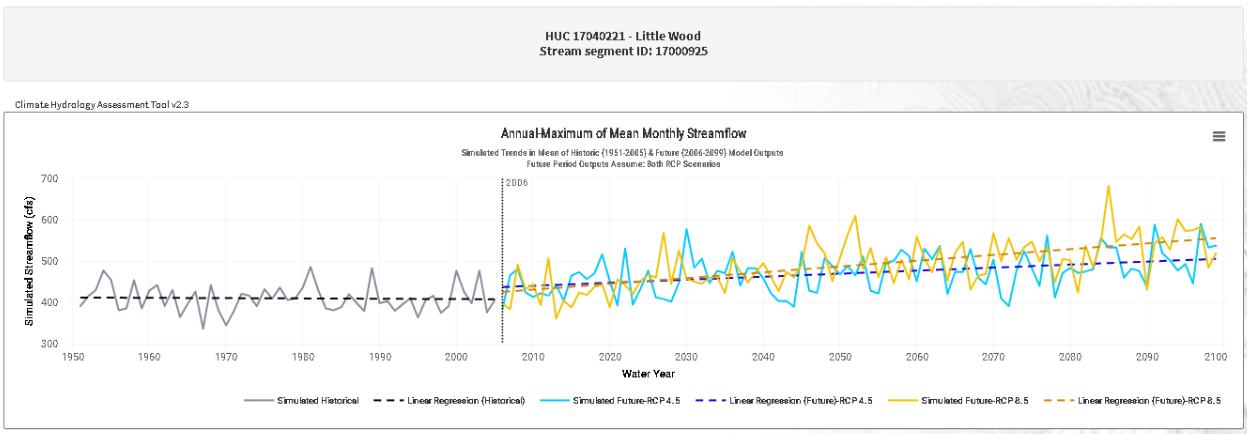


Figure 1-7. Projected Mean Annual Maximum Monthly Flows for the Upper Snake watershed (HUC 1704)

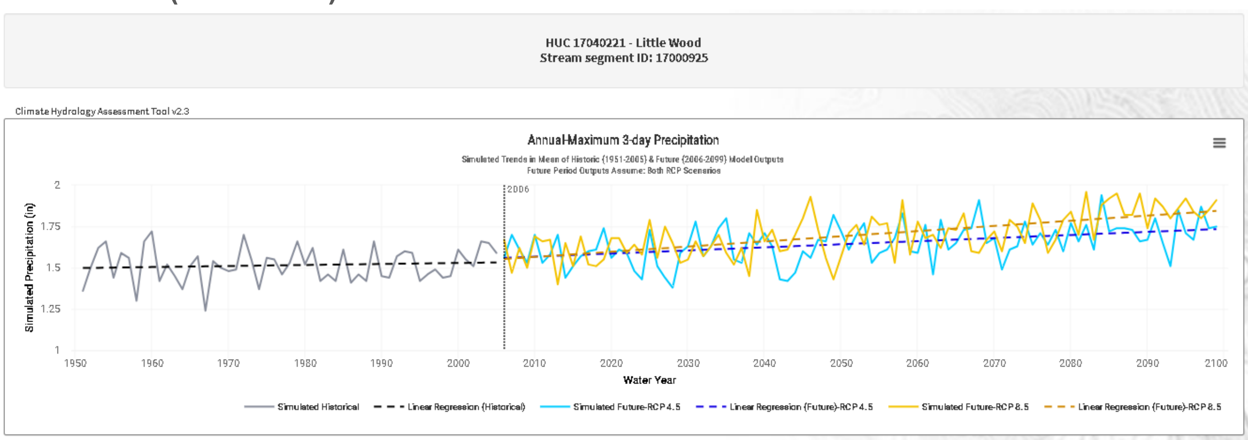


Figure 1-8. Projected Annual Maximum 3-Day Precipitation for the Upper Snake Watershed (HUC 1704)

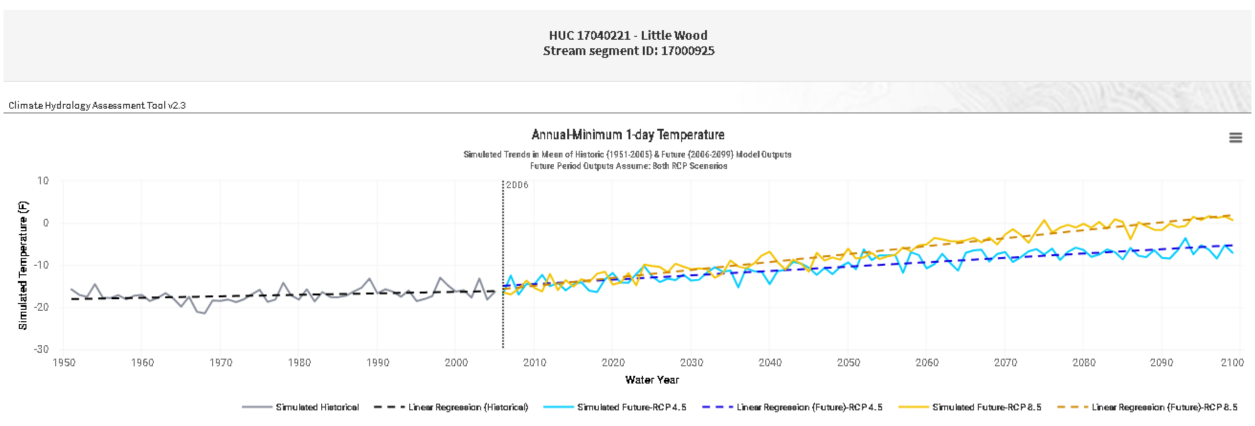


Figure 1-9. Projected Annual Minimum 1-Day Temperature for the Upper Snake Watershed (HUC 1704)

1.4 Vulnerability Assessment

The USACE Watershed Climate Vulnerability Assessment (VA) Tool facilitates a screening-level, comparative assessment of the vulnerability of a given business line and HUC-4 watershed to the impacts of climate change, relative to the other HUC-4 watersheds within the continental United States (CONUS). It uses the Coupled Model Intercomparison Project (CMIP5) GCM-BCSD-VIC dataset (2014) to define projected hydrometeorological inputs, combined with other data types, to define a series of indicator variables to define a vulnerability score.

Vulnerabilities are represented by a weighted-order, weighted-average (WOWA) score generated for two subsets of simulations (wet—top 50% of cumulative runoff projections; and dry—bottom 50% cumulative runoff projections). Data are available for three epochs. The epochs include the current time period ("Base") and two 30-year, future epochs (centered on 2050 and 2085). The Base epoch is not based on projections and so it is not split into different scenarios. For this application, the tool was applied using its default, National Standards Settings. In the context of the VA Tool, there is some uncertainty in all of the inputs to the vulnerability assessments. Some of this uncertainty is already accounted for in that the tool presents separate results for each of the scenario-epoch combinations rather than presenting a single aggregate result.

As shown in Figure 1-10, the Upper Snake (HUC 1704) watershed is not considered vulnerable to climate change impacts for the flood risk reduction business line, as compared to the other watersheds in the CONUS (202 HUC04s). This is true for both the wet and dry scenarios and both the 2050 and 2085 epochs. Indicators used to compute the Flood Risk Reduction WOWA score include: the acres of urban area within the 500-year floodplain, the coefficient of variation in cumulative annual flow, runoff elasticity (ratio of streamflow runoff change to precipitation change), and two indicators of flood magnification (indicator of how much high flows are projected to change over time), one of which includes contributions from upstream watersheds and the other focused only on the change in flood frequency within the watershed of interest. For the wet and dry scenarios, the dominant indicator for the Upper Snake's vulnerability score is Flood Magnification. The dominant indicator contributes 51%–54% of the score between the two scenarios.

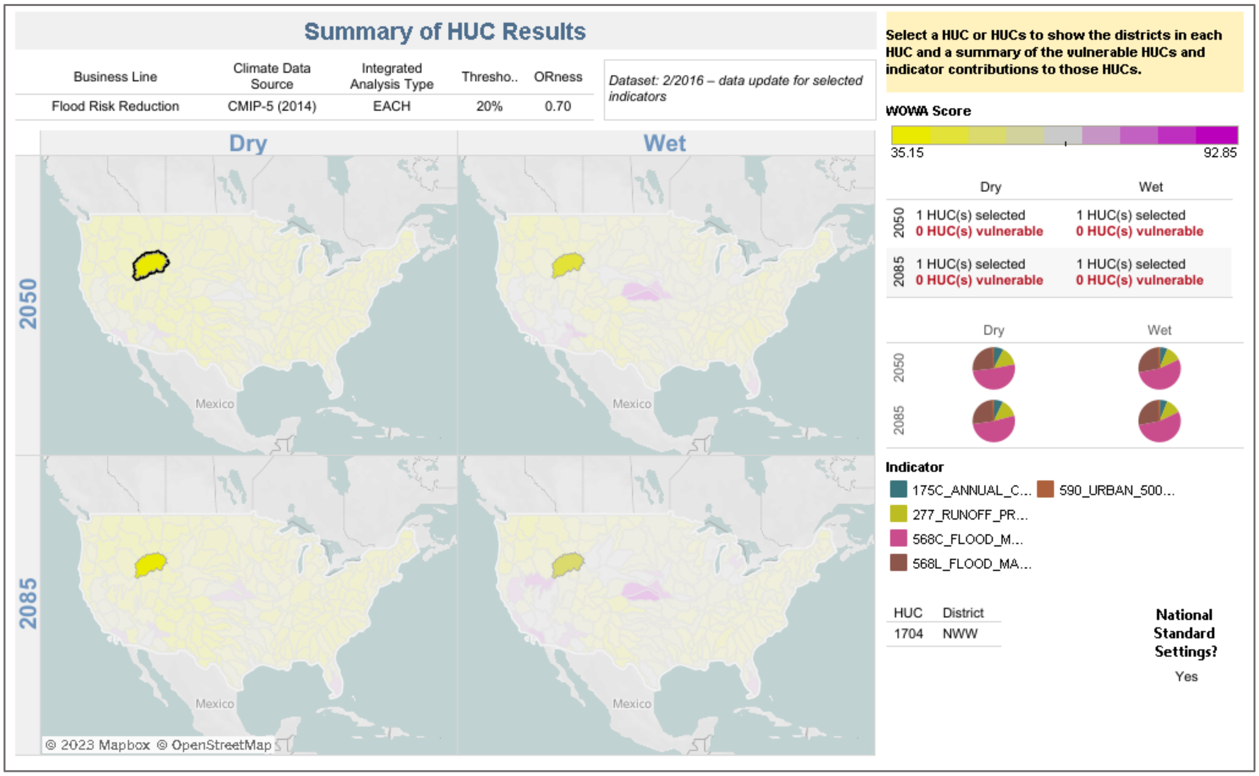


Figure 1-10. Output of the VA Tool

Note: The output indicates that the Upper Snake Watershed is not among the 20% most vulnerable CONUS watersheds for the Flood Risk Reduction business line.

1.5 Conclusion

The Gooding Canal was constructed in the 1930s and was completed in 1941. The canal is used for irrigation and water flows into and out of the river at many locations along its 1-mile length. The highest flows usually occur during the non-irrigation season, when natural flows are high and little water is diverted for irrigation. During low flow periods in the winter, the river may freeze solid. Winter high water events are primarily caused by rain on snow, or other melt events, which may further be complicated by ice jams in the canal. If there are more frequent extreme events in the future, the need for canal improvements and bridge crossings replacements will be accelerated. The TSP selected for this project is a coordination of the replacement and repair of the existing channel walls.

In the literature reviewed, a warmer and wetter climate is expected in the future. However, the literature did not contain consistency on how the hydrology within the project area will change. Analysis of projected annual maximum mean monthly streamflow, maximum 3-day precipitation, and minimum 1-day temperatures show statistically significant positive trends that is consistent with some of the literature reviewed. The USACE VA Tool indicates that Flood Risk Reduction in Upper Snake (HUC 1704) is not vulnerable to the impacts of climate change relative to other watersheds in the CONUS.

Observed annual peak streamflow data from the gage nearest the project location was reviewed to evaluate the potential for increased annual peak flows for the project area. The analysis showed a statistically significant negative trend in the annual peak data; however, the gage is significantly affected by upstream regulation and irrigation and trends in the data may not be directly attributed to changes in climate. A gage upstream in the basin that is significantly less affected by irrigation and has no upstream regulation was used as a surrogate to evaluate trends in peak streamflow. Observed annual peak streamflow data from 1980 to 2022 was reviewed to support qualitative statements characterizing the potential impacts of climate change on the project. Neither the trend nor nonstationarity analysis indicate that the peak flow regime is changing. Table 1-2 indicates potential residual risks for this project due to climate change along with a qualitative rating of how likely those residual risks are to occur.

Table 1-2. Residual Risk Due to Climate Change to the Gooding Canal

Phase III: Residual Risks					
Project Feature	**Trigger**	**Hazard**	**Harm**	**Qualitative Likelihood Rating**	**Justification for Rating**
Canal Improvements	Projected increases in peak streamflow	Future flow may be larger and more frequent than present	Flood waters may induce more frequent localized flooding	Low	Observed and projected trends in peak streamflow are likely to increase but there is no consensus among projections.
	Projected decreases in minimum temperature	Temperatures may be lower than present and more frequent ice jams may occur	Ice jams may result in localized flooding	Low-medium	Increasing minimum temperatures could shift ice jams to earlier in the year, increase-ice jam flooding due to snowmelt-dominated basins becoming more rain-snow mixed with increasing temperatures, or decrease the formation of large enough sections of ice to create ice jam flooding.

Due to the current state of the Gooding Canal's deteriorating infrastructure, it is predicted that the channel will continue to see annual localized flooding as shown by future trends analyzed in this document. The TSP selected for this project will help mitigate the impacts of any future potential climate change effects by providing increased and consistent conveyance of the Gooding Canal for the foreseeable future.

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