RAYMONDVILLE DRAIN PROJECT
ENGINEERING APPENDIX A1

ATTACHMENT G

RESILIENCE ASSESSMENT

Resilience Assessment
Raymondville Drain Feasibility Study

This assessment was conducted in November 2024 in response to ATR review comments, to highlight existing and future vulnerability of the study area due to changing conditions. This document was prepared generally in accordance with guidance valid at the time of analysis - United States Army Corps of Engineers' (USACE) Engineering Construction Bulletin (ECB) 2018-14, *Guidance For Incorporating Impacts To Inland Hydrology In Civil Works Studies, Designs, and Projects*, revised 19 August 2022. In accordance with the ECB, this evaluation identifies potential vulnerabilities for the Raymondville Drain Feasibility Study. Raymondville Drain is located in the Lower Rio Grande Valley of South Texas. This assessment highlights existing and future risks for the study area. Study background information can be found in the main Feasibility Report.

Study Background

This Raymondville Drain (RD) Integrated Feasibility Report and Environmental Assessment (EA) presents the formulation, evaluation, and recommendation for the modification and extension of the existing RD in a project corridor that traverses Hidalgo and Willacy Counties located in the Lower Rio Grande Valley (LRGV) of South Texas. The proposed project would enable the transfer of a portion of flood flows from the North Main Drain (NMD) basin (south of the RD basin) to a new diversion drain connecting to the existing RD, and improves the existing RD through to its terminus near the Laguna Madre.

The Recommended Plan generally consists of approximately 13.8 miles of new diversion drain in Hidalgo County, approximately 43 miles of drain improvements in Hidalgo and Willacy Counties, an approximately 270-acre detention basin near the South Texas International Airport in Edinburg, and five control structures (three located at the junction of the RD with other existing drains, one at the detention basin, and one at the Hidalgo-Willacy County line). The proposed project promotes community resilience and economic growth by increasing flood flow capacity, thereby reducing flood risks and damages, limiting the potential for the loss of life, and reducing public health risks within the designated study area.

Future conditions may impact the frequency and intensity of flooding in the region. This is a single purpose Flood Risk Reduction project, which is the focus of this analysis. The key analyzed variable relevant to the study is peak streamflow, representing the high flow regime. The study analyzed the 1% 10-day flow, which was considered to provide more runoff than a 24-hour or 4-day storm. Variables like temperature and precipitation may also impact streamflow response and are thus also relevant to the study.

Literature Review

A number of documents were reviewed for this analysis. Documents include: The *Fourth National Climate Assessment* (NCA4); USACE *Civil Works Technical Report CWTS-2015-11, Water Resources Region 13, Rio Grande Region* (https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/6749/rec/29); the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, *State Climate Summary 2022, Texas* (https://statesummaries.ncics.org/chapter/tx/) ; and the Office of the Texas State Climatologist's *Assessment of Historic and Future trends of Extreme Weather in Texas, 1900-2036* (https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update).

The NCA4 considers research at both a national and regional scale (USGCRP 2018). *Civil Works Technical Report CWTS-2015-11* was published by USACE in 2015 as part of a series of regional summary reports covering peer-reviewed applicable 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). RD is located in 2-digit HUC 13, the Rio Grande Region, in the NCA4 Southern Great Plains region.

These references summarize trends in historic and observed temperature, precipitation, and streamflow records, as well as provide an indication of future hydrometeorology based on the outputs from Global Models (GCMs). In this assessment, background on observed and projected temperature and precipitation is provided as context for the impact they have on observed and projected streamflow.

Temperature, precipitation, and streamflow measurements have been taken since the late 1800s and provide insight into how the patterns have changed over the past century. GCMs are used in combination with different representative concentration pathways (CPs) reflecting projected radiative forcings up to the year 2100. Radiative forcings encompass the change in net radiative flux due to external drivers of changing conditions, such as changes in carbon dioxide or land use/land cover. GCMs are used to approximate future temperature and precipitation. Projected temperature and precipitation time series can be transformed to regional and local scales (a process called downscaling). Downscaled time series can then be applied as inputs to macro-scale hydrologic models (Graham, Andreasson, and Carlsson, 2007).

Uncertainty is inherent to environmental modeling due to the coarse spatial scale of the GCMs and the many inputs and assumptions required to create changed 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). It is best practice to use multiple GCMs when studying global change impacts to understand how various model assumptions impact results (Gleckler et al. 2008).

Temperature

Temperatures in Texas have risen almost 1.5˚F since the beginning of the 20th century. While there is no overall trend in extremely hot days, the number of very warm nights was particularly high during the 2010s. The urban heat island effect increased these occurrences in city centers, although much of the study area is rural, so the impact within the study area is reduced. The summer of 2011 was the warmest summer on record (since 1895) and broke the state record for highest average number of days with temperatures of 100°F or more. The Dallas-Fort Worth area endured 40 consecutive days with temperatures higher than 100˚F, which was the second-longest streak on record (1899–2020). The record dry conditions contributed to the higher temperatures. Daily minimum temperatures in January typically range from about 20°F in the northern Panhandle to about 50°F near the mouth of the Rio Grande River. The annual number of entire days below freezing was well above average in the 1970s and 1980s but has since been near the long-term average (NOAA National Centers for Environmental Information, *State Climate Summary 2022, Texas*).

Precipitation

An analysis of possible impacts of global changes on hydrology was made in accordance with ECB 2018-14, consistent with a Feasibility-level analysis. This analysis is documented below, and in the Feasibility Report and Appendix A1.

NOAA/NWS updated precipitation frequency estimates for the region (NOAA Atlas 14, Volume 11, Version 2.0, Texas) in 2018. (https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume11.pdf) The updated Atlas 14 data provides a recent comprehensive analysis of precipitation patterns over the past 60+ years in the study area. In addition, Atlas 14 explicitly considers the potential effects of historical changes as trends in historic annual maximum series are examined. This analysis is more comprehensive than any qualitative or quantitative analysis that would be done in a feasibility level investigation.

Atlas 14 Volume 11 represents the authoritative analysis of precipitation pattern changes in Texas. While significant changes in precipitation estimates have been determined in the Houston area, as documented in the Engineering Appendix (A1), the Atlas 14 update does not significantly increase precipitation expected in the study area from previous data sources (HMR 50/51). While there is uncertainty as to future precipitation trends due to future changes, the minor changes in the updated Atlas 14 data for the study area provides an indication that additional attempts to quantify or describe this uncertainty would add little value. The team considered conducting sensitivity analyses to capture possible variability in rainfall depths/storms over the next 50 years but ultimately did not quantify such changes as the additional effort was judged to not improve the plan selection or analysis process.

The Atlas 14 volume 11 analysis by NWS explicitly confirmed the assumption of stationarity in the study area. Figure 1 indicates that in the LRGV in the vicinity of the study area, analysis of rainfall patterns showed no trend change. The stationarity assumption was tested by applying a parametric t-test and non-parametric Mann-Kendal test for trends in means and the Levene's test for trends in variance in the 1-day and 1-hour Annual maximum Series (AMS) data at 5% significance level. For the 1-day duration, testing was done on stations with at least 70 years of data; for the 1-hour duration, the minimum number of data years was lowered to 40 to increase the sample size. 164 and 325 stations satisfied the record length criterion for the 1-hour duration and 1-day duration, respectively. For 1-hour, the t-test and Mann-Kendall test indicated no statistically significant trends in the mean at about 90% and 87% of stations, respectively. In the 1-day dataset, the t-test and Mann-Kendall test results, no trends were detected at about 90% and 88% of stations, respectively. Levene's test indicated non-homogeneous variance in less than 5% of stations for both the 1-hour duration and 1-day durations. Small clusters of stations where tests indicate positive trends are often due to AMS data sampled from the same storm events at several nearby locations. Results from the regional trend analysis also indicated that the null hypothesis, that there are no trends in AMS, could not be rejected at the 5% significance level for either region for the 1-hour and 1-day durations. Because tests at both the 1-hour and 1-day durations indicated no statistically significant trends in the data, the assumption of stationary AMS was accepted for this project area and no adjustment to AMS data was recommended (*NOAA Atlas 14 Volume 11, Appendix A2*).

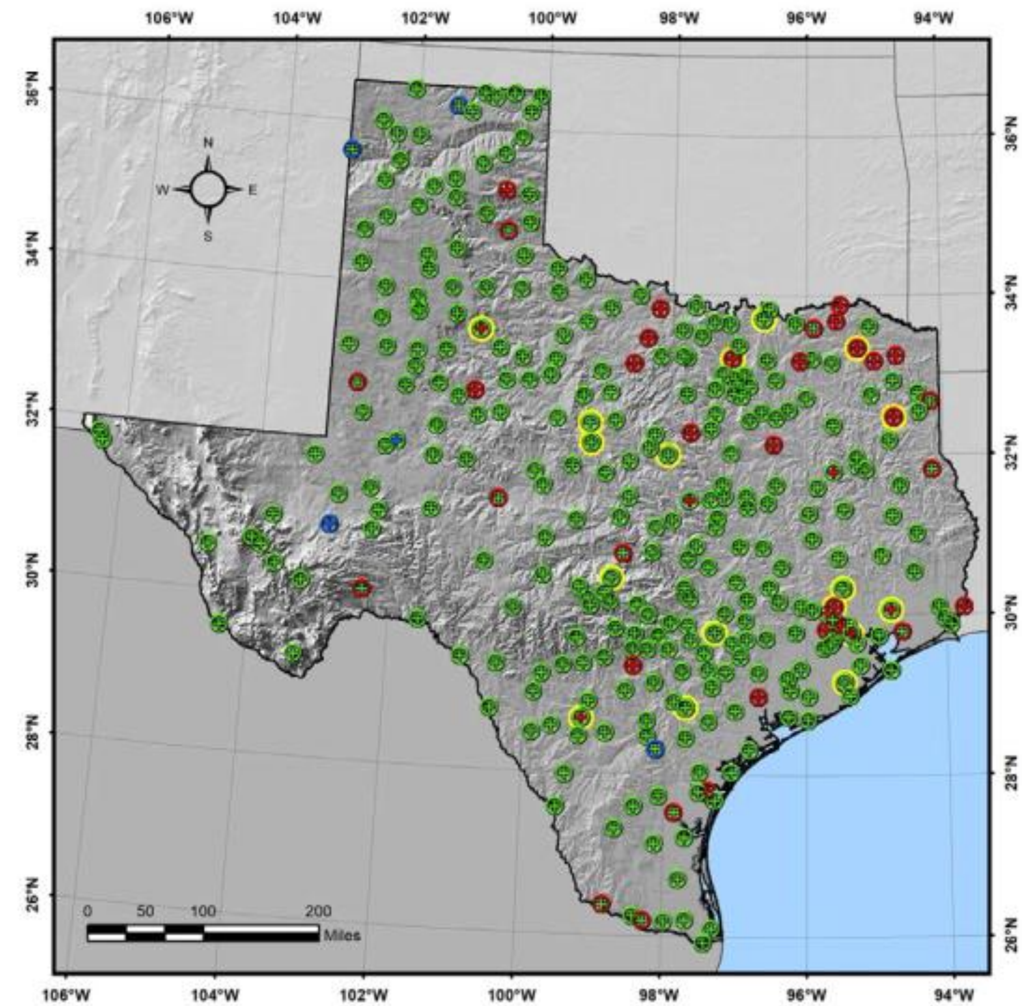

Figure 1 - Spatial distribution of results of t-, Mann-Kendall, and Levene's tests for 1-day AMS. Circles (except yellow) were used to present t-test results and plus signs were used to present Mann-Kendal test results. Red color indicates positive trends, green no trend, and blue negative trends. Yellow circles show locations where Levene's test detected changes in variance. (Source: Atlas 14 Volume 11)

This conclusion of no significant changes in rainfall is confirmed through Downscaled CMIP3 and CMIP5 Hydrology Projections (http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/). Figures 2 and 3 indicate projected changes in future precipitation. These CMIP 5 data projections confirm no change, or slight reductions, in mean annual precipitation for the LRGV study area.

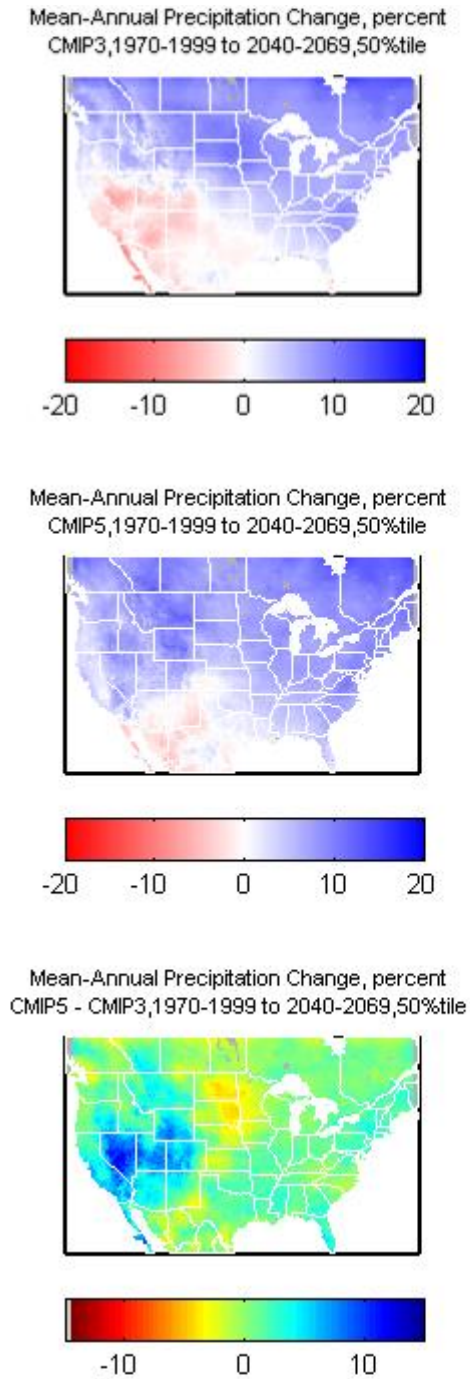

Figure 2- BCCA CMIP3 Daily Analysis example - Calendar-day, ensemble-mean change in 20-year diurnal temperature range for three percentiles of diurnal range: 10th, 50th and 90th for the period pairs shown.

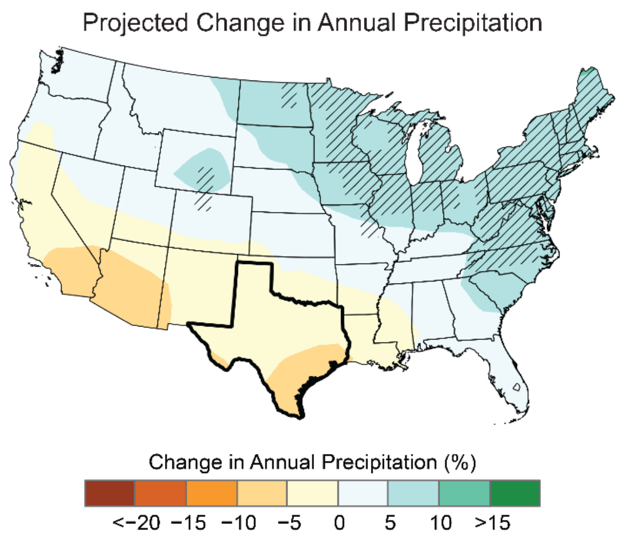

Figure 3 - Projected changes in total annual precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of models indicate a statistically significant change. Texas is part of a large area in the southwestern and central United States with projected decreases in annual precipitation, but most models do not indicate that these changes are statistically significant. Sources: CISESS and NEMAC. Data: CMIP5.

This analysis indicated that no significant changes in precipitation patterns are expected due to global changes. This analysis did not impact the study or proposed project recommendations.

Streamflow

Streamflow trends are strongly influenced by a mix of factors, including drought, precipitation patterns , temperature, and other factors such as land use and land cover in a region, groundwater dynamics, drainage patterns, channel geomorphology, and regulation. No long-term river flooding trend in the study region has been identified in the observations, nor is such a trend projected at this point, except perhaps for the most extreme floods and areas with normally high rainfall. Urban flooding is projected to increase, both as a simple matter of urban population increase and because of the projected increase of precipitation intensity, which drives flooding in fast-response drainages like those usually found in urban areas. (*Assessment of Historic and Future trends of Extreme Weather in Texas, 1900-2036, https://climatexas.tamu.edu/files/ClimateReport-1900to2036-2021Update*).

The majority of the study area is outside of heavily urbanized areas, and is therefore not at the same level of risk from urbanization. Population growth and associated increased development has been considered in the computations of future flows for this proposed project, and is documented in Appendix A1.

Sea Level Change

The USACE Sea level Analysis Tool (SLAT) was used to assess vulnerability of the RD to sea level change (https://climate.sec.usace.army.mil/slat/). Although the proposed project is not designed to reduce coastal flood damage, the RD ultimately discharges into the tidally impacted Laguna Madre. The Port Mansfield TX NOAA tide gage (8778490) was used as the reference gage closest to the RD discharge (Figure 4).

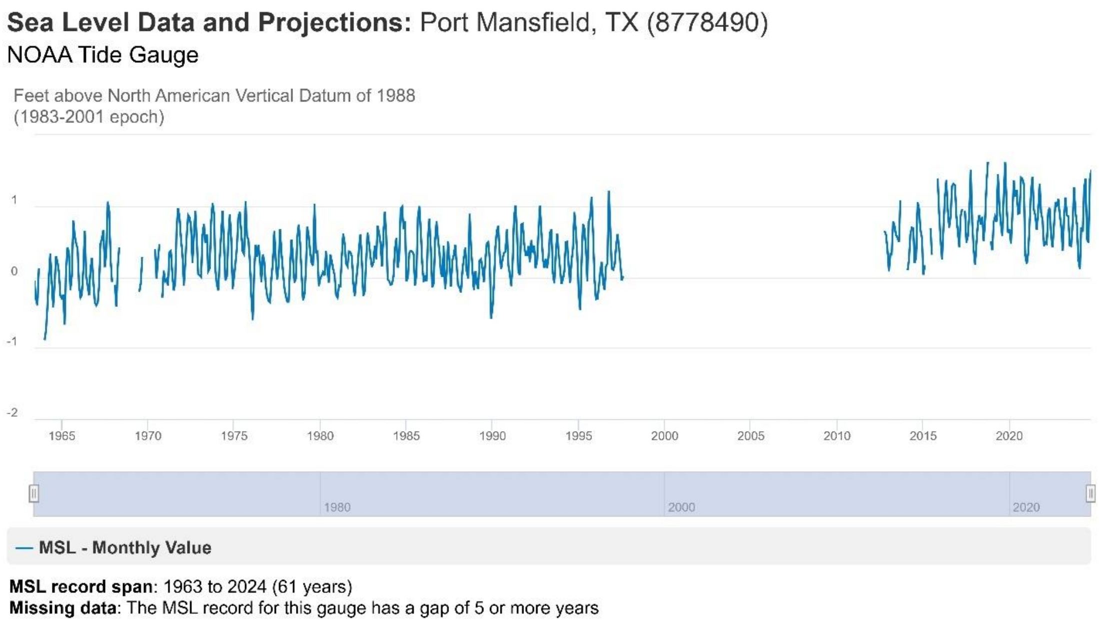

Figure 4 – Port Mansfield NOAA Tide gage data

The tidal characteristics of the Gulf of Mexico are varied and not typical of much of the US Coastal zone. The Laguna Madre is the largest of the Texas estuaries, extending in an arc 130 miles long and three-to five-miles wide from Corpus Christi southwest to the Rio Grande. The lagoon has shallow depths less than 10 feet, with most depths one-foot to five feet deep, and has several entrances into from the Gulf of Mexico. Any tidal characteristics of the Laguna Madre are the culmination of the tidal characteristics at the entrances from the Gulf tide as it progresses through the constriction of the entrances, by the effects of the inner bays, and the shallow waters and configuration of the Laguna Madre itself. (NOAA Technical memorandum NOS OES 008, *Tidal Characteristics and Datums of Laguna Madre Texas,* July 1995). These factors limit tidal influence from the Gulf of Mexico.

Figure 5 indicates the sea level projections for the three scenarios: USACE low, medium and high projections, and Table 1 provides a tabulation of the results. From the study base year (2034) under the medium scenario for the 50-year period of economic analysis (2084), an additional sea level rise of approximately 1.1 feet is projected. In 100 years, (2034), additional sea level rise under the medium scenario is estimated at approximately 2.8 feet.

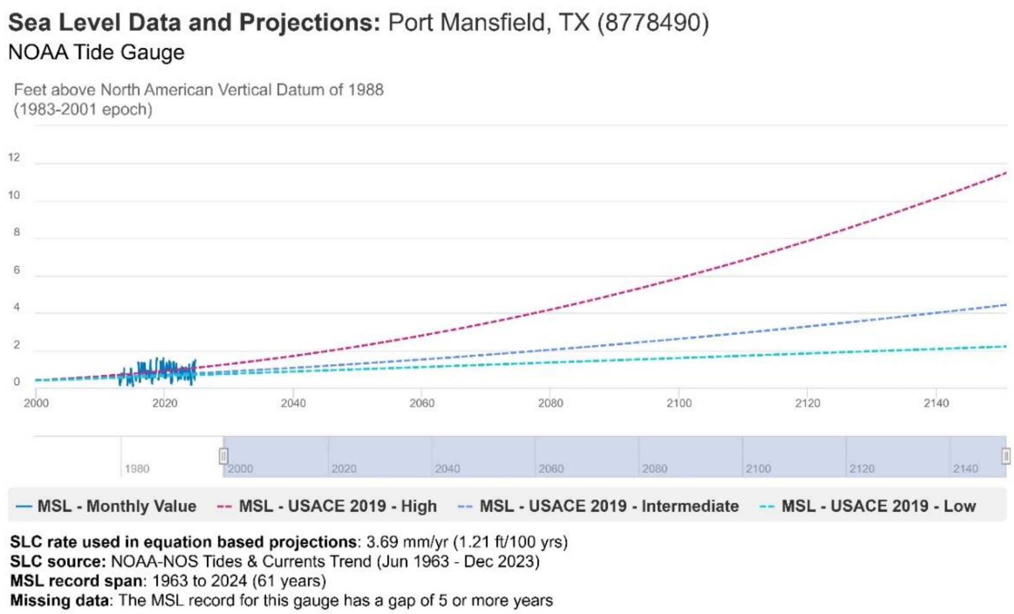

Figure 5 - Sea level trends and projection graph, Port Mansfield, TX

Year	High	Intermediate	Low
1992	0.28	0.28	0.28
2020	0.91	0.69	0.62
2030	1.28	0.87	0.74
2040	1.72	1.07	0.86
2050	2.23	1.28	0.98
2060	2.82	1.51	1.1
2070	3.48	1.77	1.22
2080	4.22	2.03	1.35
2090	5.03	2.32	1.47
2100	5.91	2.62	1.59
2110	6.87	2.95	1.71
2120	7.9	3.29	1.83
2130	9.01	3.64	1.95
2140	10.19	4.02	2.07
2150	11.45	4.41	2.19

Table 1 - Sea level trends and projection tabulation, Port Mansfield, TX

The terminus of the proposed project is located approximately 2 miles upstream of the RD crossing of State Highway 186, and approximately eight stream miles upstream of where the existing RD discharges into the back bays and wetlands of the Laguna Madre. The surrounding ground elevation around the project terminus is approximately 12-feet. Due to this buffer distance and elevation change from the Laguna Madre, the proposed project expansion is not tidally impacted, and sea level rise is not expected to impact the proposed project.

Nonstationarity Detection and Trend Analysis

The assumption that hydrologic datasets are stationary (their statistical characteristics are unchanging) in time underlies many types of hydrologic analysis. Statistical tests can be used to test this assumption using the techniques outlined in Engineering Technical Letter (ETL) 1100-2-3 *Guidance for Detection of Nonstationarities* (2017). The USACE Time Series Toolbox (TST) is a web-based tool that enables the user to perform the statistical tests outlined in ETL 1100-2-3. Both user uploaded time series data, as well as preloaded USGS annual peak discharge and stage datasets can be tested for nonstationarities and monotonic trends using the TST (USACE 2020c).

As discussed in the **Precipitation** section above, Atlas 14 volume 11 provides an authoritative analysis that indicated stationarity and no significant anomalous weather trends in the study area. Additional analysis would not improve the quality of the analysis, not change the study conclusions, however additional investigation has been accomplished in accordance with ECB 2018-14. Annual instantaneous peak streamflow can be used to evaluate observed trends in flood operations in the RD and is thus the primary focus of this assessment.

For the purpose of Formulation of a USACE Civil Works Project, actual authoritative NOAA/NWS data was used, instead of uncertain projections. This data provides a solid and defensible basis for project formulation in accordance with applicable laws, regulations, and procedures. Since the NOAA/NWS data indicated stationary data, as confirmed by the analyses above, it would not be possible to utilize any projections in the proposed project. As the proposed project primarily consists of excavated channels in stable soils, should additional capacity (adaptive management) be necessary in the future due to physical changes within the basin, or weather pattern changes, modifications to the channels could be made.

The operations process for this below-grade gravity flow drainage channel project is relatively straightforward. The three man-made offline water storage reservoirs in the RD basin (Edinburg Lake, Delta Lake, and Hargill Reservoir), and the salt lake in the LRGV National Wildlife Refuge (La Sal Vieja), are not operated as part of the system for flood damage reduction. The O&M manual for the proposed project would establish operational rules and procedures for the completed project based on flow rate triggers in the NMD basin, storage levels in the proposed detention basin, and operational rules for the drainage system. Flood flow diversion from the NMD to the RD would only occur when NMD flows approach damaging levels, and the project would be operated to avoid induced flooding downstream in Willacy County. There would be a total of five relatively simple control structures as part of the proposed project. The upstream control structure would be located at the start of the proposed bypass channel where it intersects with the existing NMD, to enable excess floodwaters to be released into the RD. The second control structure would be located at the intersection of the proposed bypass channel with the upstream end of the existing Delta Lake Drain, to enable diversion of water toward Delta Lake for irrigation storage. The third control structure would be located at the downstream end of the proposed detention basin to enable controlled outflow of water stored during storm events, and would be managed to minimize the length of time water is stored to discourage use of the proposed detention basin by waterfowl. The fourth control structure would be located at the Hidalgo-Willacy County line, to ensure flows during construction do not exceed the capacity of the RD in Willacy County prior to completion of the channel expansion. And the final control structure would replace an existing control structure at the intersection of the existing

RD with the La Sal Vieja drain channel, to enable diversion of fresh water into the salt lake if requested by the USFWS. During normal (non-flooding) flow conditions, a portion of the gates at each structure would remain open. In preparation for significant predicted weather events, the non-federal sponsor would manually open additional gates or close selected gates on a structure-by-structure basis in accordance with the operating rules in the O&M Manual, then make changes as needed during and after the storm until water levels return to normal.

The USACE Timeseries Toolbox (TST) is generally used to evaluate monotonic trends and nonstationarities in hydrologic timeseries (e.g., streamflow, precipitation, temperature) variables relevant to study purpose. Timeseries analyzed should be based on continuous observations and contain a minimum number of 30 years of record.

Unfortunately, it was not possible to run TST analyses for the study area. The proposed project is located in the LRGV of South Texas. There is no USGS gage data near or within the RD basin (https://dashboard.waterdata.usgs.gov/app/nwd/en/). There was also no preloaded TST data was for the study area, South Texas, nor the LRGV (https://climate.sec.usace.army.mil/tst_app/ - accessed November 2024). There are no hydrologically similar gages in the region found in the database. There are several USGS monitoring stations near Brownsville Texas, but they are located on a resaca, a ditch, and multiple local drains; however, these gages are not located within or adjacent to the study area, and do not represent a similar hydrological condition as the RD. The nearest other station is Los Olmos Creek near Falfurrias TX (USGS 08212400), and this is a local dry stream located approximately 50-miles northwest of the study area, and is not hydrologically similar.

Changing Hydrology Assessment Tool (CHAT)

The USACE Changing Hydrology Assessment Tool (CHAT) displays various simulated, historic and future, changed streamflow, temperature, and precipitation outputs derived from 32 GCMs (USACE 2020a). (https://climate.sec.usace.army.mil/chat/) The CHAT uses Coupled Model Intercomparison Project Phase 5 (CMIP5) GCM meteorological data outputs that have been statistically downscaled using the Localized Constructed Analogs (LOCA) method. GCMs rely on scenarios representing different pathways to a given atmospheric concentration of emissions referred to as representative concentration pathways (RCPs). RCPs describe the change in radiative forcing at the end of this century, as compared with pre-industrial conditions. Projected hydroclimate time series in the CHAT for 2006 to 2099 are produced using two future scenarios: RCP 4.5 (where gas emissions stabilize by the end of the century) and RCP 8.5 (where gas emissions continue to increase throughout the century). Simulated output representing the historic period of 1951 to 2005 is generated using a reconstitution of historic emissions.

To analyze runoff, LOCA-downscaled GCM outputs are used to force an unregulated, Variable Infiltration Capacity (VIC) hydrologic model. Areal runoff from VIC is then routed through a stream network using mizuRoute. The VIC model outputs represent the daily in-channel routed runoff (i.e., streamflow) for each stream segment – valid at the stream segment endpoint. Since the runoff is routed, the streamflow value associated with each stream segment is a representation of the cumulative flow including all upstream runoff, as well as the local runoff contributions to that specific segment. Within the CHAT, output can be selected for the terminal stream segment (outlet) associated with a given 8-digit HUC watershed.

The annual-maximum of mean, monthly streamflow is analyzed for this assessment to confirm no change in streamflow conditions will change. Maximum 3-Day precipitation is analyzed for this assessment. A monthly epoch-based comparison of accumulated annual precipitation is analyzed for this assessment to provide additional certainty compared to the NWS analysis. The range of data is indicative of the uncertainty associated with projected changed streamflow and precipitation.

The CHAT tool was used to compute annual maximum mean monthly streamflow for HUC 130000132 (Lower Rio Grande). Figure 6 shows the range of streamflow output for the historic period (1951-2005) and future period (2006-2099) for the Lower Rio Grande watershed.

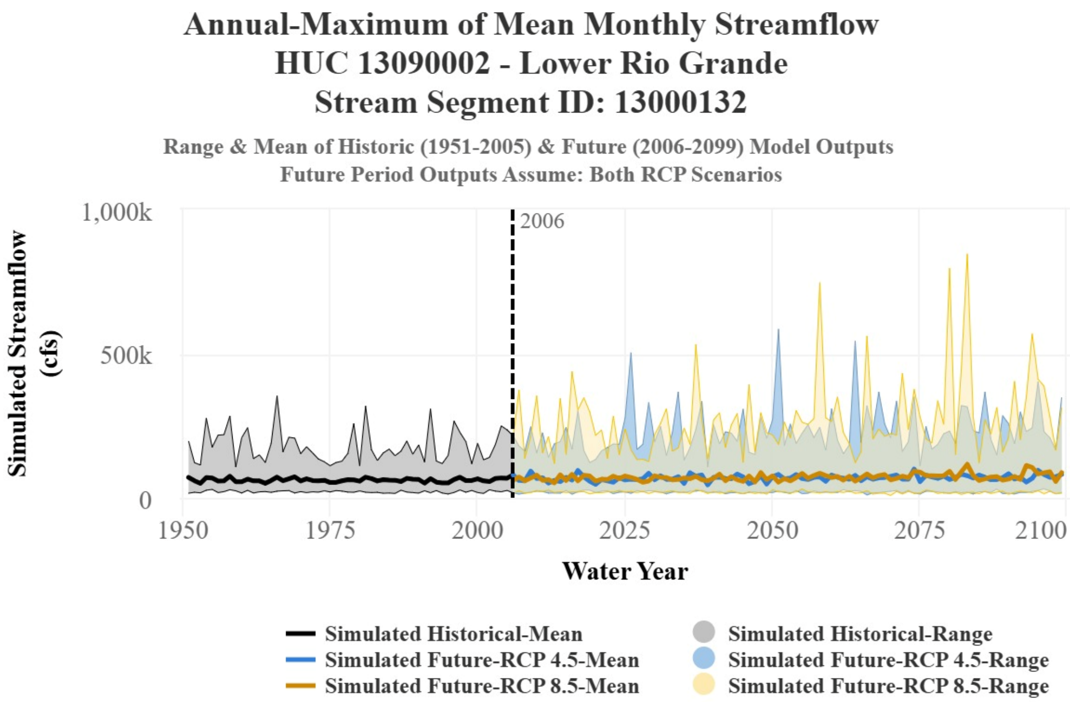

Figure 6 - Range of modeled, Annual Maximum of Mean Monthly Streamflow Output for HUC 13000132

The CHAT was also used to assess projected changes to annual maximum (by water year) 3-day total precipitation (rolling 3-day sum of daily accumulated precipitation) for HUC 13000132 (Lower Rio Grande). Figure 77 shows the range of precipitation output for the historic period (1951-2005) and future period (2006-2099) for the Lower Rio Grande watershed for the RCP 4.5 and 8.5 scenarios.

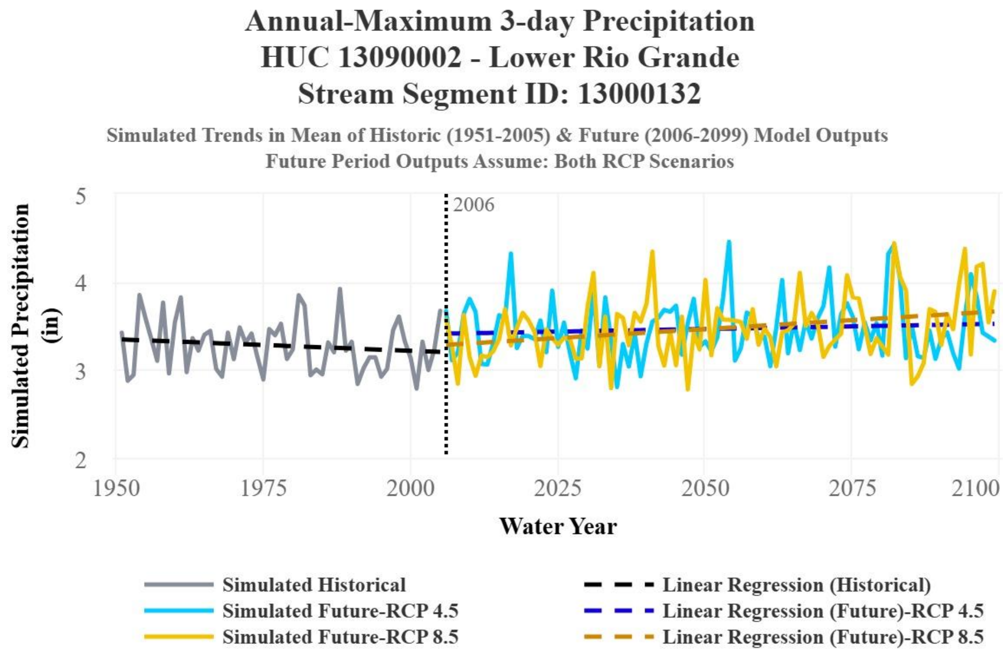

Figure 7 - Range of modeled Annual Maximum 3-day Precipitation Output for HUC 13000132

For the Lower Rio Grande (HUC 13000132) watershed, trends in projected, annual maximum monthly streamflow and annual maximum 3-day precipitation are evaluated using the t-Test, Mann-Kendall and Spearman Rank-Order tests. All three statistical tests are applied using a 0.05 level of significance (p-values<0.05 are considered statistically significant). The direction and magnitude of change in statistically significant trends is evaluated using the slope of the fitted linear regression.

Figures 8, 9, and 10 contain box plots of the change in monthly accumulated precipitation, monthly maximum temperature, and monthly mean streamflow (respectively); and Figure 11 shows Annual Mean 1-day temperature. Although the temperature plots indicate the potential for an increasing trend in the region, it is not subject to snowfall and associated runoff, so general precipitation patterns would be impacted less than in northern regions.

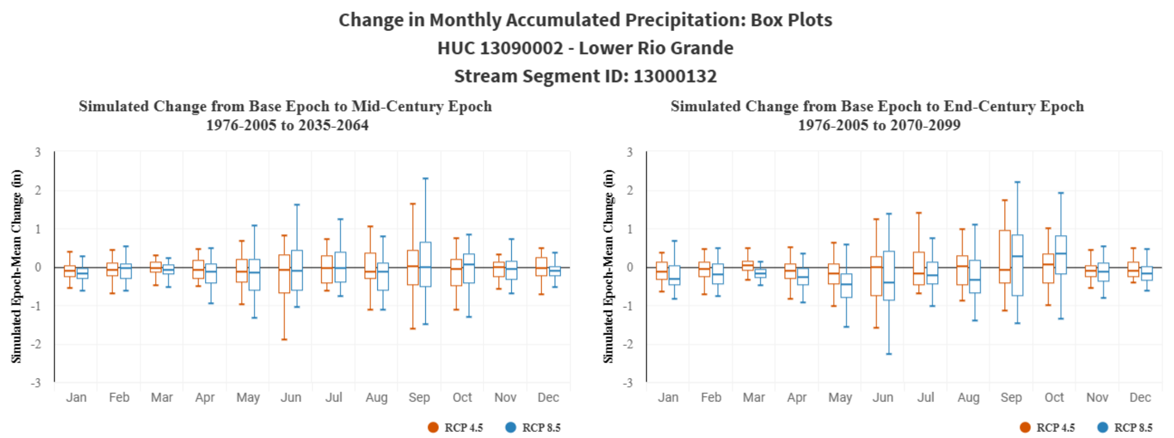

Figure 8 - Change in Epoch-Mean of Simulated Monthly Accumulated Precip Box Plots for Lower Rio Grande (HUC 1300132)

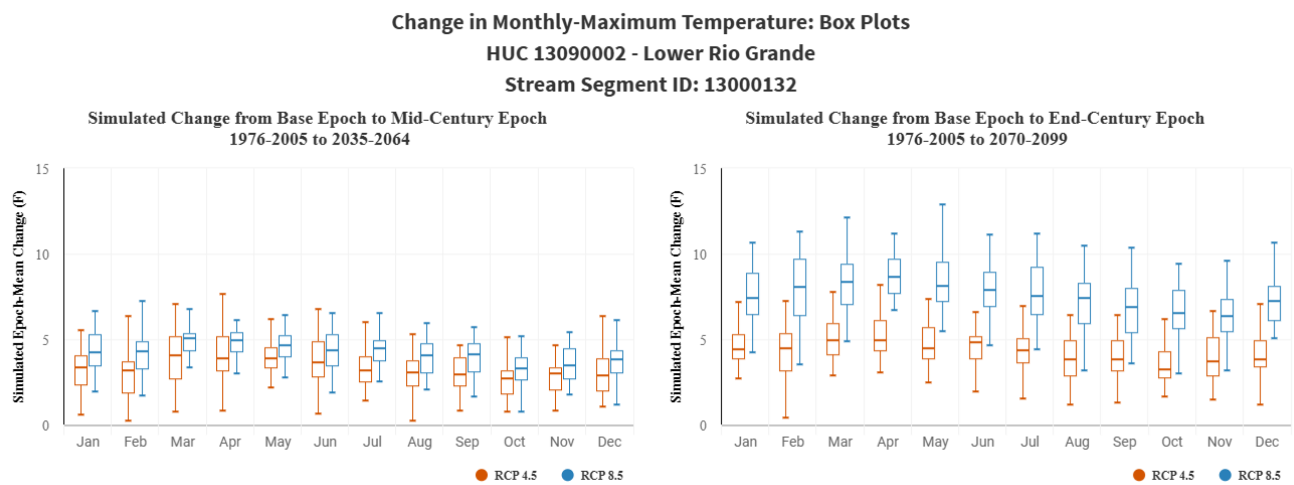

Figure 9 - Change in Epoch-Mean of Simulated Monthly Maximum Temperature Box Plots for Lower Rio Grande (HUC 1300132)

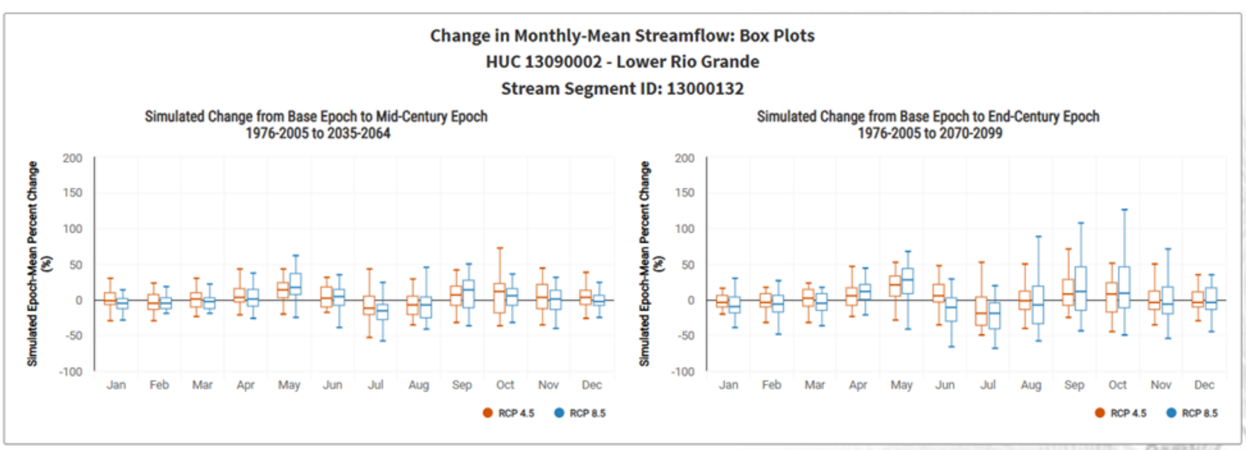

Figure 10 - Change in Epoch-Mean of Simulated Monthly Mean Streamflow Box Plots for Lower Rio Grande (HUC 1300132)

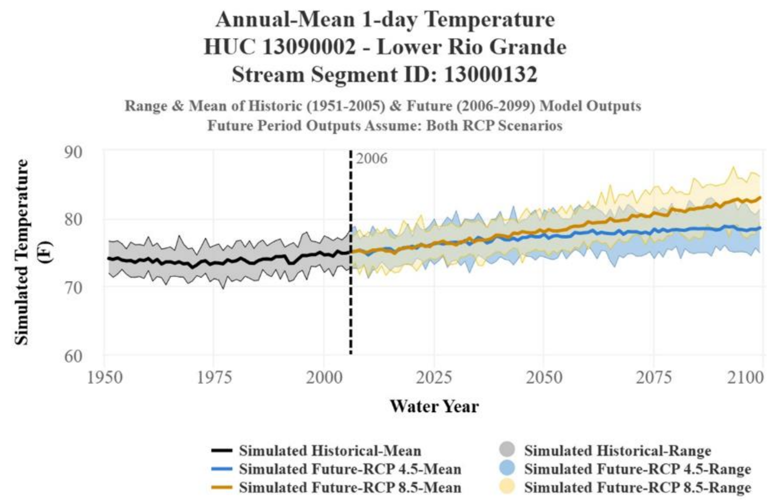

Figure 11 – Annual Mean 1-day temperature for Lower Rio Grande (HUC 1300192)

These plots and data support the report conclusions and recommendations. The CHAT analysis does not provide any actionable evidence that would change the computations, plan formulation process, benefits, or recommendations from this Feasibility study. The additional capacity provided by the expanded channel provides resilience against future changes and uncertainty inherent in an analysis of this type.

Vulnerability Assessment

The USACE Watershed Change Vulnerability Assessment (VA) Tool (https://dodclimate.sec.usace.army.mil/va) facilitates a screening-level, comparative assessment of the vulnerability for a selected USACE business line and 4-digit HUC watershed to the impacts of global changes, relative to the other 4-digit HUC watersheds within the continental United States (CONUS). It uses the Coupled Model Intercomparison Project (CMIP5) GCM-BCSD (Bias Corrected, Spatially Disaggregated) -VIC dataset (2014) to define projected hydrologic and meteorologic inputs, combined with other data types, to define a series of indicator variables to define a vulnerability score (USACE 2020b). Hidalgo and Willacy Counties are in the LRGV of South Texas. The approximately 2,500 square mile study area primarily consists of the majority of Hidalgo and Willacy Counties north of the Arroyo Colorado and Rio Grande watersheds. The study area lies adjacent to the Rio Grande and Gulf of Mexico, at the southern tip of the Texas Panhandle. Figure 12 graphically depicts the Lower Rio Grande (HUC 1309) watershed.

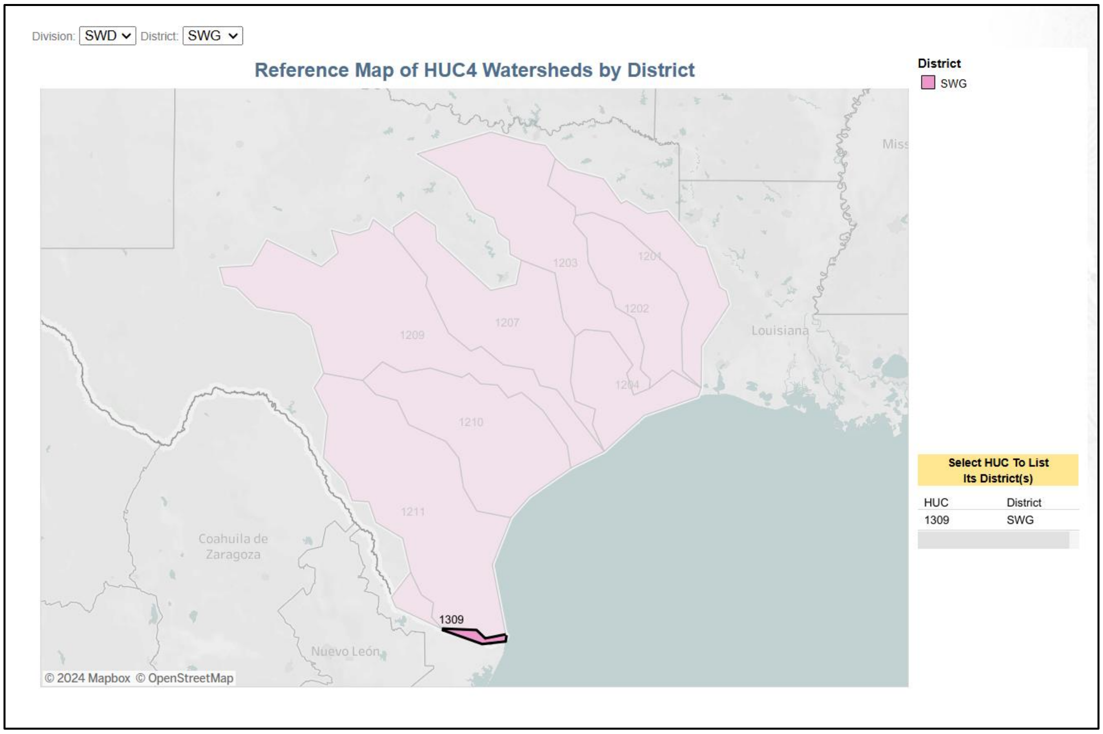

Figure 12 –HUC 1309

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 historic period ("Base" epoch) 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 reflected by the differences in results for each of the subset-epoch combinations.

As shown in Figure 13, the Lower Rio Grande (HUC 1309) watershed is considered relatively invulnerable to future change impacts for the flood risk reduction business line for four out of four epoch-subset combinations. A watershed is considered relatively vulnerable to impacts if it has a vulnerability score that falls within the top 20% of WOWA scores for a given business line in the CONUS (includes all 4-digit HUCs for flood risk management).

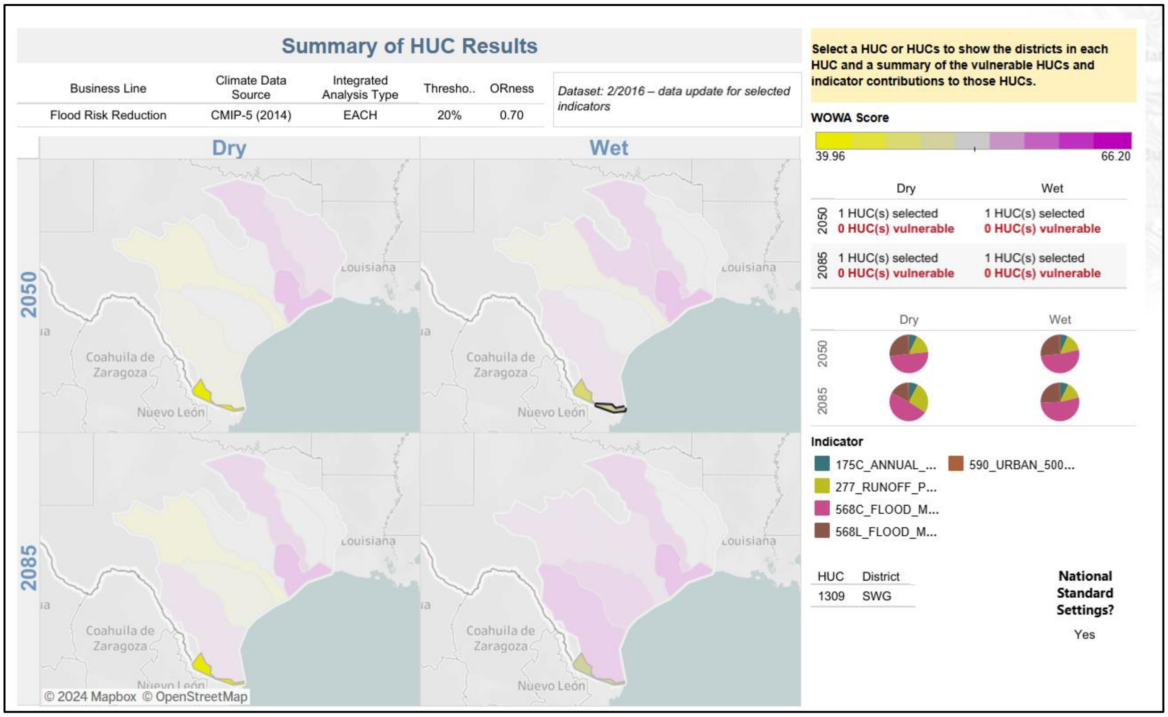

Figure 13 - VA Tool 4-Digit HUC Summary: Lower Rio Grande (HUC 1309)

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 precipitation elasticity ratio of streamflow runoff change to precipitation change (277)), 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 (cumulative, 568C) and the other focused only on the change in flood magnitude within the selected 4-digit HUC (local, 568L).

As can be seen in Figure 13 (above) and Table 2, for the Dry and Wet scenarios, the dominant indicator contributing is cumulative Flood Magnification (568C). The WOWA score changes by a WET and DRY subsets average of 4% between the 2050 and 2085 epochs. The percentage by which the indicator variable contributes to the VA score does not significantly change over time.

Subset	Epoch	VA Score (WOWA Score)	% Change in VA Score (2050 to 2085)
WET	2050	47.25	4.4%
	2085	49.33	
DRY	2050	39.96	3.6%
	2085	41.40	

Table 2 - VA Tool Output- HUC 1309 Lower Rio Grande Watershed - Flood Risk Reduction Business Line

Summary and Conclusion

An analysis of possible impacts of global changes on the project was made in accordance with USACE ECB 2018-14. The analyses conducted were appropriate for a USACE Feasibility Study. This analysis indicated that predicted changes are not expected to significantly increase flows, nor impact study recommendations.

The proposed project provides increased channel capacity throughout the study area to reduce flooding risk and reduce vulnerability, thereby increasing resilience to future changes and other future uncertainty. It consists of below grade drainage channels (expansion of existing channels, and additional new channels) in a very flat area, with slow-moving flows. The project presents no incremental life safety risk over current conditions. The stable unlined excavated drainage channels could be modified in the future if adaptive management (increased capacity) were necessary.

The NOAA/NWS update of the hydrology for the region, Atlas 14, concluded that there is no evidence of nonstationarity in the historical data. This was confirmed by this analysis.

There is little to no consensus related to trends in future streamflow, the primary driver for project design. As shown in Figure 14, the 2015 USACE Technical Report provides a visual summary of the trends in observed and projected hydrologic meteorologic variables, supporting the analyses used in the Feasibility Report. Table 3 summarizes potential RD risks by project feature.

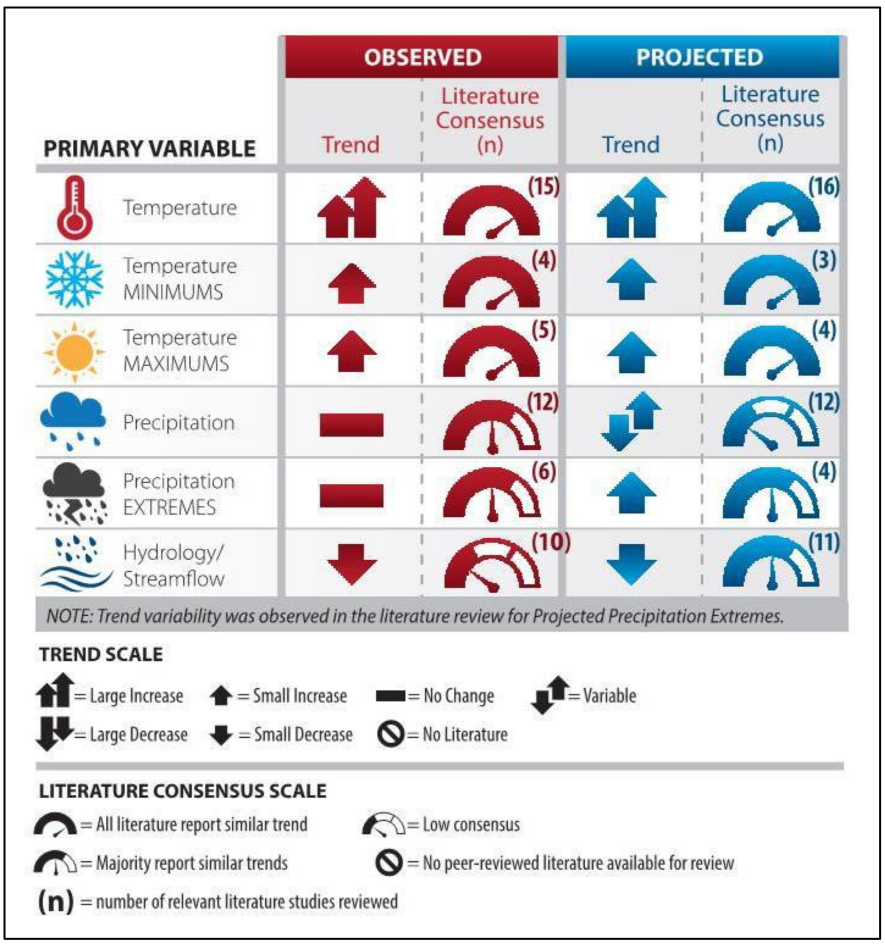

Figure 14 - Summary matrix of observed and projected trends in hydrology- 2-Digit HUC 13 – Rio Grande Region (USACE 2015)

Feature / Measure	Trigger	Hazard	Potential Harm	Qualitative Likelihood of Impacts on Project	Justification for Likelihood Rating
Proposed Channel Improvements	Increased precipitation from larger, slower moving storms.	Future flood volumes may be larger than existing. Large flood volumes may occur more frequently. Increased erosion could occur.	Flood waters may exceed the channel capacity and overflow the channel banks more frequently.	Unlikely	Upward precipitation and streamflow trends not identified. Detention basin near airport allows flexibility in release rates to control in-channel flows. Control structure at Hidalgo - Willacy County line allows more in-channel flow control and flexibility. Project is an expansion of existing historically stable channels, so erosion is unlikely. Stable below-grade earth channels could be expanded if needed.
Control Structure at upstream end of North Main Drain (NMD) flood bypass channel	Increased precipitation from larger, slower moving storms.	Future flood volumes may be larger than existing. Large flood volumes may occur more frequently.	Bypass flows could occur more frequently. Control structure could be overtopped, or gate capacity exceeded more frequently.	Unlikely	Upward precipitation and streamflow trends not identified. Control structure is adequately sized, and conveys only a portion of NMD flow. Control structure will be designed for overtopping stability. Downstream capacity in RD and detention basin provide flow control flexibility.
Stormwater detention basin	Increased precipitation from larger, slower moving storms.	Future flood volumes may be larger than existing. Large flood volumes may occur more frequently.	Detention pond could be used more frequently, or may need to be discharged slower.	Unlikely	Upward precipitation and streamflow trends not identified. Additional undeveloped land in the vicinity of the detention pond could be acquired in the future to expand storage capacity. Control structure at Hidalgo - Willacy County line allows more in-channel flow control and flexibility.

Table 3 – Assessment of Raymondville Drain risks by project feature

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