Climate Vulnerability Analysis – Changes to Surface Hydrology

Prepared for

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Prepared by

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Section 1.0 Introduction

This report discusses predicted changes to surface hydrology in Alachua County for future climate scenarios. These estimates were prepared as part of a climate vulnerability assessment for Alachua County developed by the Jones Edmunds Team. WSI was tasked with evaluating expected changes to surface hydrology based on future climate conditions and population estimates developed by other members of the project team. This report presents the data and methods used to develop these estimates and is intended to serve as a detailed appendix for the results presented in the main body of the climate vulnerability assessment.

Section 2.0 Changes to Surface Water Hydrology

The purpose of this task was to develop regression-based models that provided a quantitative impact assessment of potential trends in surface water and groundwater hydrology in Alachua County. The task aimed to evaluate the impacts to major County water resources, including three large lakes (Newnans Lake, Lake Santa Fe, and Orange Lake) and the Santa Fe River. Similarities between some lakes, limits in the scope, and available data meant that some other large lakes in Alachua County including: Lochloosa Lake, Lake Alto, Tuscawilla Lake, and Watermelon Pond were not included as part of this study.

To evaluate historic conditions, hydrologic data for each waterbody were identified and summarized below. To assess potential changes, future conditions were examined by using modeled rainfall and evapotranspiration data (ET) developed for this project. Results were summarized by the following baseline and future time periods to allow comparison with other sections of this report:

- Baseline (2005-2014)
- 2030 (2025-2034)
- 2040 (2035-2044)
- 2070 (2065-2074)
- 2100 (2091-2100)

2.1 Data and Methods

2.1.1 Data Sources

A variety of data sources were used for this analysis. Table summarizes the historic hydrologic data types and sources used in this task.

Table 1. Data Sources

Data	Source
Rainfall (1985 – 2021)	National Climatic Data Center (NCDC)[1]
Rainfall (Sept – Dec 2019)	Florida Automated Weather Network (FAWN)[2]
Reference ET (1985 – 2021)	U.S. Geological Survey (USGS)[3]
Water Level; Discharge (1985 – 2021)	USGS[4]; St. Johns River Water Management District (SJRWMD)[5]; Suwannee River Water Management District (SRWMD)[6]

[1] via iAIMS Climatic Data - Texas A&M AgriLIFE Research Center at Beaumont https://beaumont.tamu.edu/ClimaticData/ (Station – GAINESVILLE RGNL AP)
[2] https://fawn.ifas.ufl.edu/ (Station - Alachua)
[3] https://www.usgs.gov/centers/cfwsc/science/ (Location – Evaluated Waterbody)
[4] https://waterdata.usgs.gov/nwis (Location – Evaluated Waterbody)
[5] https://www.sjrwmd.com/data/hydrologic/ (Location – Evaluated Waterbody)
[6] https://www.mysuwanneeriver.com/507/Water-Data-Portal

Daily rainfall from 1985 to 2021 from the Gainesville Regional Airport Weather Station were used to evaluate historic rainfall conditions for each waterbody. Missing data for this station from September through December 2019 were supplemented with rainfall data from the Florida Automated Weather Network (FAWN) database Alachua weather station.

Daily statewide reference evapotranspiration (RET) data provided by the USGS, computed at a 2-kilometer spatial resolution, were used for the period from 1985 to 2021. Daily RET data specific to each evaluated waterbody were obtained from this dataset.

Surface water flow and stage data from 1985 to 2021 were obtained from various sources, including the USGS, SJRWMD, and SRWMD. Specific surface water stage and flow locations for each evaluated waterbody from each source are discussed in their respective sections.

2.1.2 Methods

2.1.2.1 Lakes

Two methods for modeling lake dynamics were investigated: a monthly water balance approach and a monthly net rainfall correlation analysis. The former used direct rainfall, surface inflows, evapotranspiration, surface outflows, groundwater leakance, and change in storage as primary inputs. The model used monthly averages from detailed hydrologic data and estimated missing data using neighboring stations when necessary. The latter relied on correlations between net rainfall (difference between precipitation and RET) and changes in lake stage at a monthly time scale. After investigations of both methods for each lake, the monthly water balance approach, which had large model residuals due to significant data gaps and uncertainty in model inputs, was deemed to be a less reliable method than using the net rainfall correlation. For the correlations developed for each lake a minimum stage and maximum stage were applied. This kept the model from reaching unrealistic stages during particularly wet periods, and from having stages below the lake bottom during particularly dry periods.

2.1.2.1.1 Newnans Lake

Figure 1 and **Error! Reference source not found.** provide a summary of hydrologic locations for Newnans Lake including:

- Surface Inflows - Little Hatchet Creek (LHC), Hatchet Creek (HC), Lake Forest Creek (LFC)
- Surface Outflows - Prairie Creek (PC)
- Stage - Newnans Lake (NL)

Figure 1. Newnans Lake Hydrologic Station Locations

Table 2. Newnans Lake Hydrologic Station Data Sources

No	Station	Station Name	Latitude	Longitude	Type	Source
1	1920187 / 2240806	Little Hatchet Creek at Gainesville Discharge	29.69806	-82.28000	D	SJRWMD; USGS
2	2840233	North Branch Little Hatchet Creek Discharge	29.69078	-82.25568	D	SJRWMD
3	8631958	Prairie Creek at Gainesville Discharge	29.61095	-82.24816	D / WL	SJRWMD
4	14342633	Hatchet Creek at Gainesville Discharge	29.69333	-82.20047	D	SJRWMD
5	19244274	Lake Forest Creek at Kincaid Hills on CR329B Discharge	29.65180	-82.25128	D	SJRWMD
6	4831007	Newnans Lake Baker at Gainesville (WL)	29.65095	-82.23886	WL	SJRWMD
7	2240900	Newnans Lake nr Gainesville, FL	29.65111	-82.23944	WL	USGS

D – Discharge; WL - Water Level

For Newnans Lake, changes in lake stage and monthly net rainfall were well correlated as shown in Figure 2. This relationship in conjunction with the rainfall and RET data developed for this project were used to generate monthly estimates of the lake stage for the project period. These estimates, combined with lake bathymetry information, allowed for the calculation of the lake area and volume over time. Newnans Lake bathymetry was evaluated in a 2002 study (Environmental Consulting & Technology, Inc., 2002) that occurred during the significant drought that lowered water levels to approximately 61 feet (NAVD88). The bathymetry in the ECT study was combined with area and stage values described in the SJRWMD 1996 SWIM Plan (Lasi & Shuman, 1996) to yield an approximate stage-area-volume curve for a range of elevations from 56.1 to 67.1 feet (NAVD88).

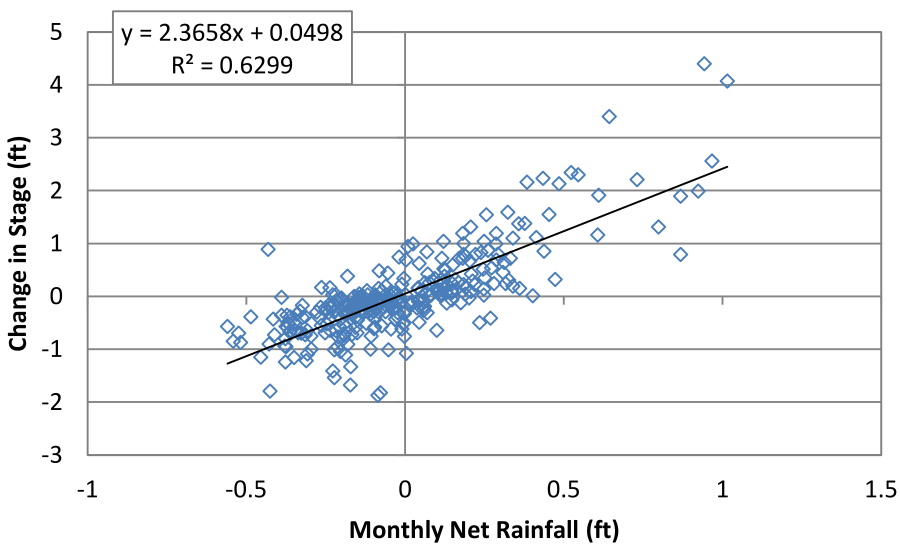


Figure 2. Relationship between Monthly Net Rainfall and Newnans Lake Change in Stage (1995 – 2021)

Figure 3 summarizes the relationship between monthly Newnans Lake stage and Prairie Creek discharge from 2000 through 2021. Only data after 1999 were used since reconfiguration of the downstream weir structure occurred in 1999 as part of the modification of State Road 20 at Prairie Creek by the Florida Department of Transportation (FDOT) (Lippincott, 2011). This relationship was used with the future lake stage estimates to approximate Prairie Creek discharges for future time periods.

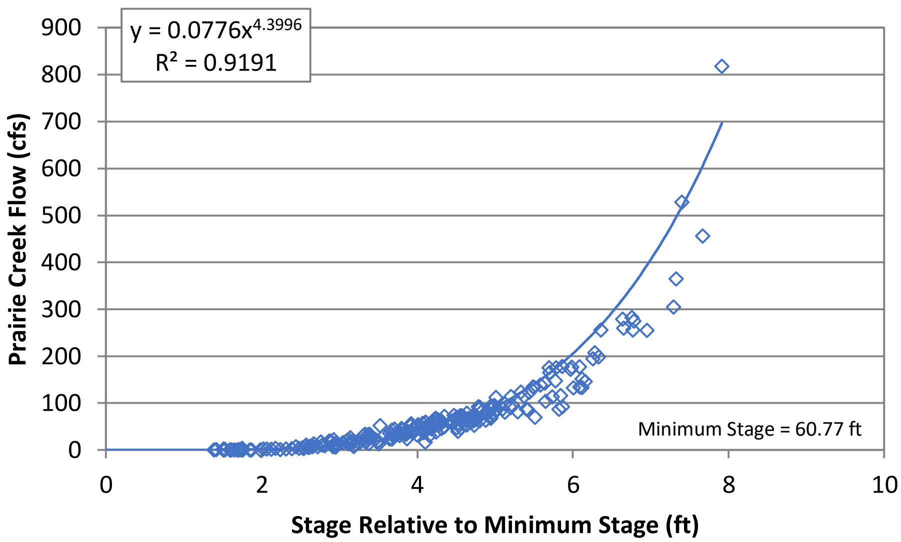


Figure 3. Relationship between Newnans Lake Stage and Prairie Creek Discharge (2000-2021)

2.1.2.1.2 Lake Santa Fe

Figure 4 and **Error! Reference source not found.**3 provide a summary of hydrologic locations for Lake Santa Fe. Stage data were available for both Lake Santa Fe and Little Lake Santa Fe. No discharge data were available for the study period for the lake and most outflows from Lake Santa Fe occur via overland flow through a large wetland located north of Little Lake Santa Fe.

The correlation between monthly net rainfall and Lake Santa Fe stage changes was investigated from 1985 to 2021 (Figure 5). This relationship in conjunction with rainfall and RET data projected for this project were used to generate monthly estimates of the lake stage for that period. These estimates, combined with lake bathymetry information[7], allowed for the calculation of the lake area and volume over time.

[7] https://plants.ifas.ufl.edu/manage/bathymetric-maps/

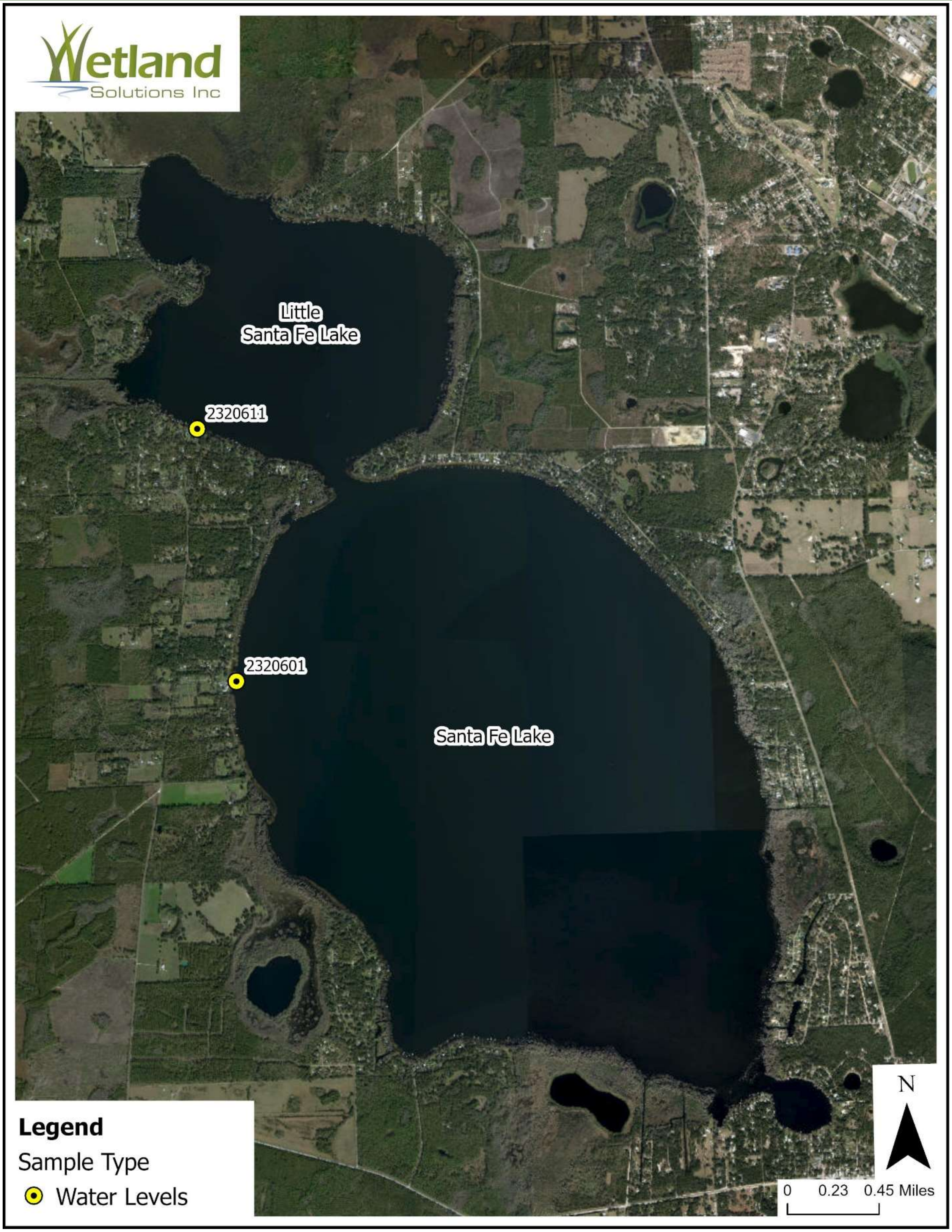


Figure 4. Lake Santa Fe Hydrologic Station Locations

Table 3. Lake Santa Fe Hydrologic Station Data Sources

No.	Station	Station Name	Latitude	Longitude	Type	Source
SF	2320601	Santa Fe Lake near Earleton	29.74611	-82.09806	WL	SRWMD
LSF	2320611	Little Santa Fe Lake	29.76417	-82.10083	WL	SRWMD

WL - Water Level

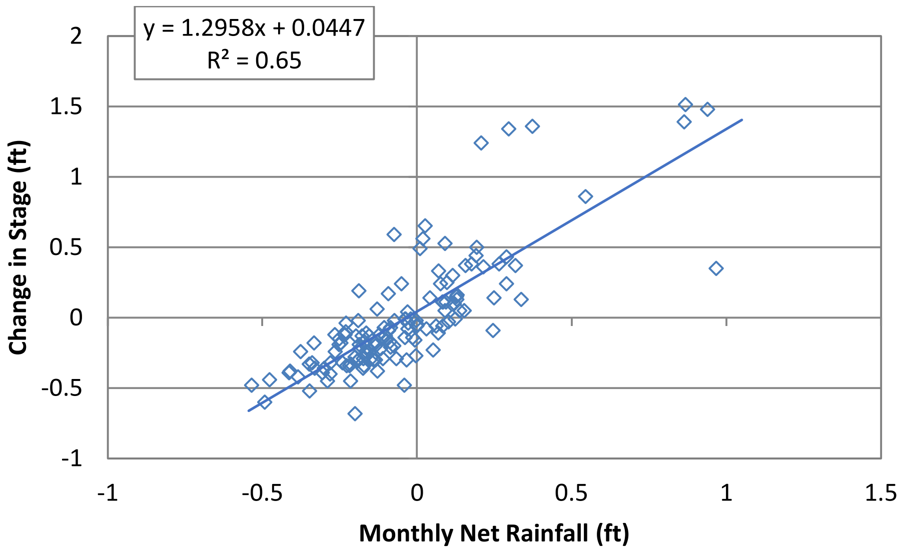


Figure 5. Relationship between Monthly Net Rainfall and Lake Santa Fe Change in Stage (1985 – 2021)

2.1.2.1.3 Orange Lake

Figure 6 and **Error! Reference source not found.**4 provide a summary of hydrologic locations for Orange Lake including:

- Surface Inflows –River Styx (RS) and Cross Creek (CC)
- Surface Outflows – Orange Creek (OC)
- Stage - Orange Lake (OL)

The correlation between monthly net rainfall and Orange Lake stage changes was investigated from 1985 to 2021 (Figure 13). This relationship in conjunction with rainfall and RET data projected for this project was used to generate monthly estimates of the lake stage for that period. These estimates, combined with lake bathymetry information[8], allowed for the calculation of the lake area and volume over time.

Figure 8 summarizes the relationship between monthly Orange Lake stage and Orange Creek discharge from 1985 to 2021. This relationship was used with the future lake stage estimates to approximate Orange Creek discharges for future time periods. Multiple equations were used to describe the flow duration curve, including exponential and power functions that over predicted flows. The polynomial function was found to better predict flows above a stage of 56.8 feet NAVD88. Flows below this elevation were estimated using a linear fit. Lippincott (2011) reported

[8] https://plants.ifas.ufl.edu/manage/bathymetric-maps/

that significant outflows in Orange Creek only occur at water levels over 56.3 feet NAVD88. Bathymetric data for Orange Lake were available up to an elevation of 54.52 feet NAVD88, but levels above this are expected in the future period. Areas above the bathymetric survey elevation (54.52 ft NAVD88) to the historic maximum stage of 59.52 ft NAVD88 (March 1998) were estimated based on a data fit of the bathymetric data.

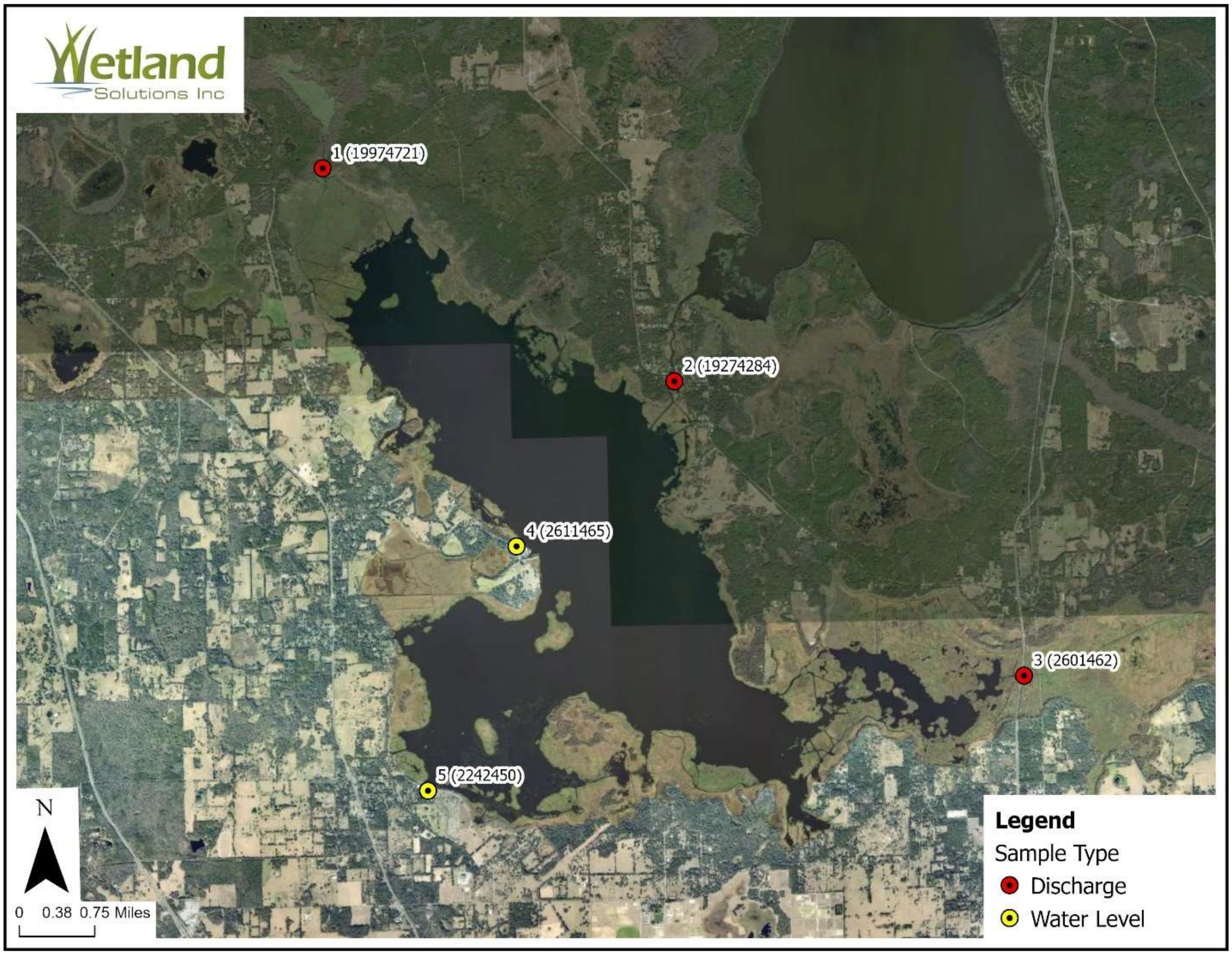


Figure 6. Orange Lake Hydrologic Station Locations

Table 4. Orange Lake Hydrologic Station Data Sources

No.	Station	Station Name	Latitude	Longitude	Type	Source
1	19974721	River Styx Nr Micanopy	29.51711	-82.22255	D	SJRWMD
2	19274284	Cross Creek on CR325 at Gainesville	29.48537	-82.16520	D	SJRWMD
3	2601462	Orange Lake Outlet at Citra	29.44178	-82.10851	D	SJRWMD
4	2611465	Orange Lake at Boardman	29.46195	-82.19180	WL	SJRWMD
5	2242450	Orange Lake at Orange Lake, FL	29.42694	-82.20722	WL	USGS

D – Discharge; WL - Water Level

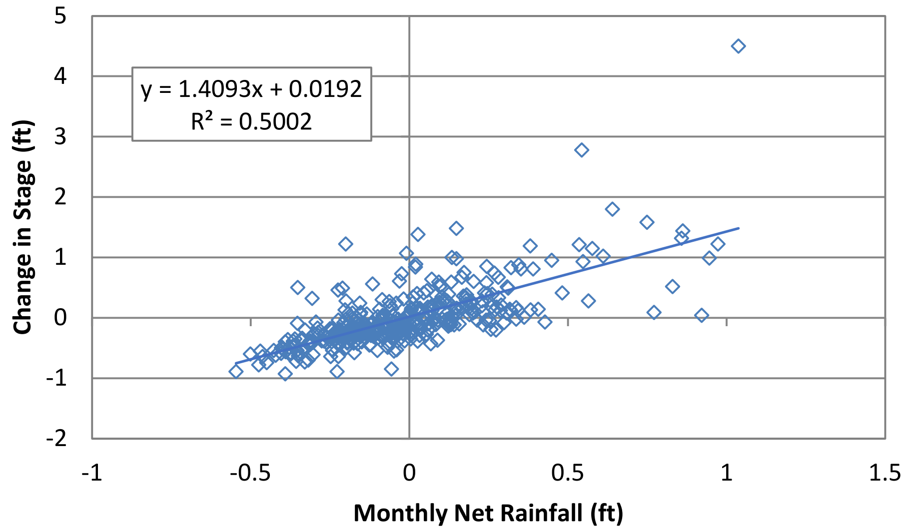


Figure 7. Relationship between Monthly Net Rainfall and Orange Lake Change in Stage (1985 – 2021)

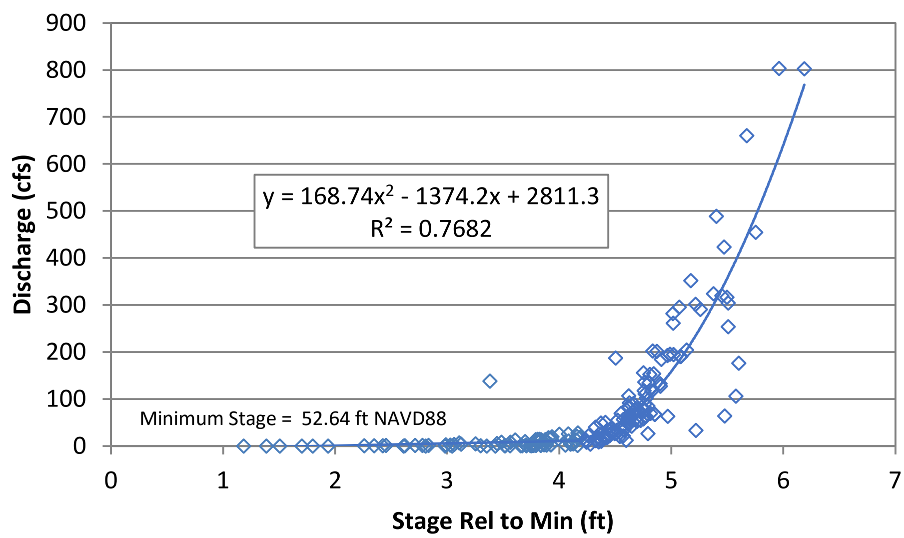


Figure 8. Relationship between Orange Lake Stage and Orange Creek Discharge (1985-2021)

2.1.2.2 Santa Fe River

To model Santa Fe River flows methods developed by the USGS were applied to separate the streamflow hydrograph into baseflow and surface-runoff components (Sloto & Crouse, 1996). The HYSEP local-minimum method was used to estimate baseflow (groundwater springs) contributions to the Santa Fe River for the USGS station evaluated for this study, USGS 2322500 (Santa Fe River near Fort White).

Figure 9 and **Error! Reference source not found.**5 provide a summary of hydrologic locations for the Santa Fe River including:

- Santa Fe River Stations
  - USGS 2321500 (at Worthington Springs)
  - USGS 2321898 (at O'Leno State Park)
  - USGS 2322500 (near Fort White)
- Spring Inputs – 36 named springs

For this study flows were estimated at the USGS 2322500 station which is an MFL compliance point for the Lower Santa Fe River and is slightly below the downstream extent of the Santa Fe River in Alachua County. At this location there are significant spring flows that provide a consistent and large baseflow. The hydrologic record at this location had flows separated between baseflow and runoff by applying the HYSEP local-minimum method previously presented. Daily discharge data were used to estimate monthly average baseflow for this station. The correlation between the three-year average net rainfall and annual baseflow was investigated from 1995 to 2021 and is shown in Figure 10. The three-year net rainfall was found to produce a better data fit and is consistent with the impacts of longer-term net rainfall on aquifer storage and spring flows. Flows above the calculated baseflow represent runoff with the correlation between net rainfall and runoff shown in Figure 11.

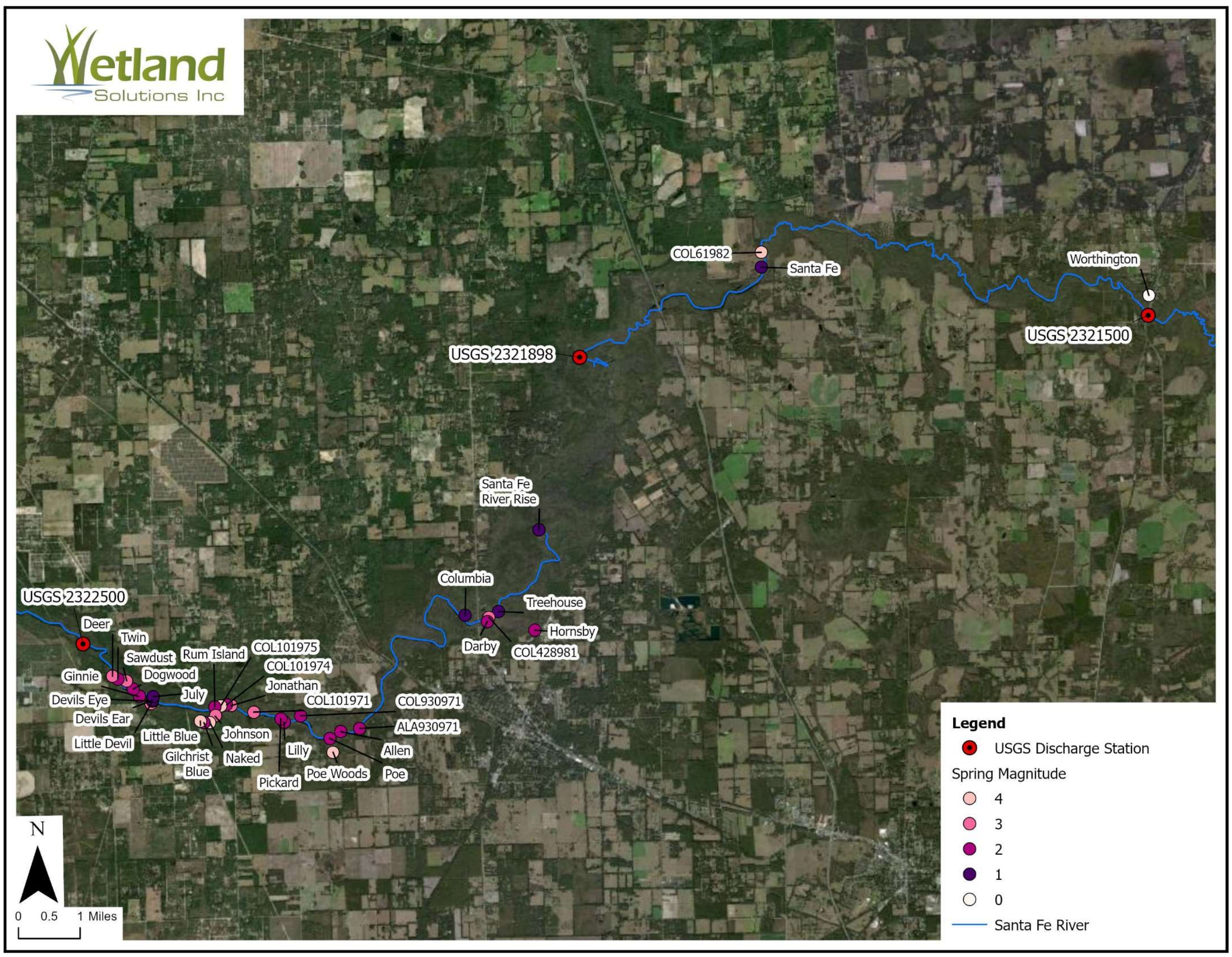


Figure 9. Santa Fe River Hydrologic Station Locations

Table 5. Santa Fe River Hydrologic Station Data Sources

StnID	Name	Lat	Long	Mag	Drainage area (mi^2)
2321500	Santa Fe River at Worthington Springs	29.92191	-82.42623	---	575
	Worthington Spring	29.92661	-82.42592	0	---
	COL61982	29.93830	-82.53037	4	---
	Santa Fe Spring	29.93480	-82.53042	1	---
2321898	Santa Fe River at O'Leno State Park	29.91441	-82.57984	---	820
	Santa Fe River Rise	29.87389	-82.59164	1	---
	Hornsby Spring	29.85036	-82.59320	2	---
	Treehouse Spring	29.85489	-82.60288	1	---
	COL428981	29.85354	-82.60552	3	---
	Darby Spring	29.85262	-82.60596	2	---
	Columbia Spring	29.85411	-82.61195	1	---
	ALA930971	29.82794	-82.64084	2	---
	Allen Spring	29.82727	-82.64602	2	---
	Poe Woods Spring	29.82248	-82.64817	4	---
	Poe Spring	29.82572	-82.64897	2	---
	COL930971	29.83116	-82.65674	2	---
	Lilly Spring	29.82972	-82.66121	2	---
	Pickard Spring	29.83053	-82.66209	2	---
	COL101971	29.83221	-82.66936	3	---
	Jonathan Spring	29.83379	-82.67542	3	---
	COL101974	29.83400	-82.67668	2	---
	COL101975	29.83382	-82.67821	4	---
	Rum Island Spring	29.83352	-82.67983	2	---
	Johnson Spring	29.83150	-82.67971	3	---
	Naked Spring	29.82992	-82.68127	4	---
	Gilchrist Blue Spring	29.82990	-82.68285	2	---
	Little Blue Spring	29.83032	-82.68383	4	---
	Little Devil Spring	29.83456	-82.69703	3	---
	Devils Eye Spring	29.83516	-82.69659	2	---
	Devils Ear Spring	29.83535	-82.69660	1	---
	July Spring	29.83618	-82.69640	1	---
	Ginnie Spring	29.83634	-82.70012	2	---
	Dogwood Springs	29.83806	-82.70179	2	---
	Sawdust Spring	29.84001	-82.70351	3	---
	Twin Spring	29.84045	-82.70586	2	---
	Deer Spring	29.84117	-82.70732	3	---
2322500	Santa Fe River near Fort White	29.84885	-82.71512	---	1,017

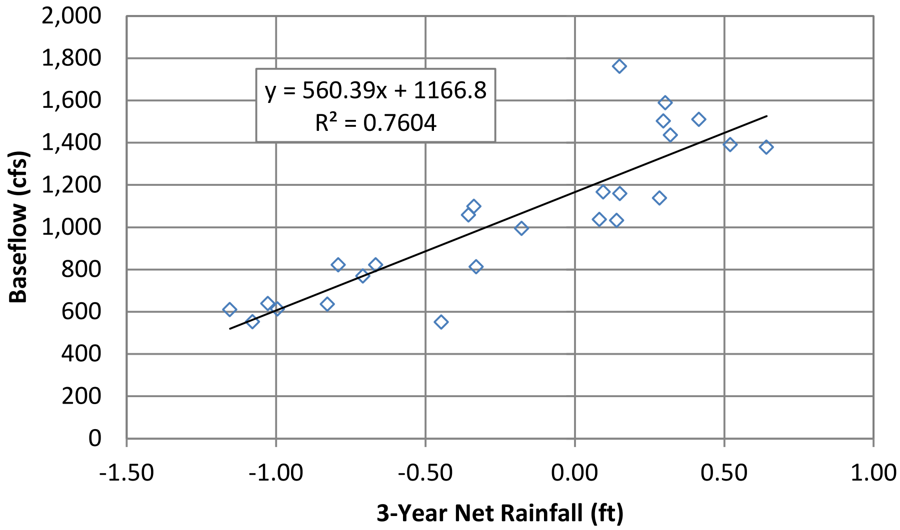


Figure 10. Relationship between Net Rainfall and Santa Fe River Baseflows (USGS 2322500, 1995 – 2021)

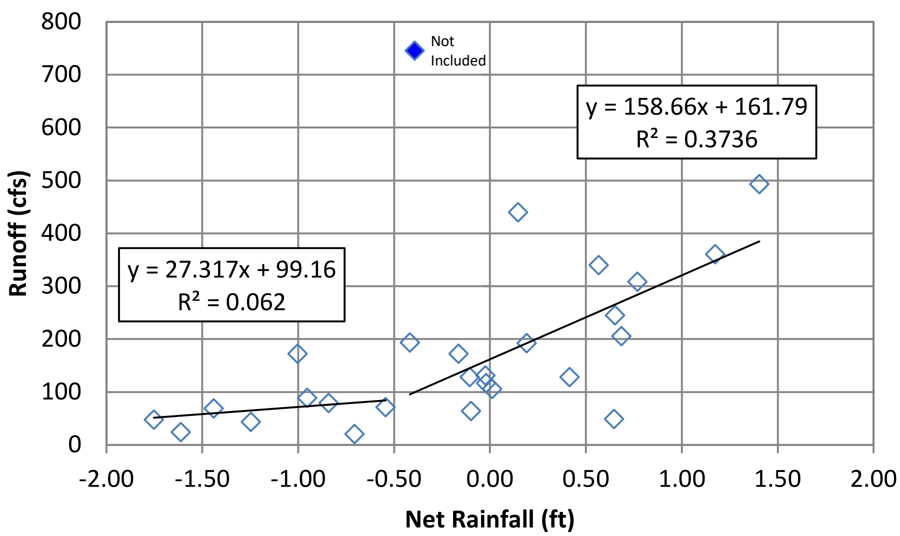


Figure 11. Relationship between Net Rainfall and Santa Fe River Runoff (USGS 2322500, 1995 – 2021)

2.2 Results

By applying the methods discussed, the future hydrologic conditions of the assessed systems were evaluated.

2.2.1 Lakes

2.2.1.1 Newnans Lake

2.2.1.1.1 Rainfall and Evapotranspiration

Figure 12 provides a timeseries of the annual average rainfall and RET data for the historic and future projected time-period developed for this project. Annual average totals for the historic, baseline, and future time periods are summarized in Figure 13. Annual average rainfall increased from 48.4 inches during the historic period (44.6 inches for the baseline period) to 56.5 inches in 2100. While average RET increased from 51.4 inches during the historic period (51.7 inches for the baseline period) to 60.5 inches in 2100.

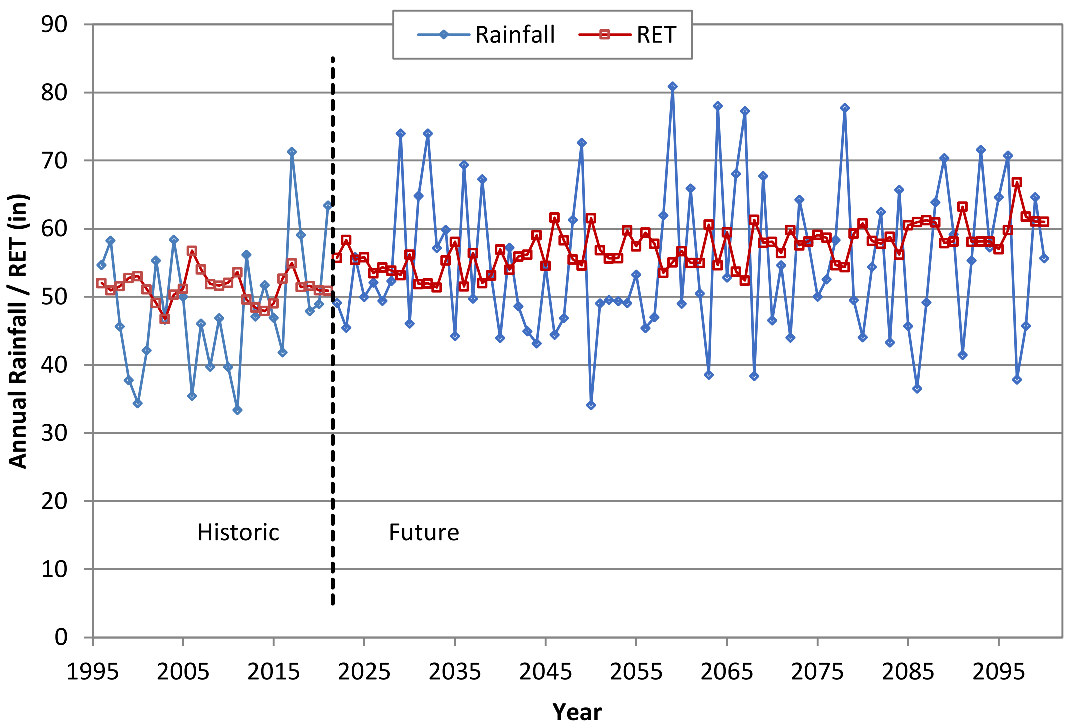


Figure 12. Newnans Lake Annual Rainfall and RET

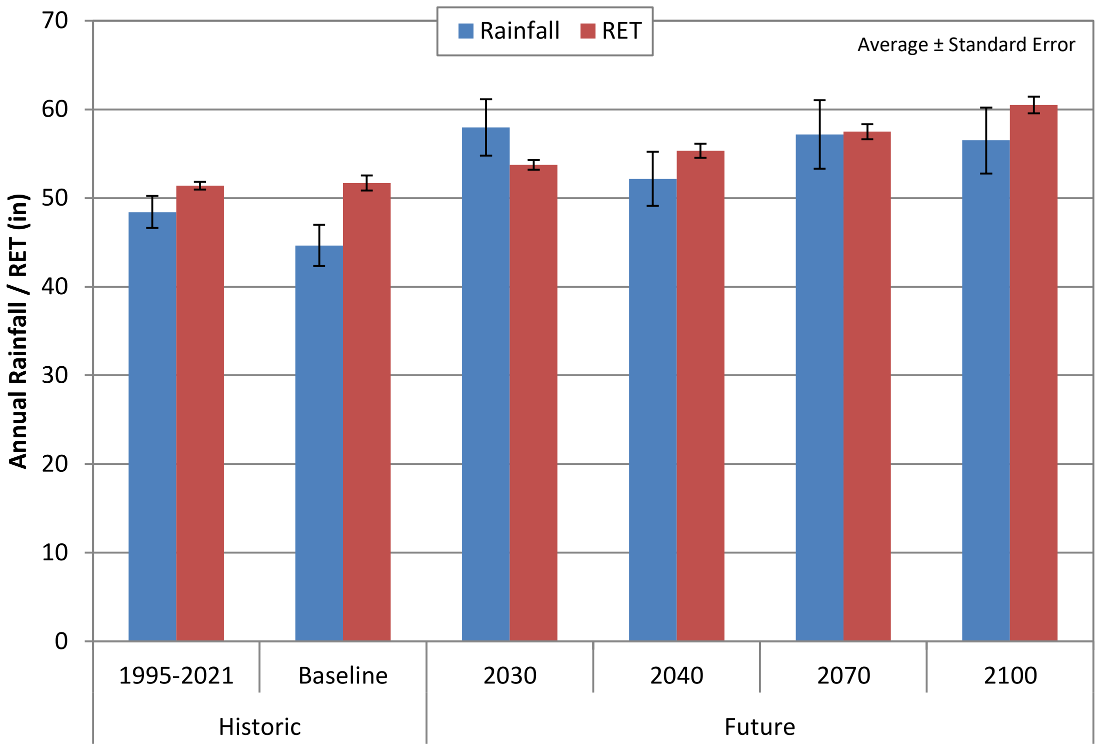


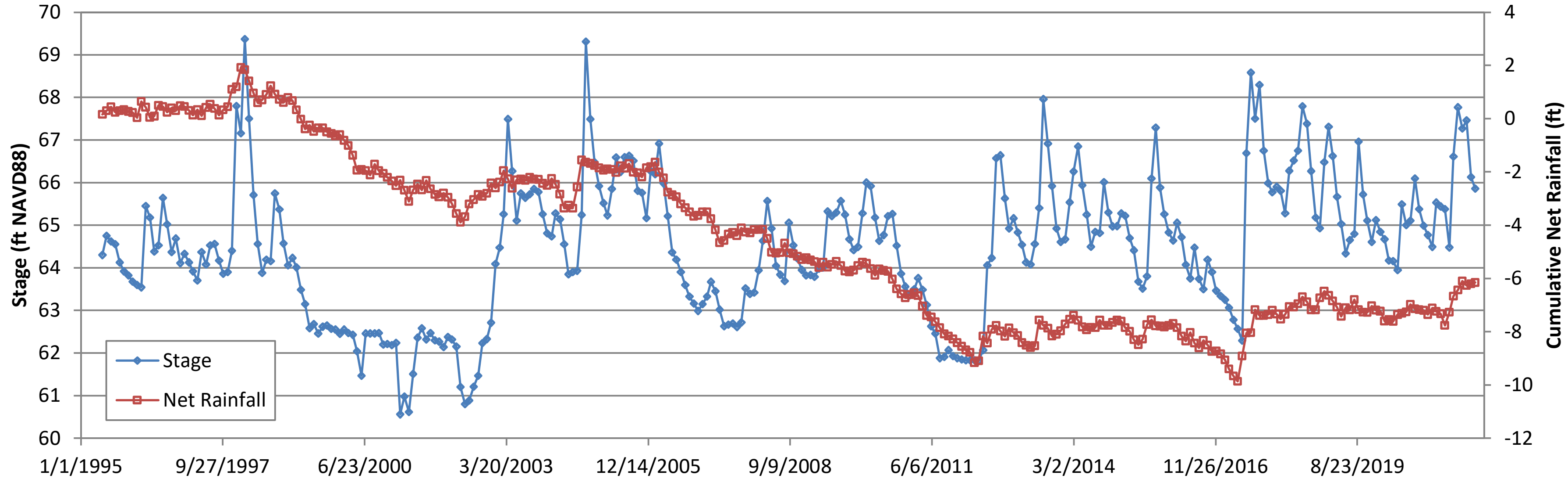
Figure 13. Newnans Lake Average Annual Rainfall and RET for Historic and Future Model Periods

2.2.1.1.2 Lake Stage and Prairie Creek Discharge

Figure 14 presents a monthly record of actual stages measured in Newnans Lake during the historic period (1995-2021) and modeled stages during the future projected period (2022-2100). The modeled stages were computed using the future rainfall and RET data and the historic correlations between monthly net rainfall and changes in lake stage (Figure 2).

Average lake stage for the historic, baseline, and future time periods are summarized in Figure 15. The average stage decreased from 64.5 feet NAVD88 during the historic and baseline periods to 62.5 feet NAVD88 in 2100. However, for a period during the 2040s to 2050s and again in the 2080s the lake was modeled to fall to near 56 feet for extended periods of time. This is more than 4 feet below the lowest recorded levels on the lake. These lower water levels will likely have an effect on lake water quality. Wetland Solutions, Inc. (2020) examined the associations between water quality and Newnans Lake levels, revealing significant inverse relationships, where lower lake levels were generally associated with higher TN and TP concentrations, along with increases in other parameters such as TSS, turbidity, and chlorophyll *a*.

To approximate the discharges of Prairie Creek, the modeled stage estimates from Newnans Lake were combined with the stage-discharge curve developed using monthly historic stage and flow data from Prairie Creek (Figure 3). Average Prairie Creek discharge decreased from 61.8 cfs during the historic period (45.3 cfs for the baseline period) to 31.2 cfs in 2100, while 2030 and 2040 showed an increase to approximately 92.8 cfs (Figure 16).



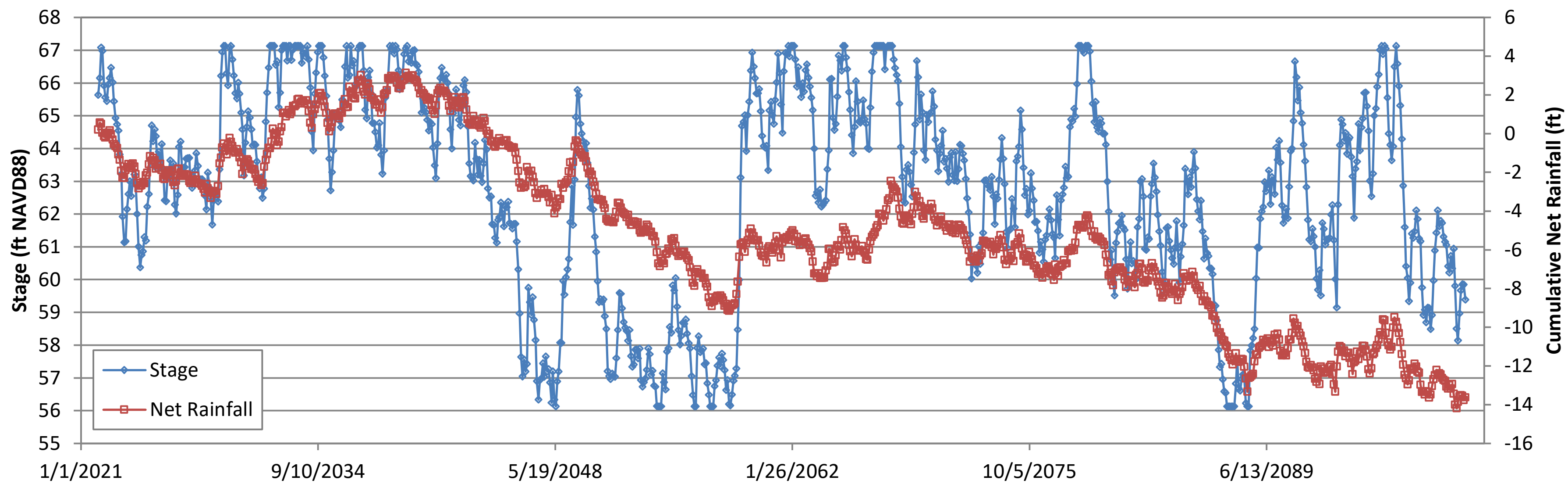


Figure 14. Newnans Lake Monthly Stage and Net Rainfall for the Historic (Top) and Future Projected Period (Bottom)

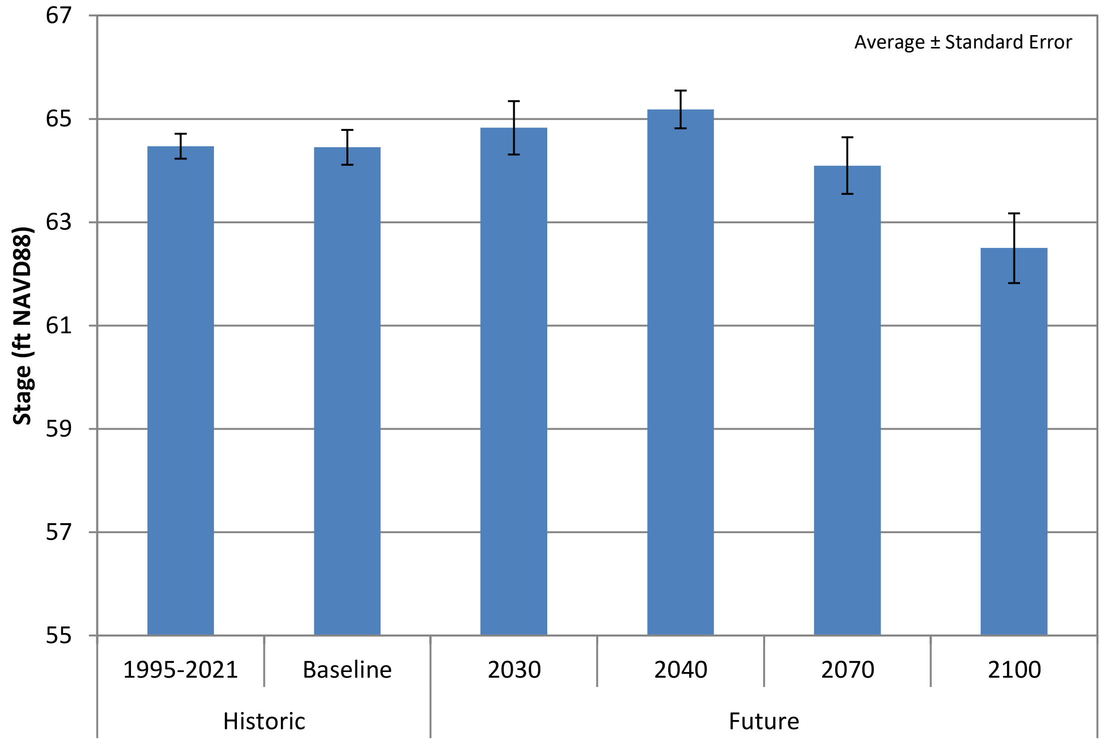


Figure 15. Newnans Lake Annual Average Stage for Historic and Future Model Periods

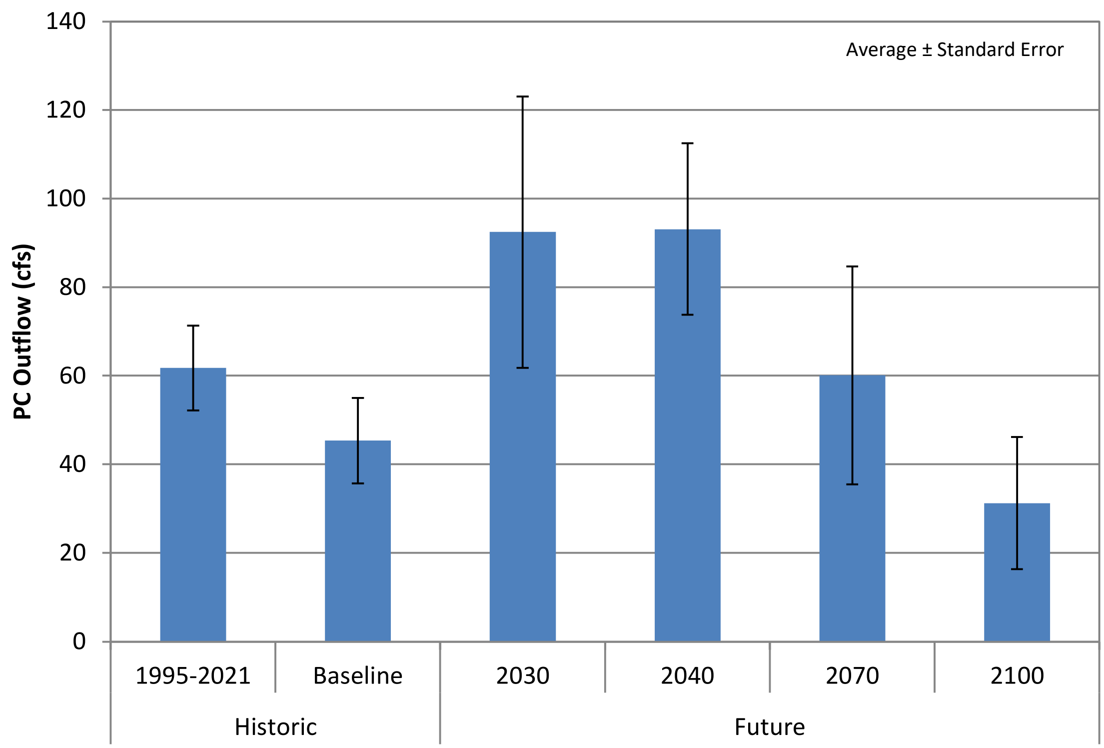


Figure 16. Newnans Lake Annual Average Prairie Creek Outflow for Historic and Future Model Periods

2.2.1.1.3 Lake Area

The Newnans Lake water surface area was estimated using modeled stage estimates and lake bathymetry information (Figure 17). As with lake stage, average water surface areas are projected to decrease from approximately 6,200 acres during the historic and baseline periods to about 4,300 acres by 2100. However, there are 134 months in the future projection when levels in the lake are expected to lead to the wetted lake area falling below 100 acres.

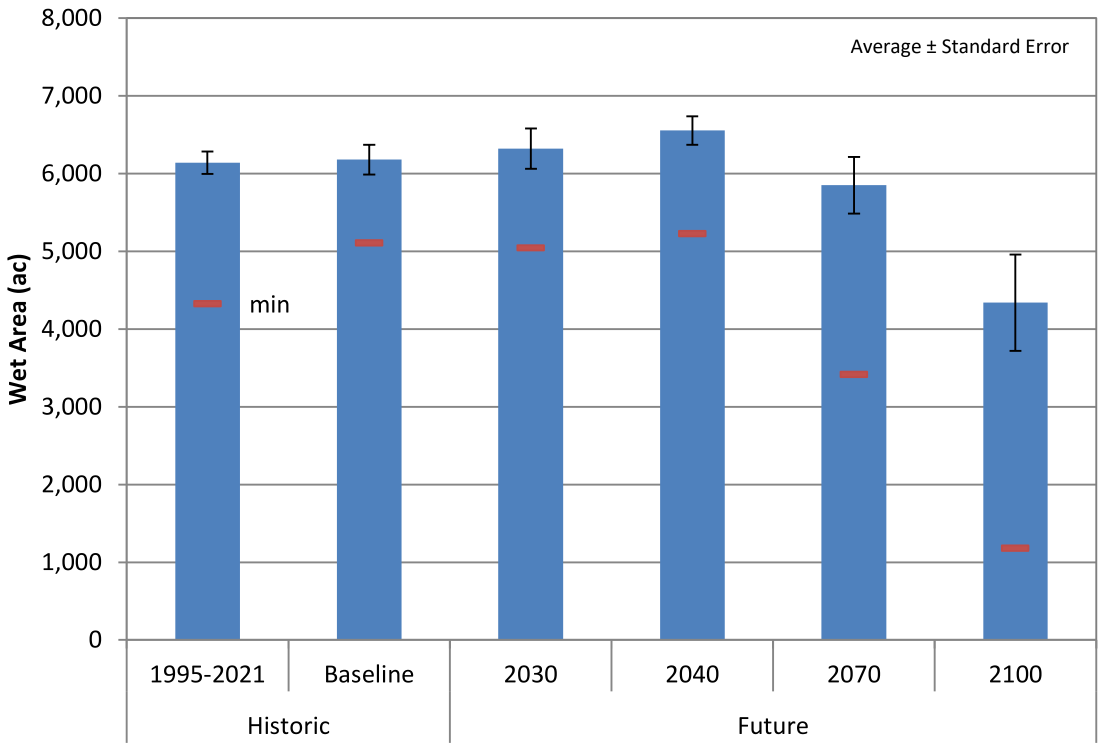


Figure 17. Newnans Lake Annual Average Area for Historic and Future Model Periods

2.2.1.2 Lake Santa Fe

2.2.1.2.1 Rainfall and Evapotranspiration

Figure 18 provides a timeseries of the annual average rainfall and RET data for the historic and future projected time-periods developed for this project. Annual average totals for the historic, baseline, and future time periods are summarized in Figure 19. Annual average rainfall increased from 48.7 inches during the historic period (44.6 inches for the baseline period) to 56.5 inches in 2100. While average RET increased from 51.2 inches during the historic period (50.9 inches for the baseline period) to 60.5 inches in 2100.

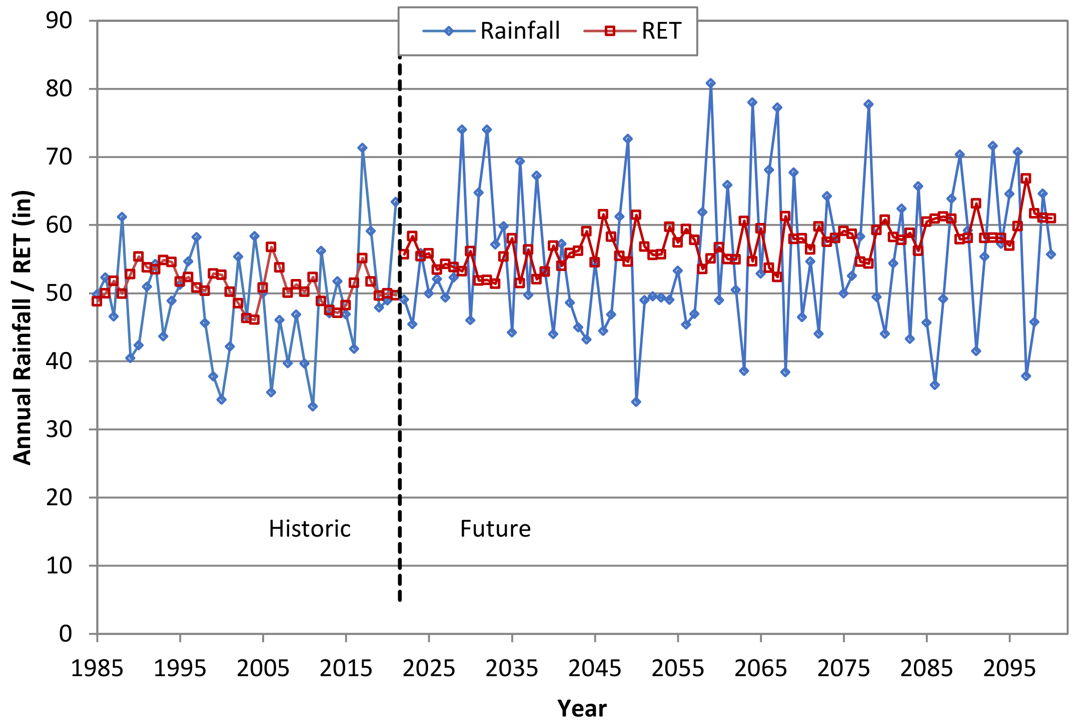


Figure 18. Lake Santa Fe Annual Rainfall and RET

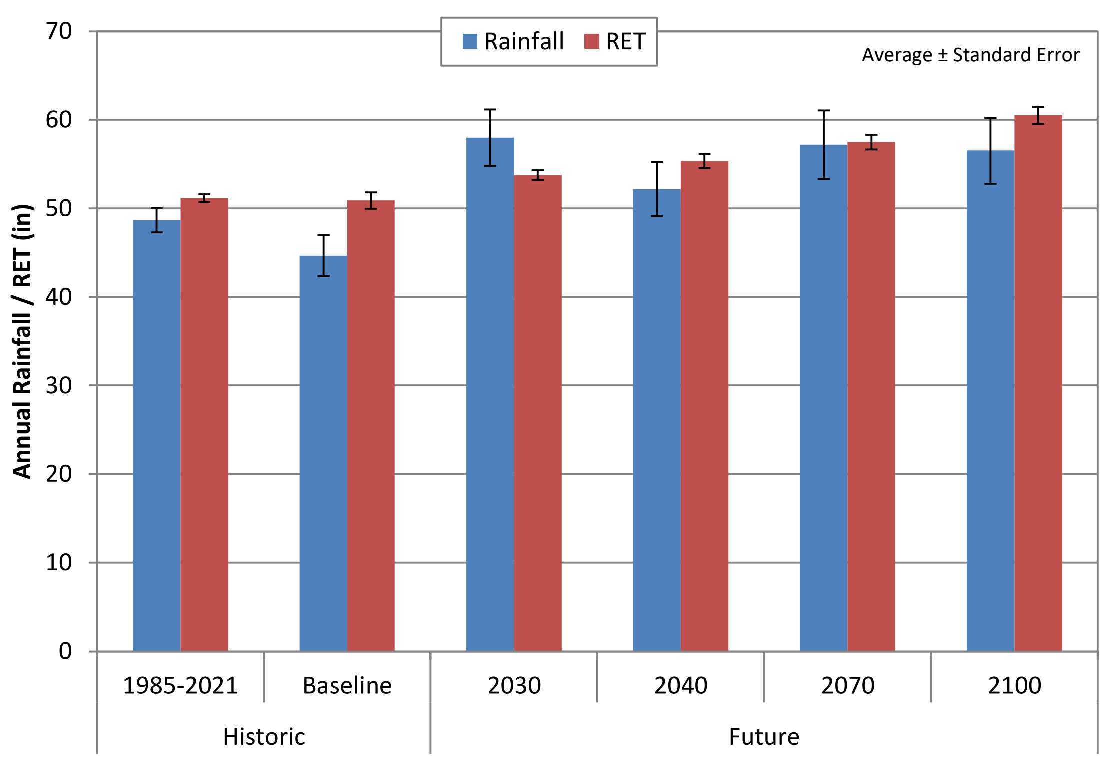


Figure 19. Lake Santa Fe Average Annual Rainfall and RET for Historic and Future Model Periods

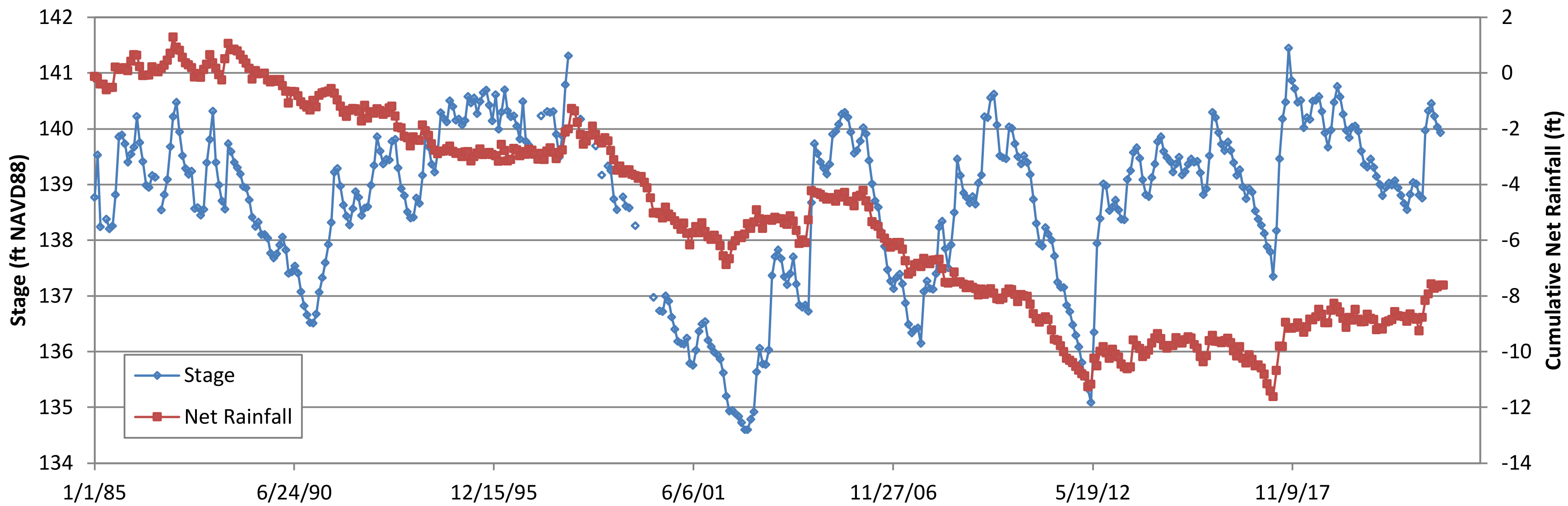
2.2.1.2.2 Lake Stage

Figure 20 presents a monthly record of actual stages measured in Lake Santa Fe during the historic period (1985-2021) and modeled stages during the future projected period (2022-2100). The modeled stages were computed using developed rainfall and RET data and the correlation between monthly net rainfall and changes in lake stage (Figure 5). The maximum stage was assumed to be 141.7 feet NAVD88 based on historic stage data.

Average lake stage for the historic, baseline, and future time periods are summarized in Figure 21. The average stage increased from approximately 138.6 feet NAVD88 during the historic and baseline periods to 139.4 feet NAVD88 in 2100. Average lake stage in 2030, 2040, and 2070 were all above the historic period, averaging about 140.7 feet NAVD88.

2.2.1.2.3 Lake Area

Lake Santa Fe wet areas were also estimated using modeled stage estimates and lake bathymetry information and are summarized in Figure 22. As with lake stage, average wet areas are projected to increase from approximately 4,970 acres during the historic and baseline periods to about 5,000 acres in 2100.



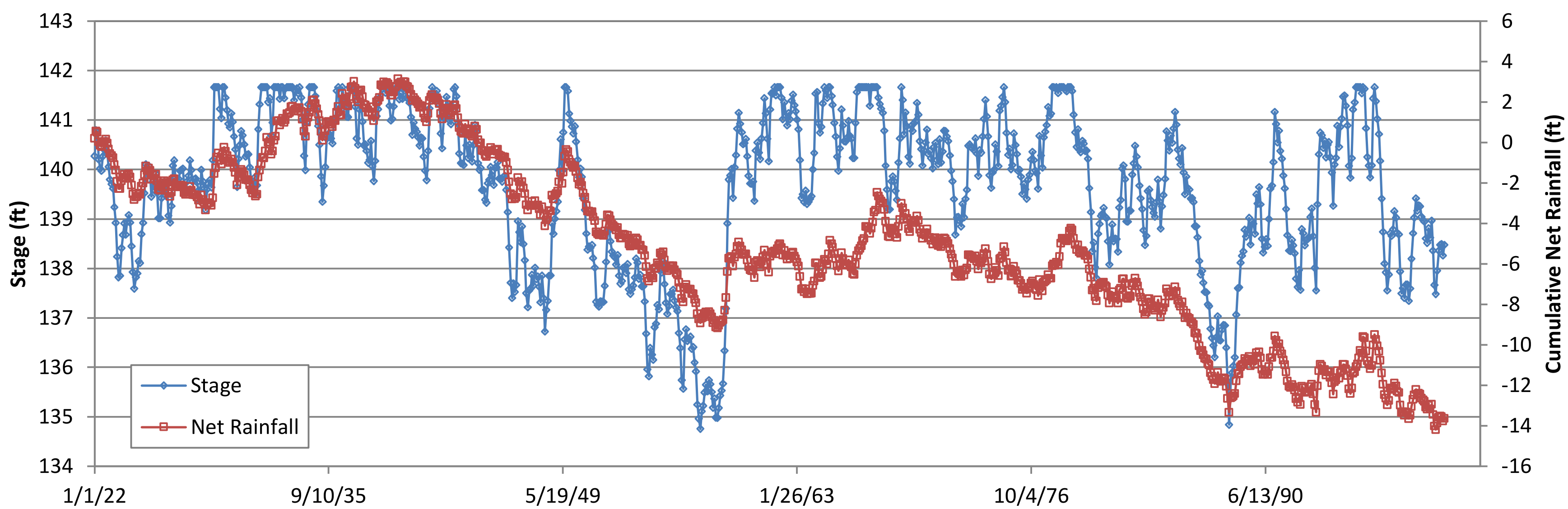


Figure 20. Lake Santa Fe Monthly Stage and Net Rainfall for the Historic (Top) and Future (Bottom) Projected Period

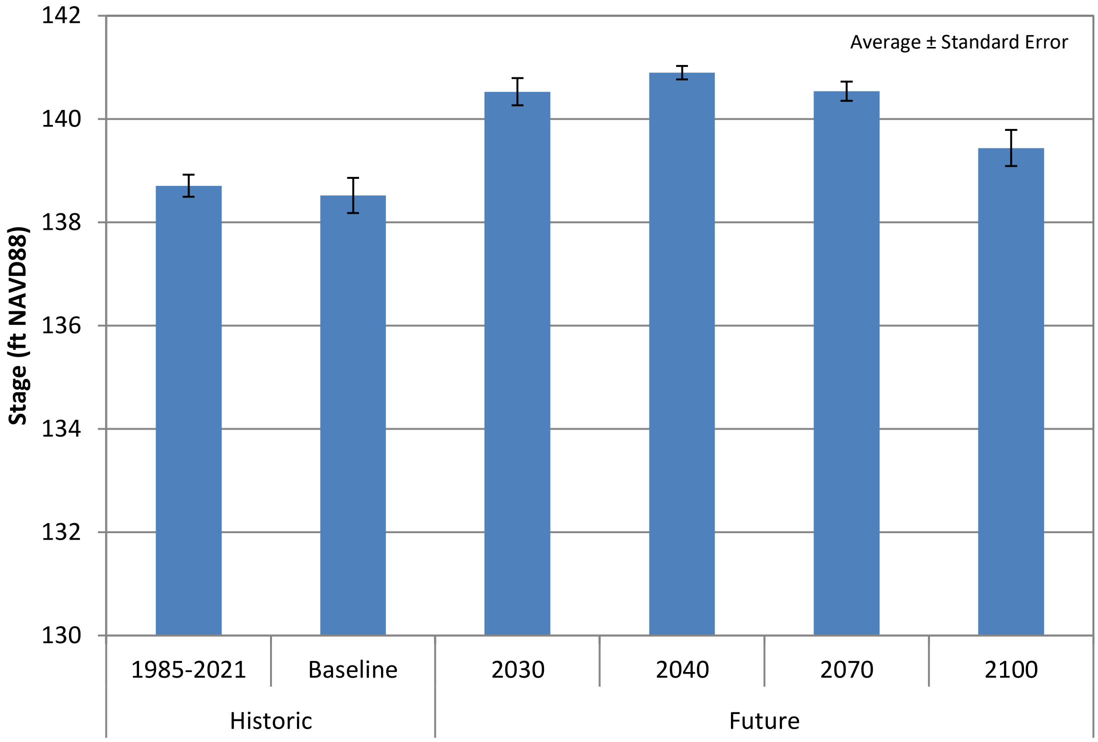


Figure 21. Lake Santa Fe Annual Average Stage for Historic and Future Model Periods

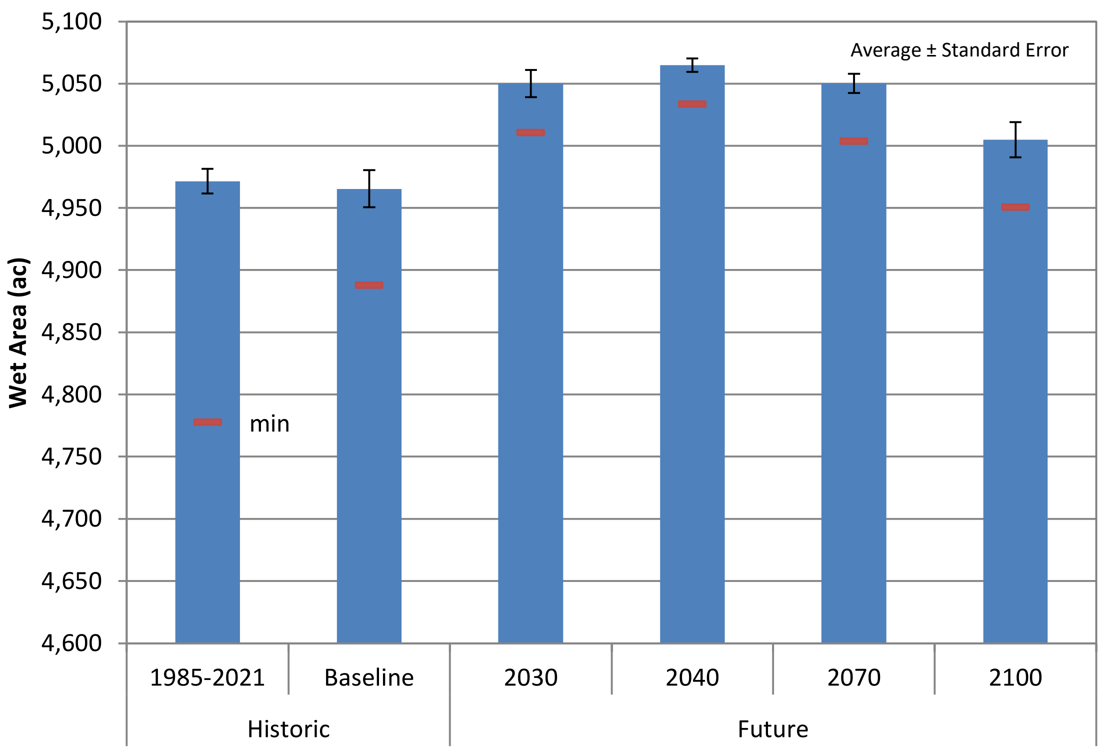


Figure 22. Lake Santa Fe Annual Average Area for Historic and Future Model Periods

2.2.1.3 Orange Lake

2.2.1.3.1 Rainfall and Evapotranspiration

Figure 23 provides a timeseries of the annual average rainfall and RET data for historic and future projected time-period developed for this project. Annual average totals for the historic, baseline, and future time periods are summarized in Figure 24. Annual average rainfall increased from 48.7 inches during the historic period (44.6 inches for the baseline period) to 56.5 inches in 2100. Average RET increased from 50.8 inches during the historic period (49.8 inches for the baseline period) to 60.5 inches in 2100.

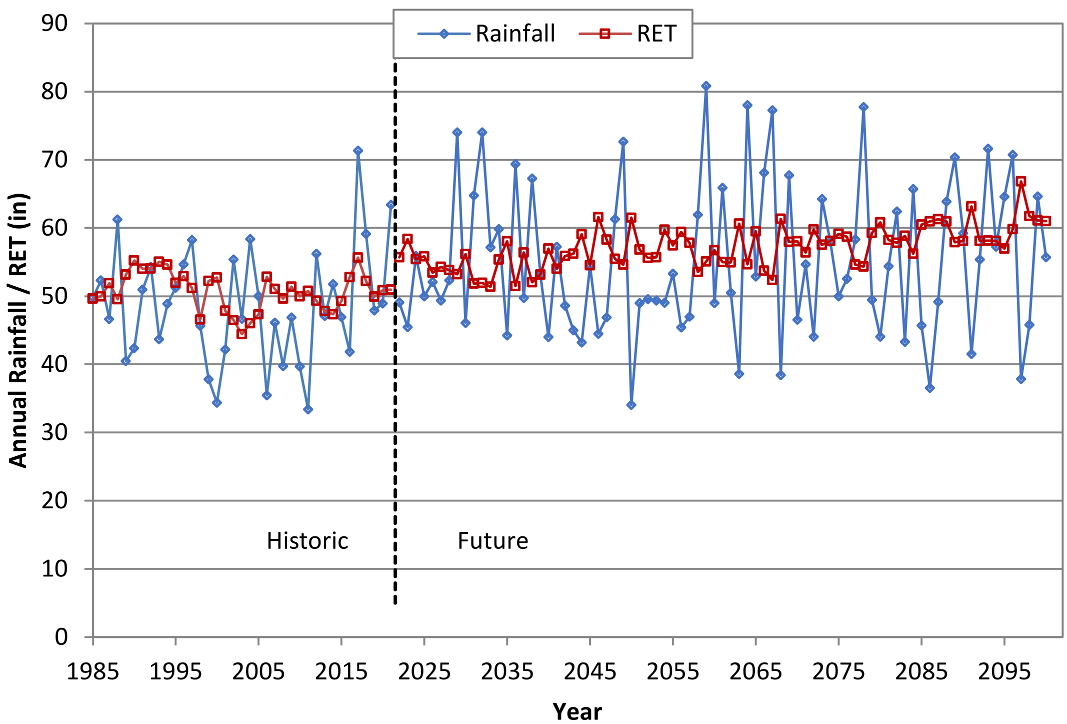


Figure 23. Orange Lake Annual Rainfall and RET

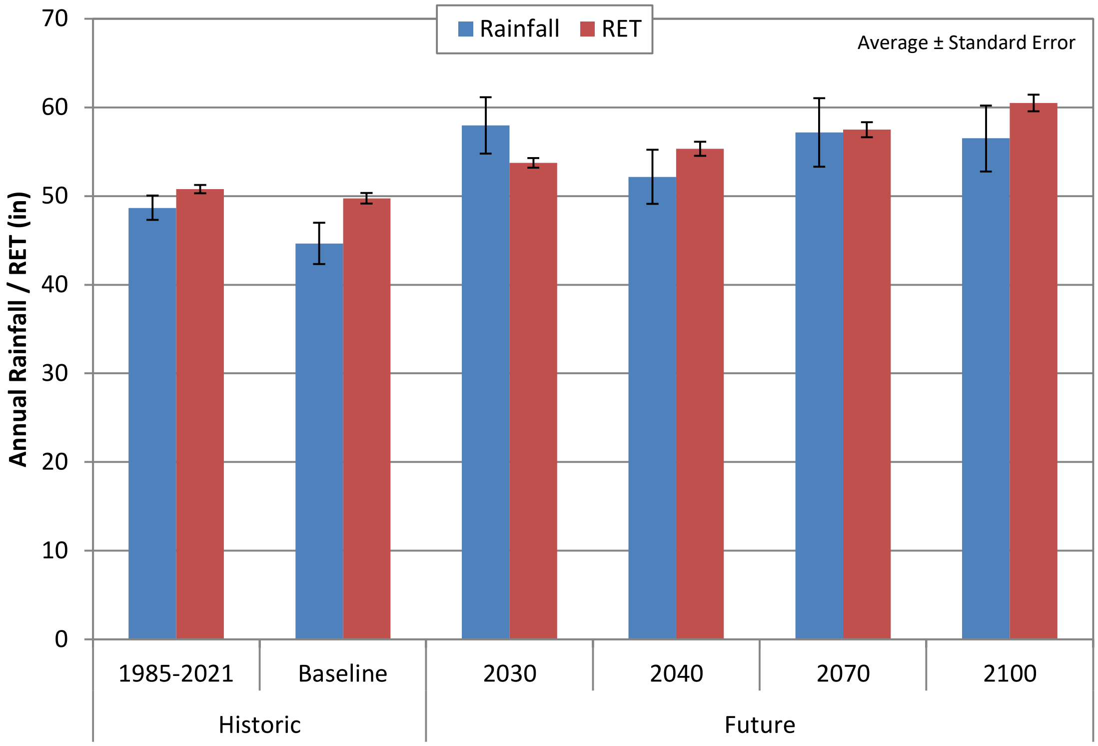


Figure 24. Orange Lake Average Annual Rainfall and RET for Historic and Future Model Periods

2.2.1.3.2 Lake Stage and Orange Creek Discharges

Figure 25 presents a monthly record of actual stages measured in Orange Lake during the historic period (1985-2021) and modeled stages during the future projected period (2022-2100). The modeled stages were computed using developed rainfall and RET data and the historic correlations between monthly net rainfall and changes in lake stage (Figure 8).

Average lake stage for the historic, baseline, and future time periods are summarized in Figure 26. The average stage decreased from 54.9 feet NAVD88 during the historic period (53.8 feet NAVD88 during the baseline period) to 51.2 feet NAVD88 in 2100. Average lake stage in 2030 and 2040 were above the historic period averaging about 57.2 and 58.2 feet NAVD88, respectively.

To approximate the discharges of Orange Creek, the modeled stage estimates from Orange Lake were combined with the stage-discharge curve developed using monthly historic stage and flow data from Orange Creek (Figure 8). Average Orange Creek discharge decreased from 61.2 cfs during the historic period (35.3 cfs for the baseline period) to virtually no flow in 2100, while 2030 and 2040 showed an increase to approximately 391 and 522 cfs, respectively (Figure 27).

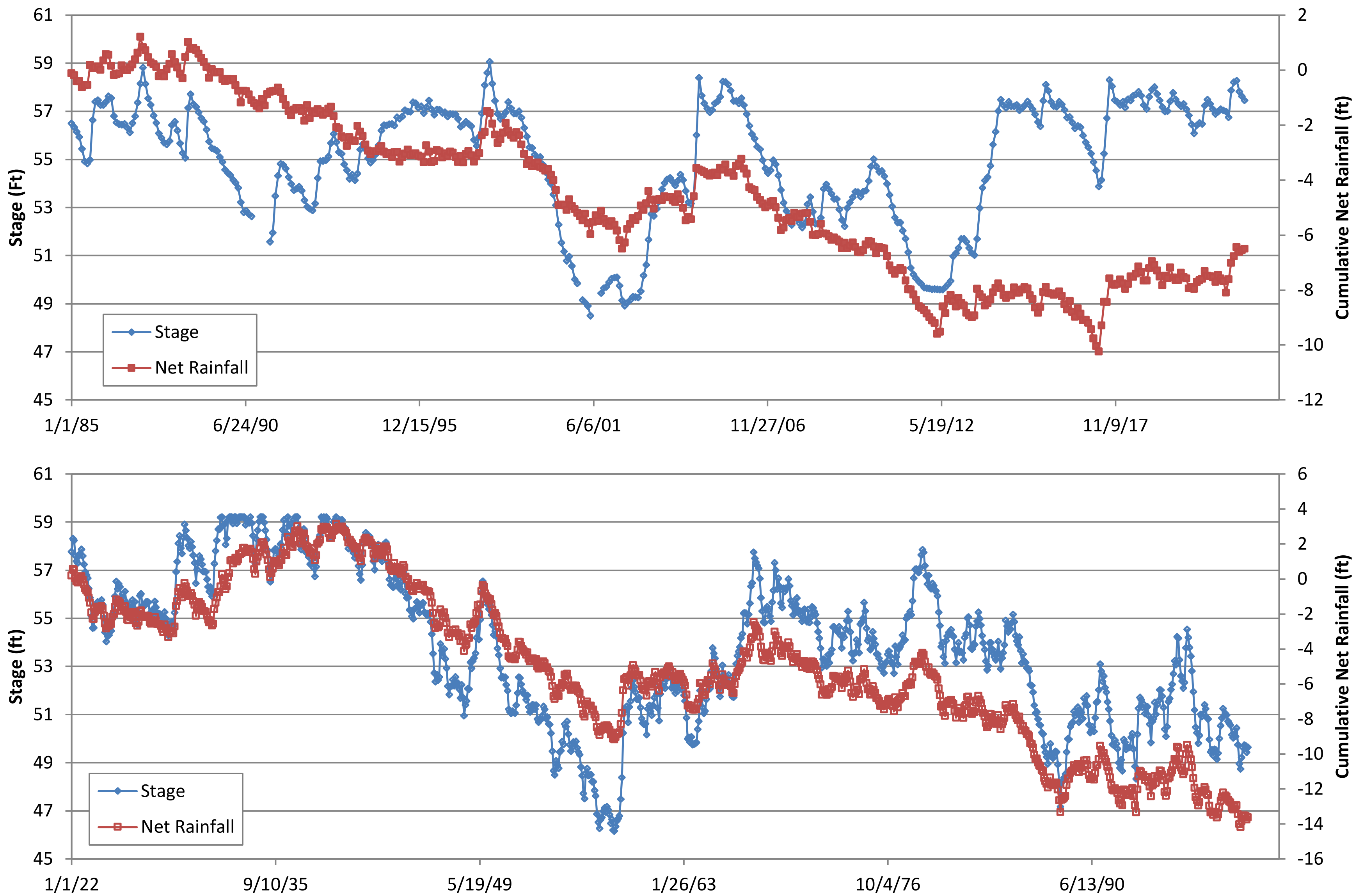


Figure 25. Orange Lake Monthly Stage and Net Rainfall for the Historic (Top) and Future (Bottom) Projected Period

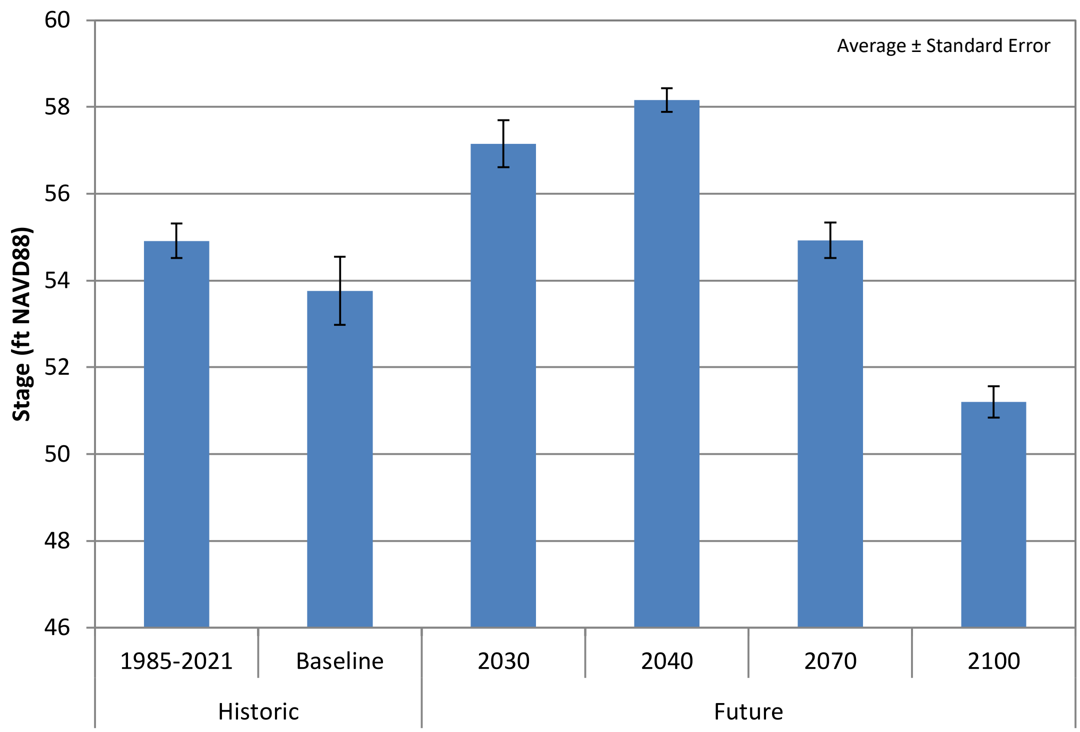


Figure 26. Orange Lake Annual Average Stage for Historic and Future Model Periods

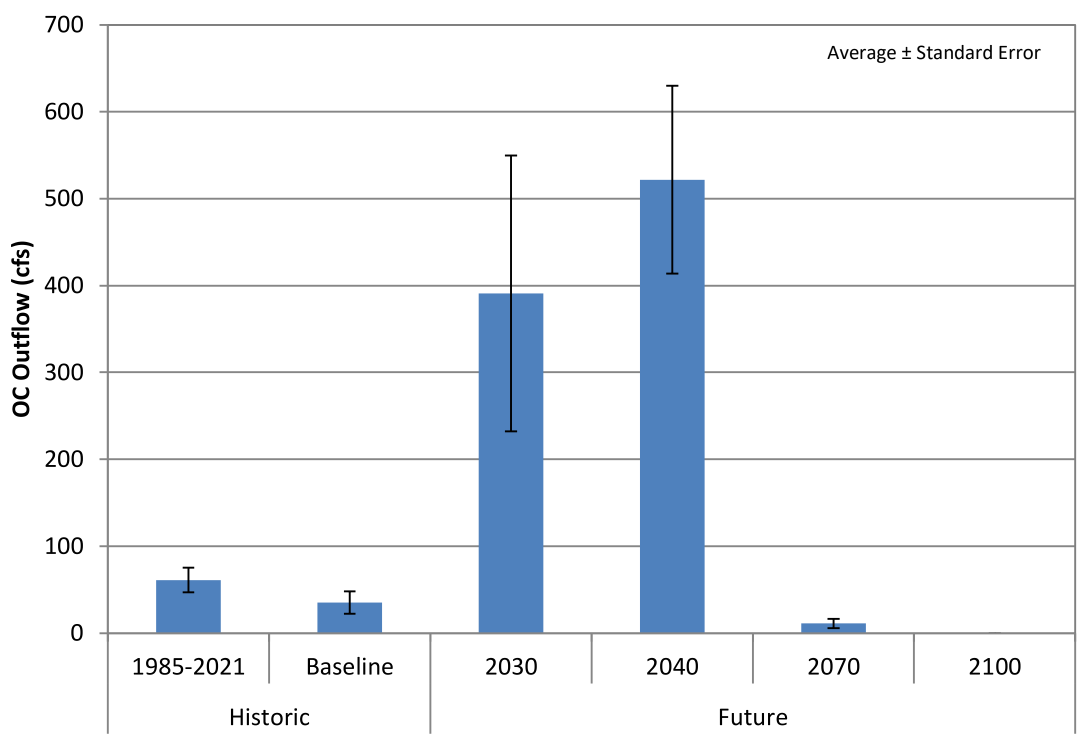


Figure 27. Orange Lake Annual Average Orange Creek Outflow for Historic and Future Model Periods

2.2.1.3.3 Lake Area

Orange Lake wet areas were also estimated using modeled stage estimates and lake bathymetry information and are summarized in Figure 28. As with lake stage, average wet areas are projected to decrease from approximately 7,700 acres during the historic period (6,900 acres during the baseline period) to about 5,100 acres in 2100. Average lake areas in 2030 and 2040 were above the historic period and above the available stage-area relationship but were estimated based on a data fit of the available data to be about 9,400 and 10,300 acres, respectively.

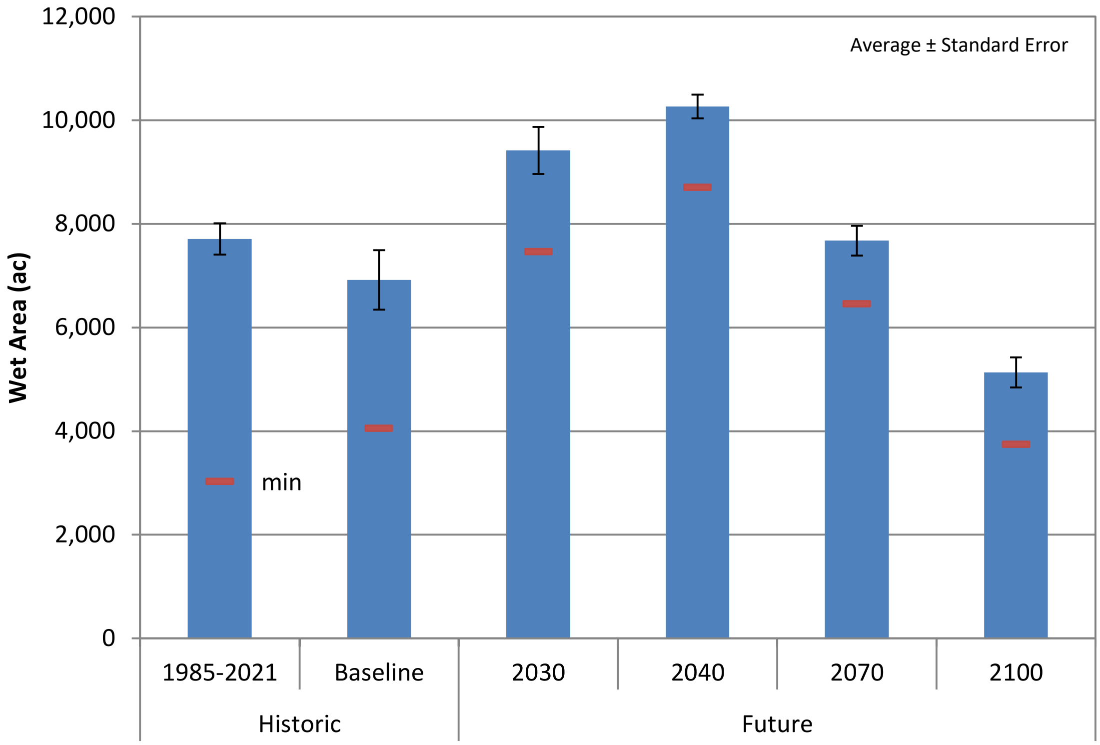


Figure 28. Orange Lake Annual Average Area for Historic and Future Model Periods

2.2.1.4 Lake Summary

Changes in climate are expected to have varying effects on waterbodies within the County. This includes significant decreases in levels, areas, and outflows in Newnans Lake and Orange Lake with smaller changes in levels in Lake Santa Fe and flows in the Santa Fe River. Percent changes in lake stages are shown in Figure 29, with changes in lake areas shown in Figure 30. These are average changes for the decade and do not include the minimum stages and areas that occur during the reported decade. For each of the lakes the average future condition in 2030 and 2040 was expected to be wetter, resulting in elevated stages. This was most pronounced in Orange Lake where stages were expected to increase by 6% and 8% in 2030 and 2040, respectively. By 2070, Newnans Lake was expected to experience decreases in stage of less than 1% compared to the baseline period. By 2100, both Newnans Lake and Orange Lake were expected to have negative departures from the average during the baseline of -5% and -3%, respectively. Lake areas showed a similar trend except that Orange Lake was shown to have a substantial average area increase in 2030 and 2040 of 36% and 48%, respectively. By 2100, both Newnans Lake and Orange Lake were expected to experience significant declines in the average lake surface area of -30% and -26%, respectively.

2.2.2 Santa Fe River

2.2.2.1.1 Rainfall and Evapotranspiration

Figure 31 provides a timeseries of the annual average rainfall and RET data for the historic and future projected time-periods developed for this project. Annual average totals for the historic, baseline, and future time periods are summarized in Figure 32. Annual average rainfall increased from 48.7 inches during the historic period (44.6 inches for the baseline period) to 56.5 inches in 2100. While average RET increased from 51.2 inches during the historic period (50.9 inches for the baseline period) to 60.5 inches in 2100.

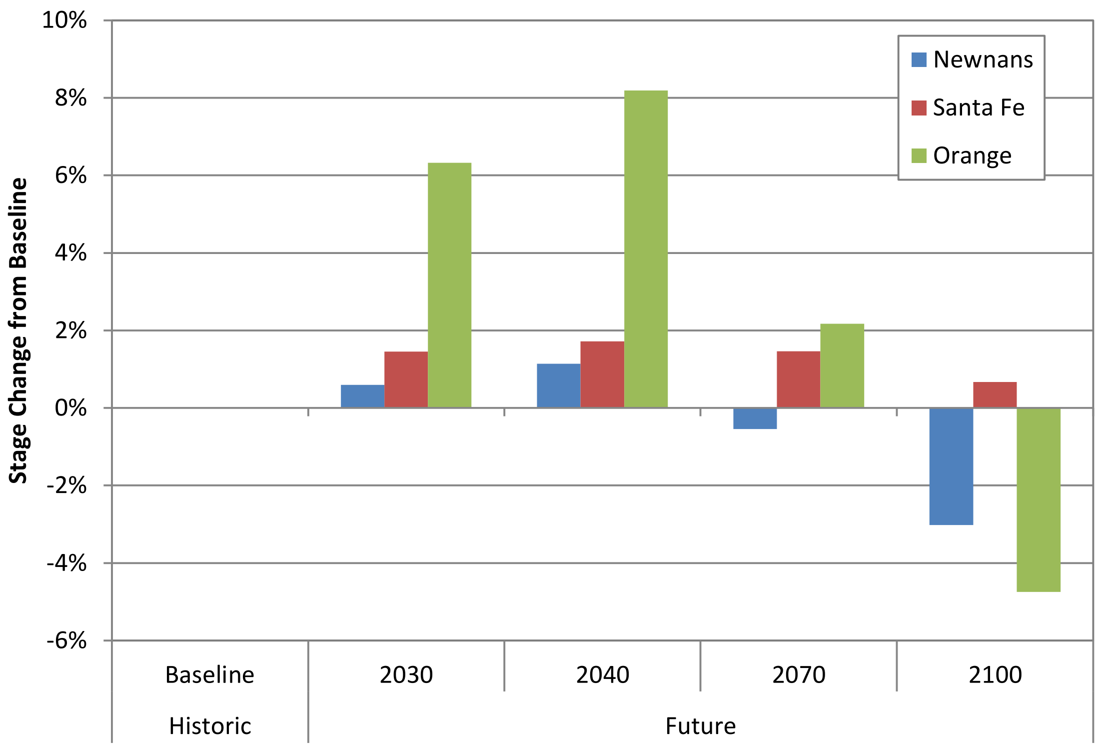


Figure 29. Percent Change in Lake Stage from Baseline

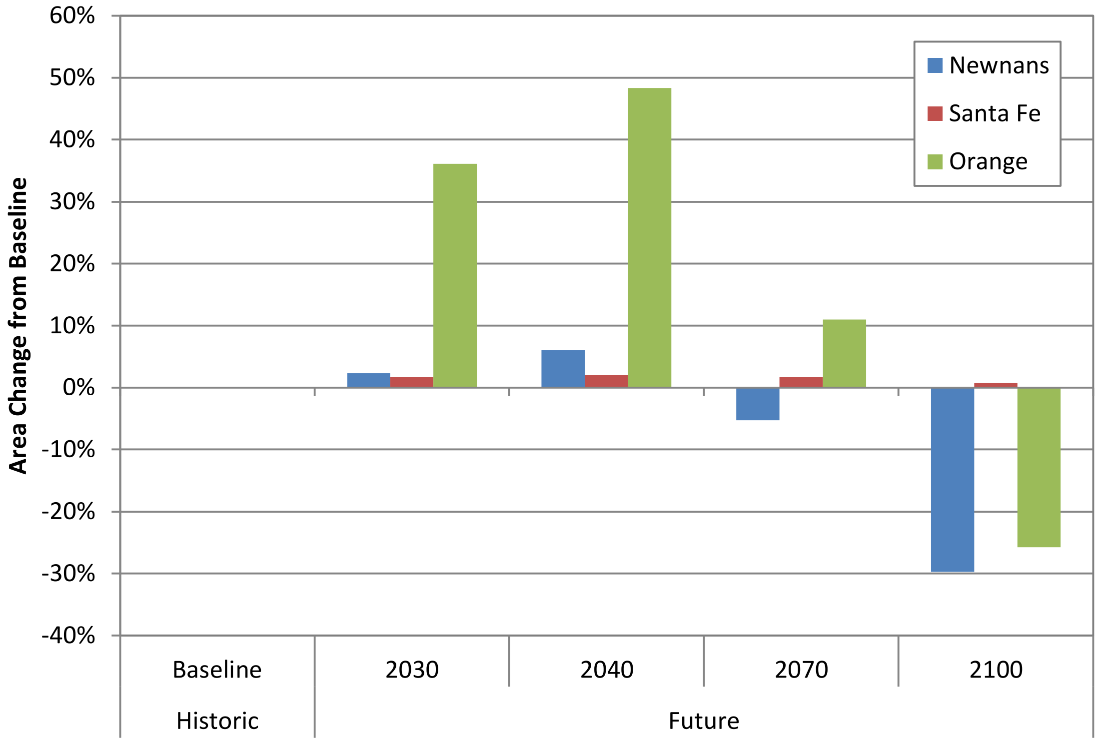


Figure 30. Percent Change in Lake Area from Baseline

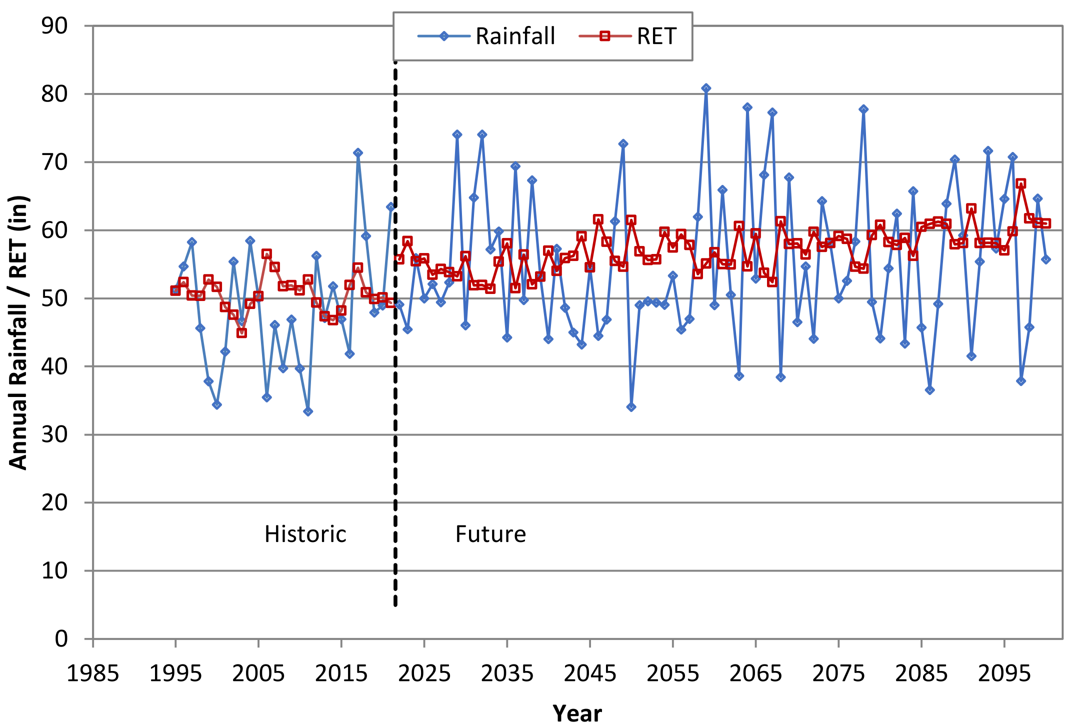


Figure 31. Santa Fe River Annual Rainfall and RET

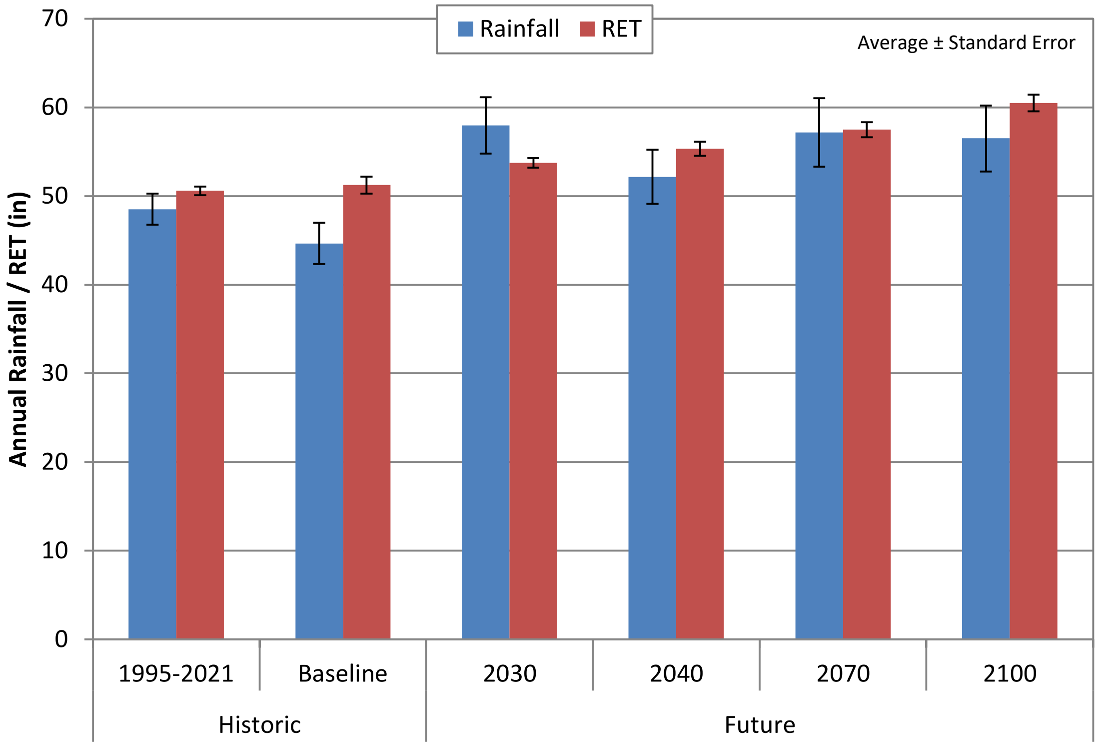


Figure 32. Santa Fe River Average Annual Rainfall and RET for Historic and Future Model Periods

2.2.2.1.2 Santa Fe River Flows

Figure 33 presents annual average flows for the Santa Fe River during the historic period (1995-2021) and modeled annual average flows during the future projected period (2022-2100). Santa Fe River flows were modeled following separation into baseflow and runoff using the USGS local-minimum baseflow separation method described in Section 2.1.2.2. The modeled baseflows were calculated using the relationship between the three-year average net rainfall and the historic annual baseflow (Figure 10). Santa Fe River runoff was then calculated using the relationship between net rainfall and runoff (Figure 11). Modeled baseflow and runoff flows, shown in Figure 34, were summed to yield the average annual flows for the Santa Fe River.

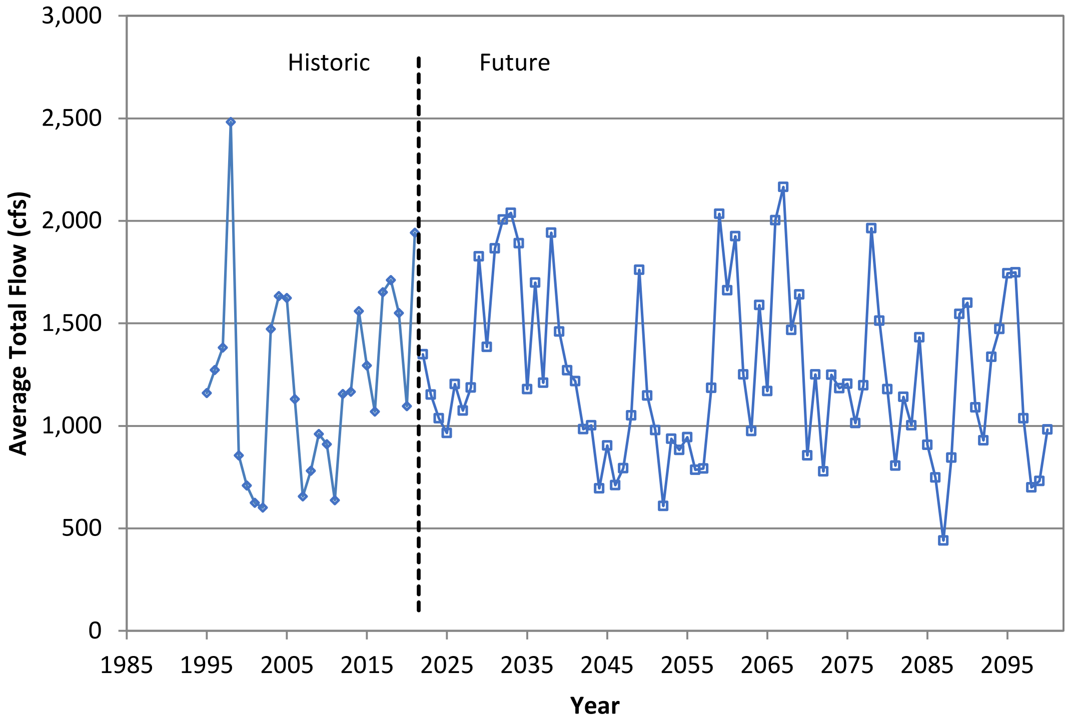


Figure 33. Santa Fe River Annual Total Flow for the Historic and Future Projected Periods

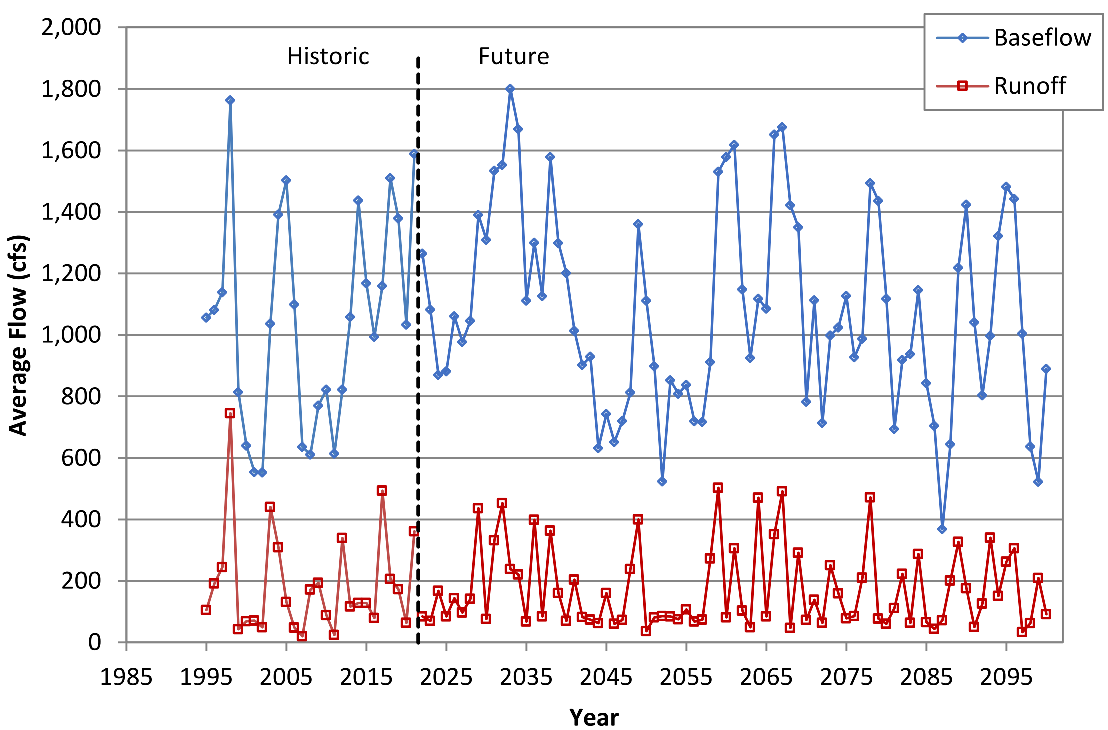


Figure 34. Santa Fe River Annual Baseflow and Runoff for the Historic and Future Projected Periods

Average river flows were estimated to decrease between 2022 and 2100, although with the exception of a single year (2087), flows were projected to be within the range of flows observed during the historic period. Additionally, the years with the highest average flows appeared to be lower than during the historic period with no years exceeding the year with the highest average flow in the historic record (1998). Decreases in total flow appeared to be primarily driven by decreases in baseflow observed in the later portions of the modeled period (Figure 35). Decreases in baseflow could result in changes in the frequency of brownouts in springs, but the frequency of these events is driven by short-term high flows when the stage of the river exceeds the potentiometric elevation at the spring, allowing tannin-stained water to backflow into the spring vent. These events occur at a temporal scale that is not captured in the modeling approach used for this study.

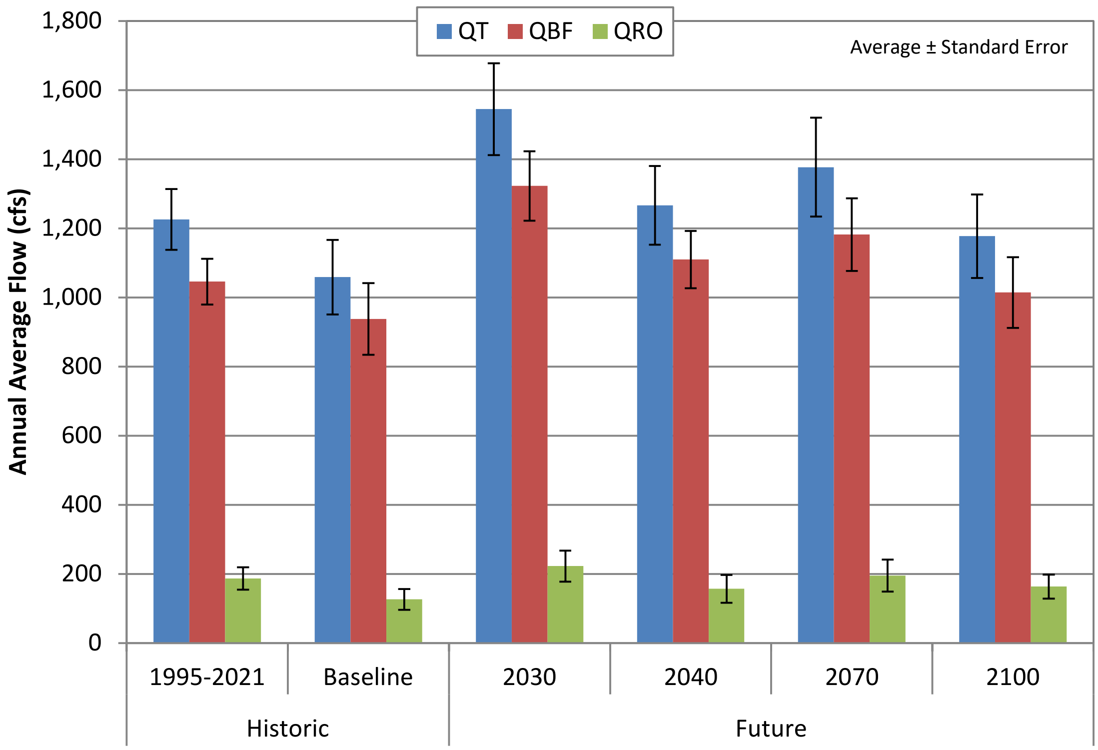


Figure 35. Santa Fe River Annual Average Flow (Total, Baseflow, and Runoff) for Historic and Future Model Periods

Section 3.0 References

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