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Freshwater Availability in Guam With Projected Changes in Climate

Guam receives 85 to 116 inches of rain a year, two-thirds of which has historically fallen during the wet season. On average, three tropical storms and one typhoon pass within 80 nautical miles of Guam each year, generally during the rainy season. Both drought and flooding can impact freshwater supply and the associated infrastructure. Department of Defense (DoD) installations and non-military populations on Guam share freshwater resources, which will be impacted by changes in demographics, freshwater demand, and climate. This DoD Strategic Environmental Research and Development Program (SERDP) funded study evaluated potential climate impacts on freshwater supplies in Guam, and identified methods of increasing the water distribution system's resilience.

Climate models were designed for Guam's location and topography to estimate climate and water-use scenarios at the end of the century (2080–99). Future climate scenarios help managers plan a range of adaptive strategies depending on their risk tolerance. This study used the warming scenario RCP8.5, which describes a "high-greenhouse-gas-emissions" and "business-as-usual" future to provide an upper limit for adaptation needs that are relevant to a high-risk system.

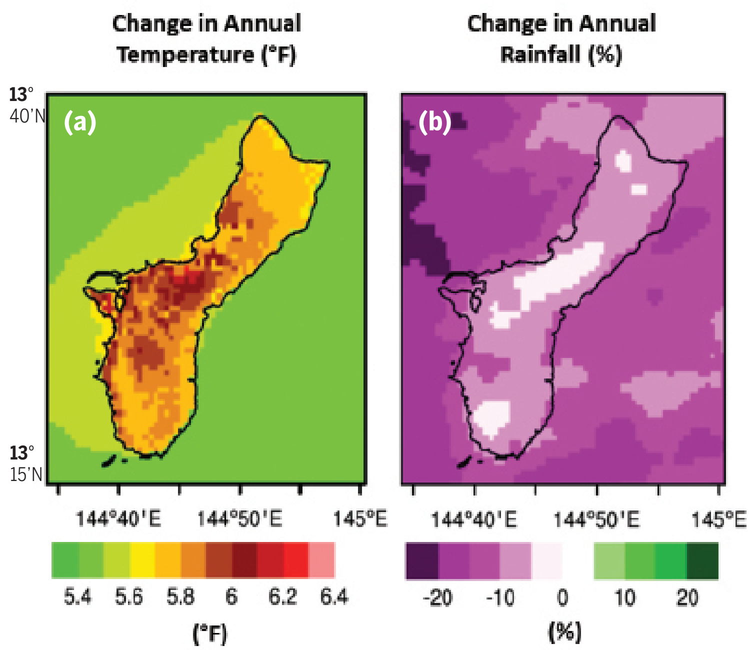

Figure 1. Projected changes in average annual (a) temperature (°F) and (b) rainfall (% change) in 2080–99 using warming scenario RCP8.5 ("business-as-usual"), as compared to the 1990–2009 baseline[11].

Future climate projections for Guam.

In this document, climate and hydrologic projections are for the future period 2080–99, and changes are expressed relative to historic conditions (1990–2009, unless stated otherwise).

- Average annual air temperature on Guam is projected to be 5.8°F warmer[1] in the future (Fig. 1a).
- The number of "very hot days" (days when the air temperature exceeds 90°F) increased from zero days a year in the 1950s to 120 days in 2016[2]. In the future, the number of very hot days is projected to increase further to 257 days a year, or 70% of the year[3].
- Projected average annual rainfall will be about 7% lower[4] (Fig. 1b).
- Average rainfall during the wet season (July to December) is projected to be 12% less, whereas average rainfall during the dry season (January to June) is projected to be 9% more[5].
- Drought conditions are projected to be more frequent, occurring 4 years out of every 10 years, instead of the historic rate of 1.6 years out of every 10 years[6].
- Guam lies within one of the most active tropical storm regions in the world. In the future, typhoons will be less frequent, but stronger. The decrease in rainfall may be due to the projected decrease in the number of storms[7].

Southern Guam is dependent on surface freshwater supplies from rivers and the Fena Valley Reservoir (FVR).

- Future annual streamflow will be about 18% lower in southern Guam, ranging from 12 to 36% lower in different watersheds[8].
- Future annual evapotranspiration will be about 14% higher in southern Guam, and up to 29% higher in some areas, which is partly related to higher temperatures[9].
- Operational costs of the Ugum River treatment plant for water supply have increased because of high turbidity of the river during high-flow events[10].
- The FVR is the DoD's primary water source for the Naval Base and nearby civilians. Its water-storage capacity is reduced over time by sediment buildup. The sediment load to FVR

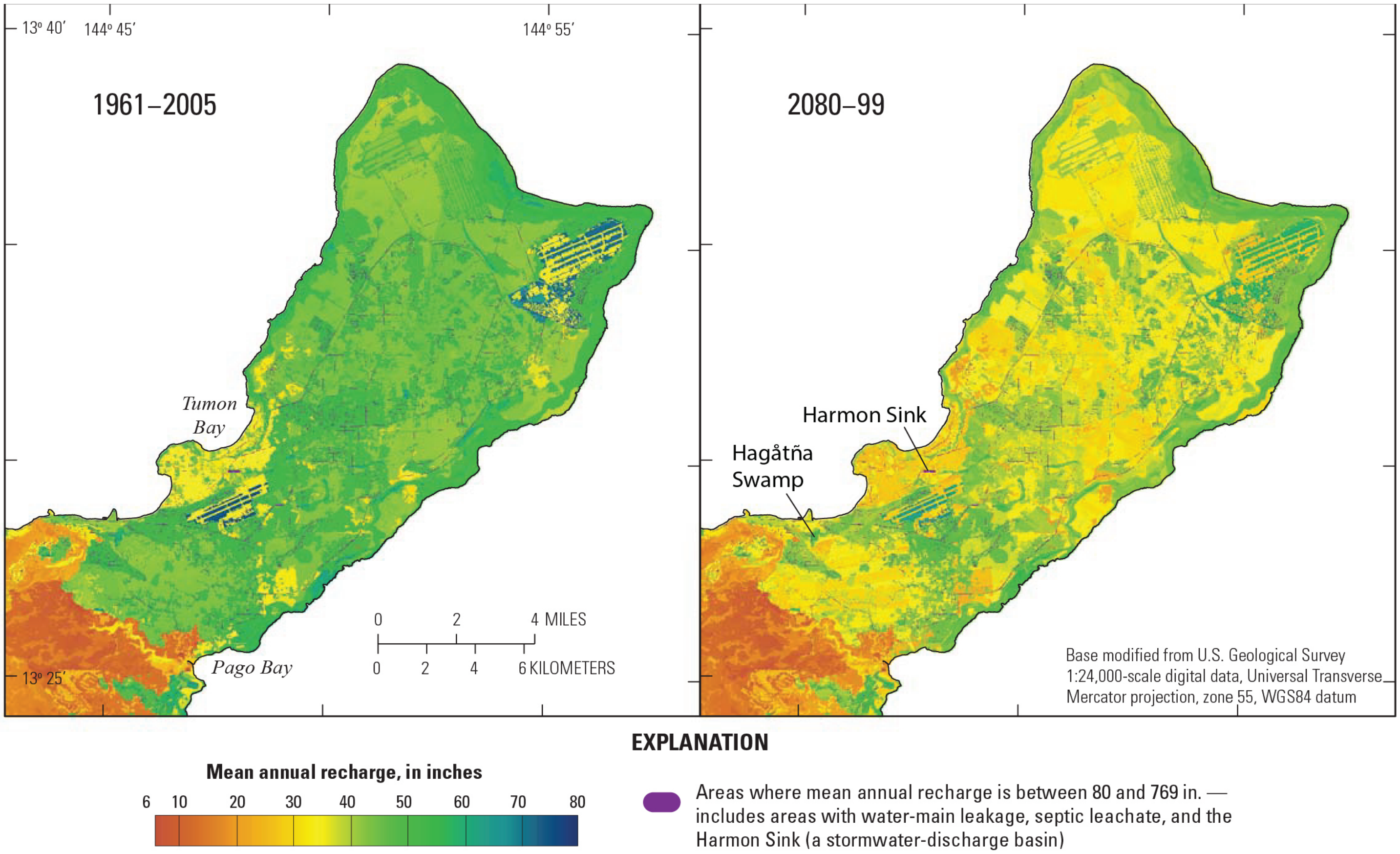

Figure 2. The distribution of mean annual groundwater recharge (in inches) estimated for the Northern Guam Lens Aquifer for historic (1961–2005) and future (2080–99) climate conditions. Modified from Gingerich et al., 2019.

will be 32% less in the future, although stronger typhoons could increase sediment from the increased intensity of rare storms[11].

- A two-year drought simulation highlights impacts from climate change, resulting in the FVR not recovering to the level of the spillway after the dry season, and water levels decreasing to the elevation of the pump intake under sustained pumping of 11 million gallons per day[12].

Northern Guam is dependent on groundwater from the Northern Guam Lens Aquifer (NGLA).

- Future mean annual recharge for the NGLA is projected to be about 19% lower than historic (1961–2005) recharge (Fig. 2)[13].
- Because of the steep coastal topography of northern Guam, even with a rise in sea level of 6.6 feet, only about 0.1% of the land surface would be flooded, mostly in the low-lying Hagåtña Swamp area[14].
- The freshwater lens becomes smaller when withdrawal increases or recharge is reduced. By the end of a two-year drought, groundwater-model results show that wells throughout the NGLA would be expected to become more saline, with 72% of the water withdrawn from the wells having a chloride concentration over 500 mg/L[15]. The U.S. Environmental Protection Agency Secondary Standard for chloride in drinking water is 250 mg/L.
- Increased pumping, sea-level rise, and decreased recharge in a future climate have compounded effects that increase the salinity of groundwater (Fig. 3).
    - A 6.6-ft sea-level rise will have only a minor impact on the current average salinity in the NGLA wells (Fig. 3a).
    - With only the 19% projected decrease in recharge considered, the chloride concentration in 47 production wells moves into a higher concentration category as indicated in the figure legend (Fig. 3b).
    - However, when a 3.3-ft sea-level rise is coupled with the 19% decrease in recharge, 53 wells move into a higher concentration category as indicated in the figure legend (Fig. 3c).

Adaptive management strategies for the FVR and the NGLA.

Warmer, drier conditions and more frequent drought coupled with more intense storms and sea-level rise will negatively impact freshwater resources, but a combination of proactive strategies can mitigate these impacts.

- For the Fena Valley Reservoir, lowering the intake elevation and raising the spillway elevation would increase surface-water avail-

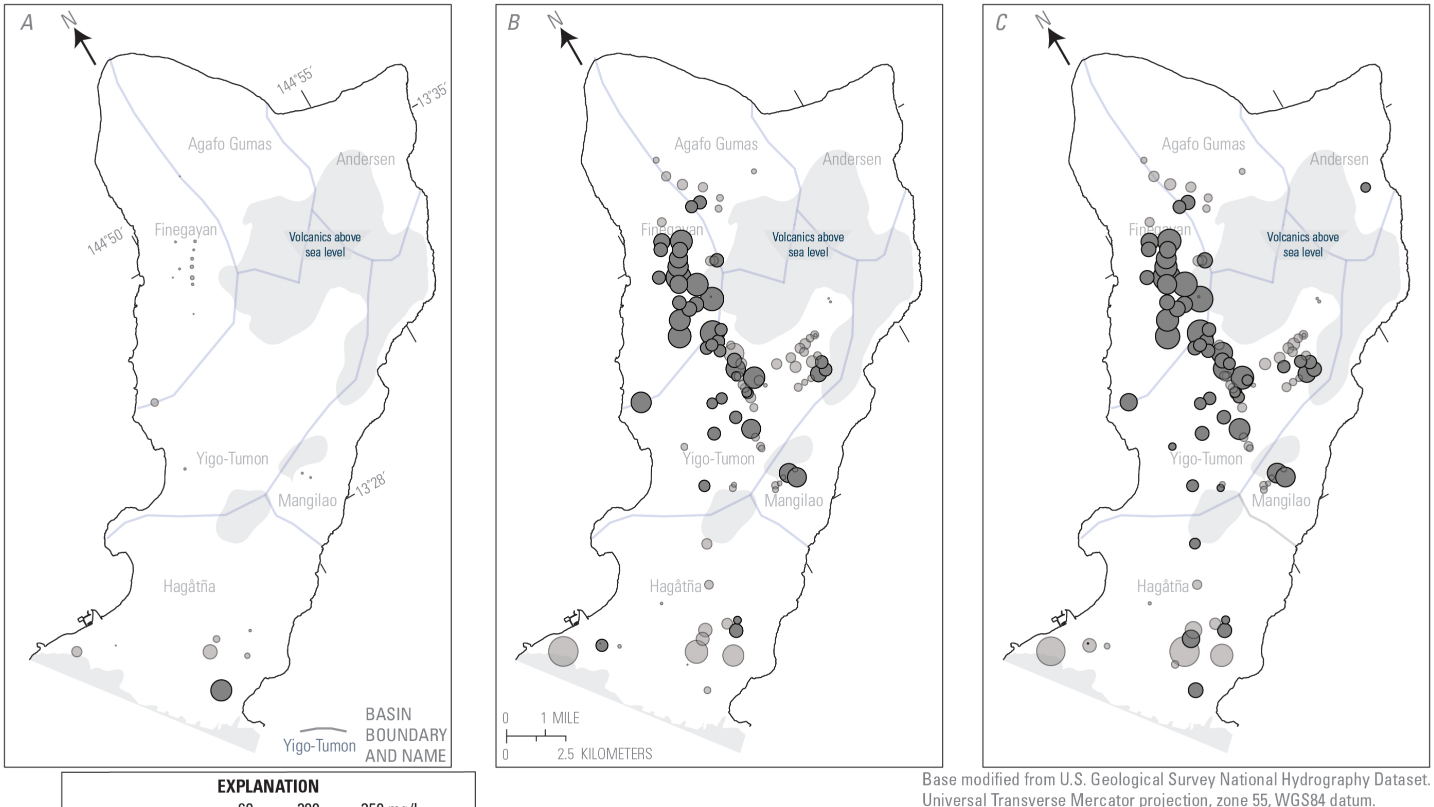

Figure 3. Withdrawal wells with simulated salinity increases for future conditions in the Northern Guam Lens Aquifer for (a) 6.6-ft higher sea level, (b) 19% lower recharge, and (c) 3.3-ft higher sea level and 19% lower recharge. Wells shown in dark gray are those that have chloride-concentration increases large enough to move into a higher concentration category as indicated in the figure legend[16].

ability and lessen the time spent in critical water-conservation conditions, but the benefits must be considered relative to the costs[17].

- In the NGLA, reducing the depth and the withdrawal rates of high-salinity production wells penetrating near the freshwater/saltwater transition zone will reduce the number of negatively impacted wells (Fig. 4)[18].
- Increasing awareness and knowledge among community leaders and members about how water systems may be impacted by climate change and variability, especially before the dry season, can increase Guam's resilience.

For information on how scientists make these projections about future climate in Guam, and links to articles about the models, please visit **www.PacificRISA.org/projects/guam-serdp/.**

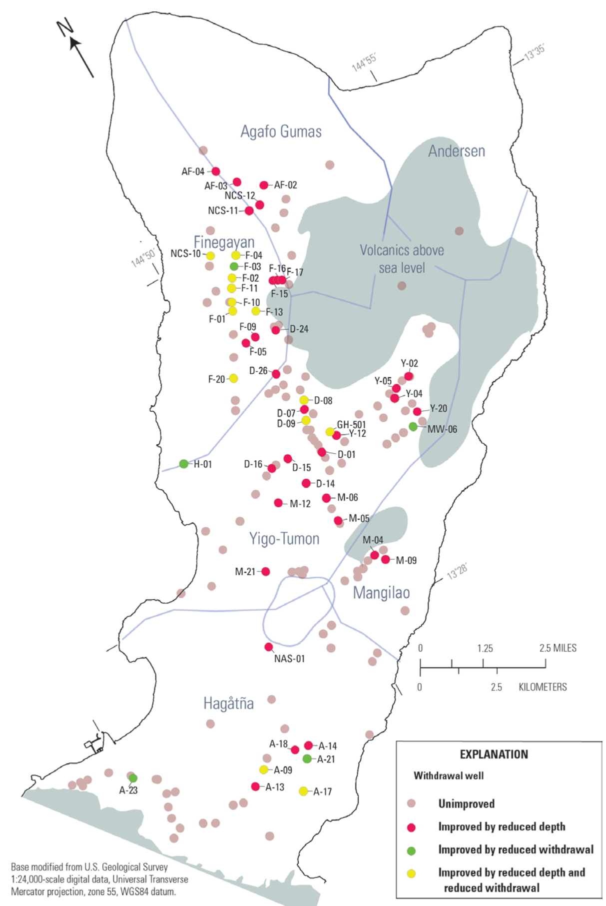

Figure 4. Withdrawal wells in which salinity would be reduced by shortening well depths or reducing withdrawal rates in the future (2080–99) recharge scenario, Northern Guam Lens Aquifer, Guam[11].

Endnotes

[1] Zhang, C., 2016, Dynamical downscaled and projected climate for the Pacific Islands/Guam: https://cida.usgs.gov/thredds/catalog.html?dataset=cida.usgs.gov/guam.

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[3-6] Zhang, 2016.

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[13-18] Gingerich et al., 2019.

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