Extreme Weather Vulnerability Assessment - ADOT Pilot Study for Transportation Infrastructure

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Abstract

The Arizona Department of Transportation (ADOT) conducted a pilot study to assess the vulnerability of its infrastructure to extreme weather, including high temperatures, drought and intense storms within the context of the surrounding landscape. Understanding the risks and identifying vulnerable sections of the roads will allow ADOT to spend construction and maintenance dollars more efficiently while improving public safety. The pilot study focused on a 322-mile study corridor from Nogales through Tucson, Phoenix and up to Flagstaff. The analysis considered high temperatures, drought, and intense storms and how they contribute to dust storms, wildfire and flash flooding as well as how these stressors affect pavement, bridges and culverts, and road closures.

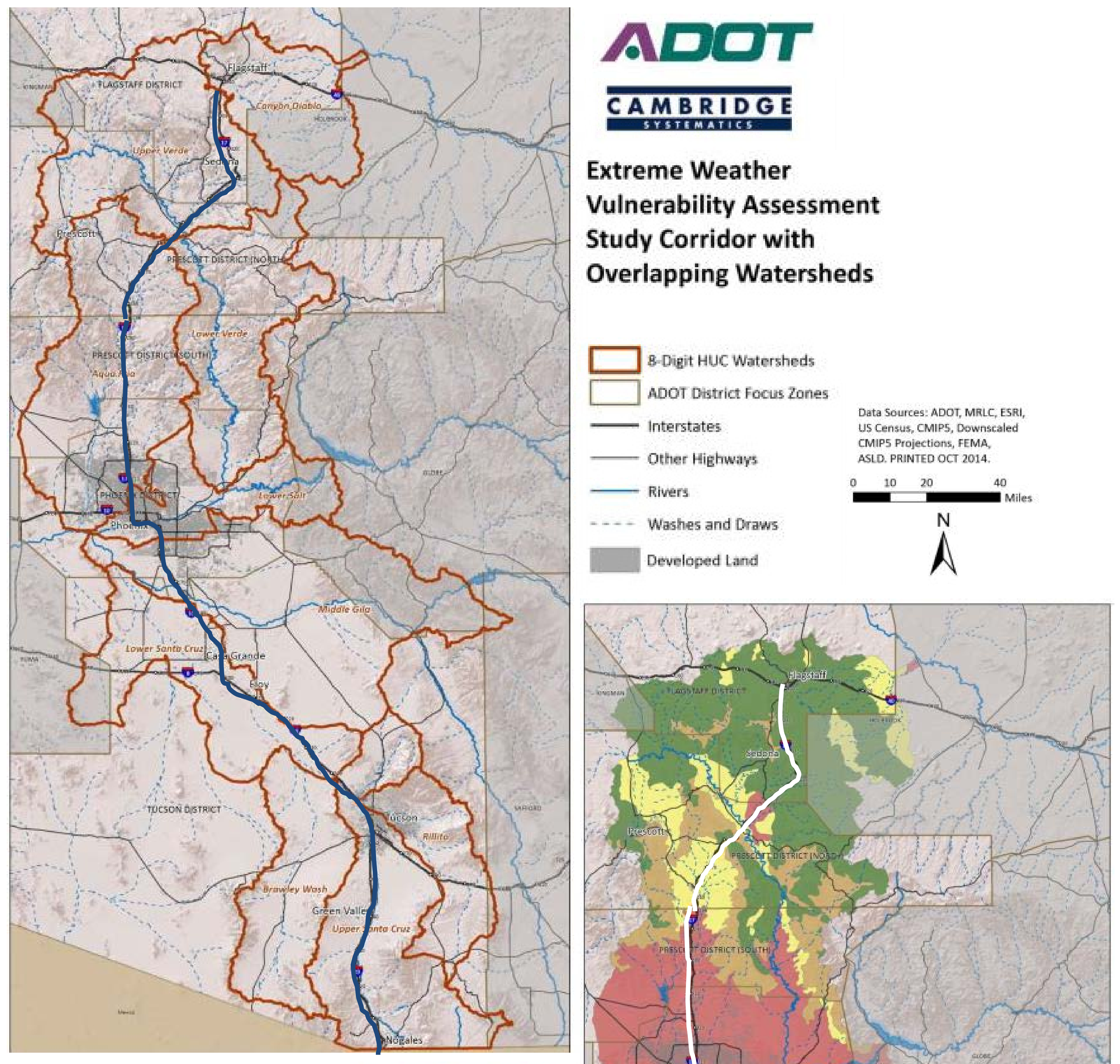
The pilot study was based on a framework for vulnerability assessment and adaptation developed by the Federal Highway Administration (FHWA). Nineteen groups are piloting the framework; ADOT's study is one of the first to consider multiple biotic communities in the analysis. The objectives of the study were:

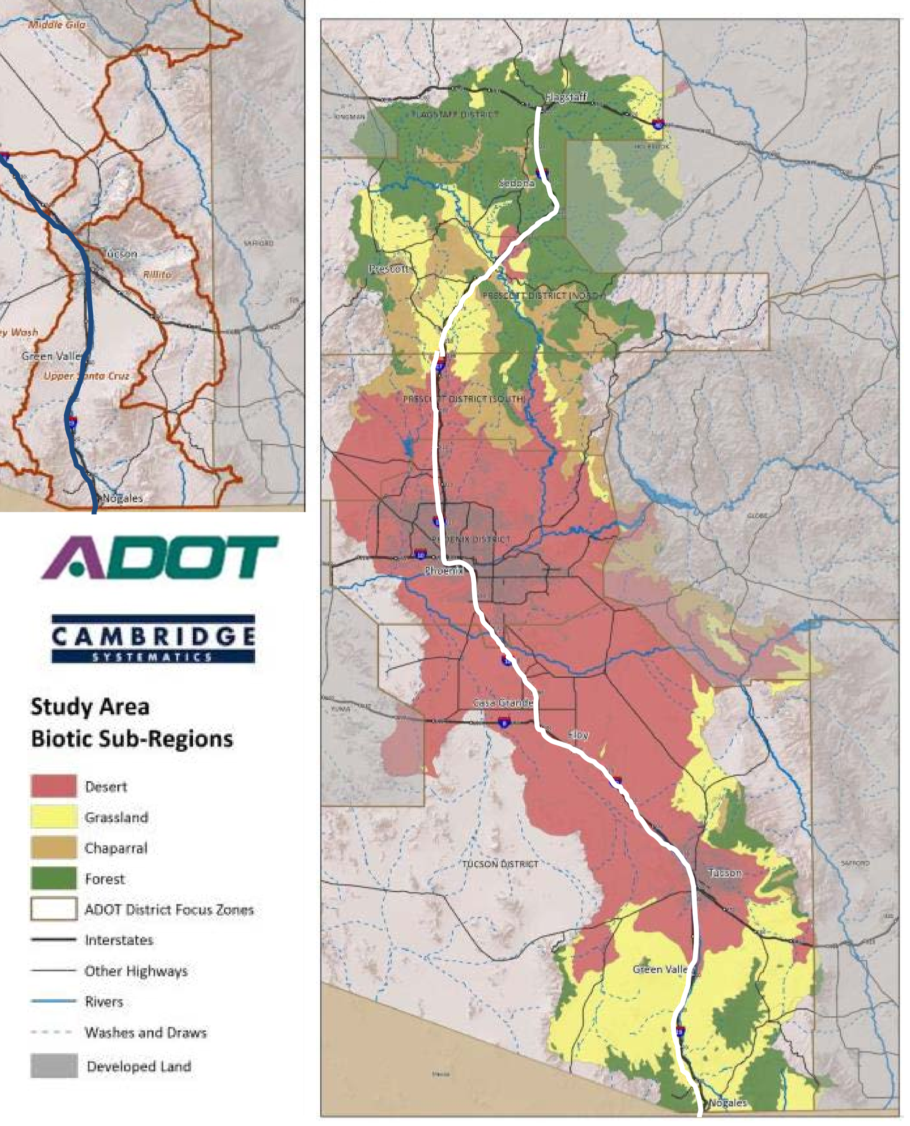
(1) identify and prioritize vulnerable assets and stressors of most concern within the study corridor, and

(2) assess the effects of extreme weather stressors in different biotic communities within the study corridor with the goal of developing model approaches for assessing transportation infrastructure throughout the state.

Input was gathered from a large number of internal and external stakeholders. The results of the pilot study will be used to inform further research, both more intense analysis of portions of the initial study corridor as well as extending the analysis to additional roads in the state highway system.

Study Area: Corridor, Watersheds and Land Cover





Stressors

Climate Variables	Direct Stressors	Secondary stressors
Maximum Temp	Extreme heat	Dust, Wildfire
Minimum Temp	Freeze frequency	Rockfall, Landslide
Max Precipitation	24 hr precipitation	Flood
Min Precipitation	Drought	Dust, Wildfire

Grouping of Biotic Communities into Land Cover Types

Biotic Community (Brown and Lowe 1982)	Land Cover Type	ADOT Districts
Interior Chaparral	Chaparral	Prescott, Flagstaff
Arizona Upland Sonoran Desertscrub	Desert[a]	Tucson, Phoenix, Prescott
Lower Colorado River Sonoran Desertscrub		
Chihuahuan Desertscrub[b]		
Great Basin Desertscrub[b]		
Great Basin Conifer Woodland	Forest	Tucson, Prescott, Flagstaff
Madrean Evergreen Woodland		
Petran Montane Conifer Forest		
Plains and Great Basin Grassland	Grassland	Tucson, Prescott, Flagstaff[b]
Semidesert Grassland		

[a] The larger urban areas in the study area are located within the Desert land cover type.
[b] Limited presence in study area or district.

Regional Risk Summary

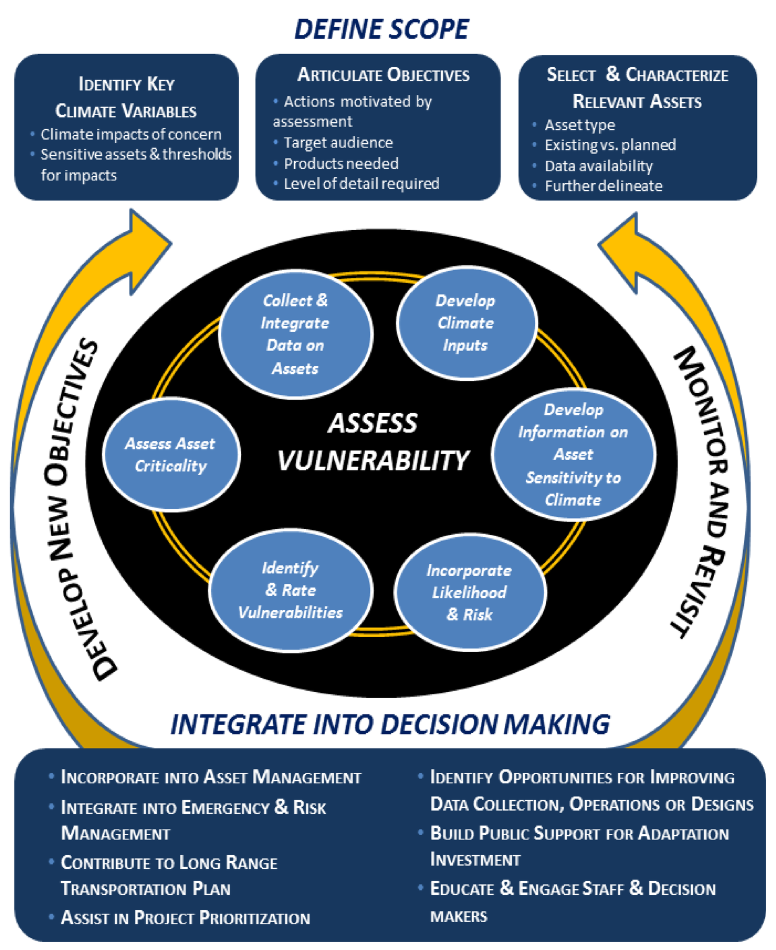
Region of Study Corridor	Extreme Heat	Freezing Temps	Extreme Precip	Wildfire Risk
Northern	+	-	<?>	+++?
Central	++	-	<?>	+?
Southern	++	-	<?>	++?

+: increased frequency/costs; -: decreased costs, <>: equivocal, ?: uncertain

Future steps

- Expand data sets used to assess repeated maintenance actions and road closures
- Expand analysis to include state highways and state routes, which may be more susceptible to effects of extreme weather
- Hydrologic modeling of runoff and flooding risks with updated USGS StreamStats modules
- Refine wildfire and dust analyses with help of external stakeholders
- Incorporate changing biotic community composition and geographic distribution over time
- Cost benefit analysis of different adaptation strategies
- Consider integrating risks into a scenario planning framework

FHWA Vulnerability Assessment Framework



Particular Transportation Concerns

- Match time frames to transportation planning horizons
- Output parameters comparable to those used in engineering design
- Which CMIP models to use with focus on extreme events rather than averages?
- Direct relevance to design and maintenance decisions

Downscaled Climate Projections - U.S. DOT's CMIP Processing Tool

Climate Data Parameters

Parameter	Selection for Assessment
Projections and Historical Data Source	CMIP5 Bias Corrected – Spatially Disaggregated (BCSD) daily projections and historical data
Emissions Pathway	Representative Concentration Pathway 8.5
Downscaled General Circulation Models (GCM)	NorESM1-M, HadGEM2-ES, CSIRO-MK3.6, CanESM2, MPI-ESM-LR, MPI-ESM-P, GFDL-ESM2M
Horizontal Spatial Resolution	1/8° (~7.5 mile or ~12 km)
Temporal Resolution	Daily for 1950-2000 (backcasting from models in addition to historical data), 2025-2055, and 2065-2095

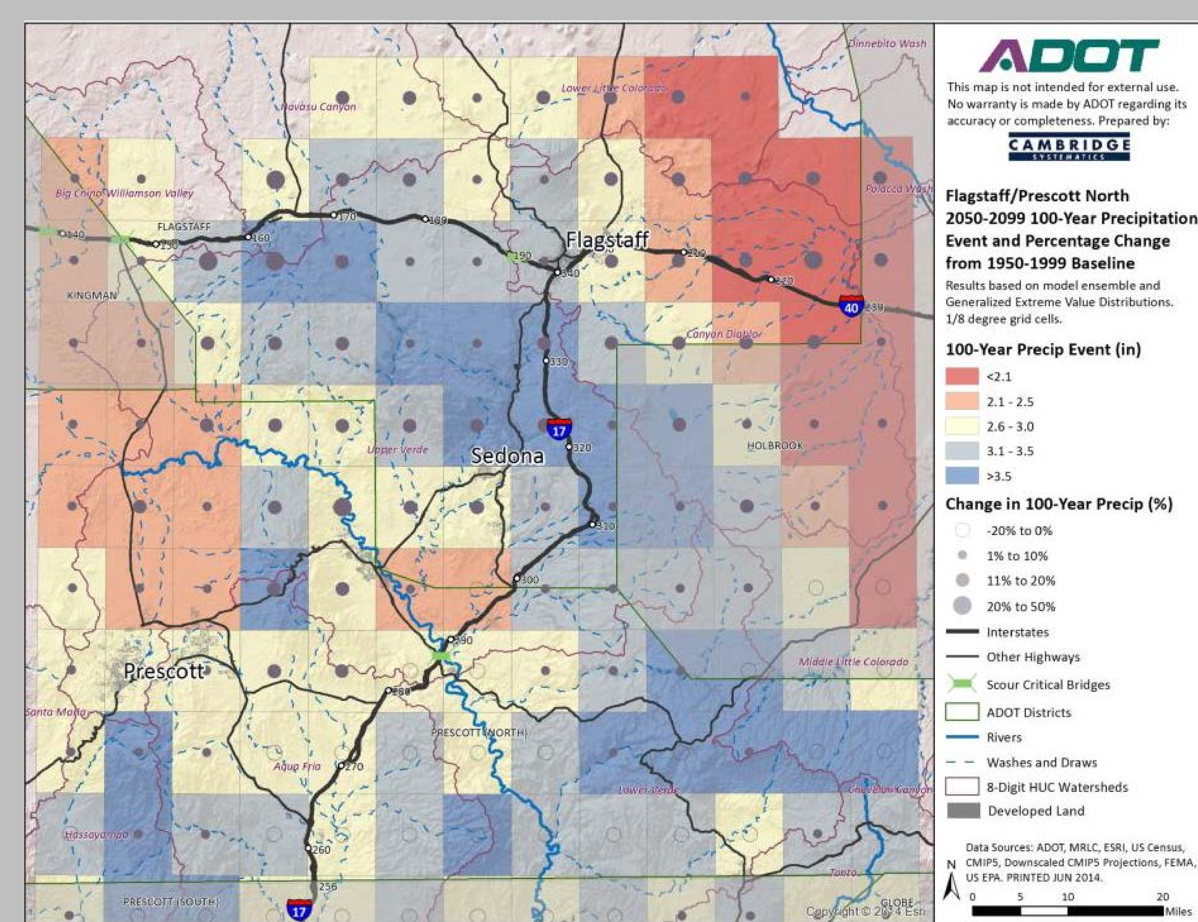
[a] The team acknowledges the World Climate Research Programme's Working Group on Coupled Modeling, which is responsible for CMIP; and we thank the climate modeling groups (listed in Table A.2 of this paper) for producing and making available their model output. Downscaled CMIP5 projections and accompanying historical observations may be downloaded from the "Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections" archive at gdo-dcp.ucllnl.org.

Climate Data Fields Summary

Field Name(s)	Temporal Periods
Maximum 1-Day Precipitation Event (by time period)	1950-1999 (backcasting[a] and historical), 2000-2049, 2050-2099
100-/200-Year Maximum Precipitation Event[b]	
Minimum Annual Precipitation	1950-1999 (backcasting and historical), 2025-2055, 2065-2095
Average Annual Precipitation	
Average Number of Days Per Year in which Precipitation Exceeds Baseline Period's 99th Percentile Precipitation Event	
Average May-June-July-August Precipitation	
Average Daily Maximum Temperature	
Maximum Temperature	
Average Number of Days Per Year in which Temperature equals or exceeds 100 degrees	
Average Number of Days Per Year in which Temperature equals or exceeds 110 degrees	
Average Number of Days Per Year in which Temperature falls below or is equal to 32 degrees	
Average Daily Minimum Temperature	

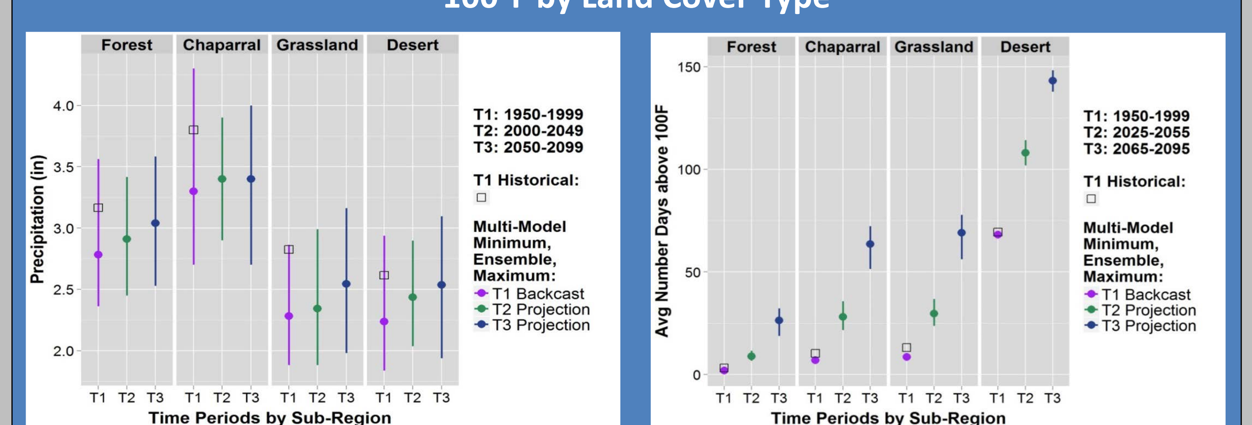
[a] In this context, the term "backcasting" (also called "hind-casting") refers to the simulation of past climate conditions (effectively, the opposite of a "forecast," which simulates future conditions). Comparing backcasted values with actual historical values is an important step in validating climate models.
[b] Added feature. Estimated by fitting Generalized Extreme Value (GEV) distribution to annual precipitation maxima. 2000 to 2049 and 2050 to 2099 are the future analysis periods for GEV-generated projections.

Projected 100-Year (1-Percent Chance) Rainfall (2065 to 2095), Flagstaff District



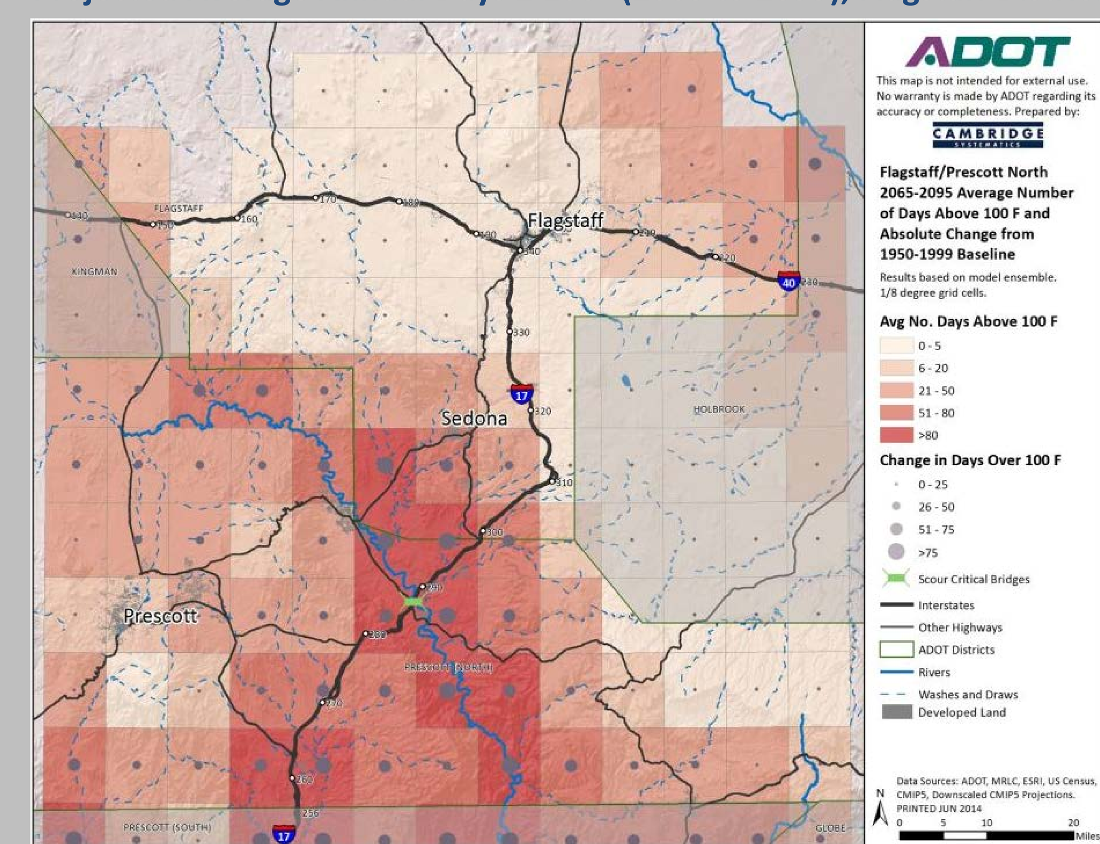
Consistent with NOAA Atlas 14, the elevated areas south of Flagstaff (such as Oak Creek Canyon) and, to a lesser extent, south of Prescott (such as Groom Creek), are projected to experience relatively greater extreme rainfall volumes. However, ensemble projections generally show increases in magnitude north of MP 300 and decreases south of MP 300.

100-Year Precipitation Magnitudes and Average Number of Days above 100°F by Land Cover Type[a]

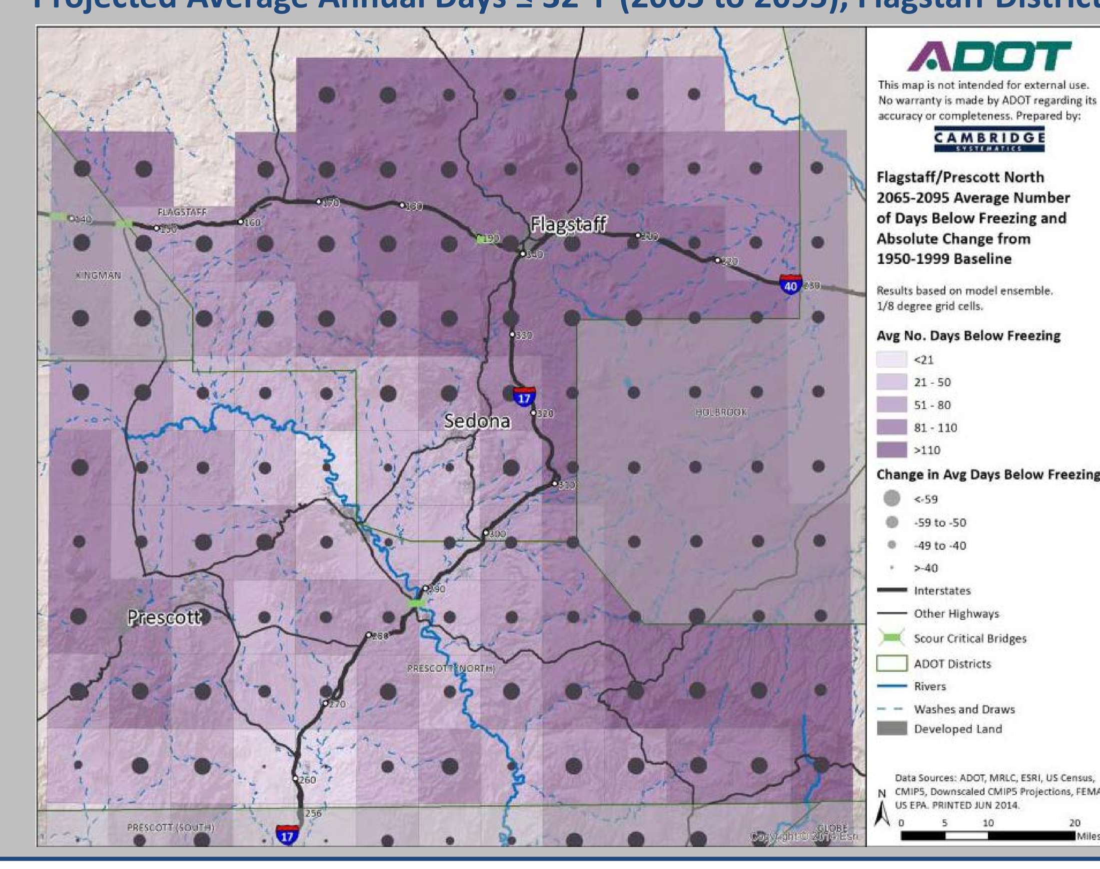


[a] Values represent blended averages by land cover type over the entire study area.

Projected Average Annual Days ≥ 100° (2065 to 2095), Flagstaff District



Projected Average Annual Days ≤ 32°F (2065 to 2095), Flagstaff District



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