ENTERPRISE-WIDE CLIMATE CHANGE ANALYSIS FOR INRMPS

CLIMATE CHANGE SUMMARIES FOR INCORPORATION INTO INSTALLATION INRMPS

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ACRONYMS

AFCEC	U.S. Air Force Civil Engineer Center
ATP	Army Techniques Publication
BMGR	Barry M. Goldwater Range
CCSM	Community Climate System Model
CONUS	Contiguous United States
CSU	Colorado State University
DoD	Department of Defense
GAP	Gap Analysis Project
GDD	Average annual accumulated growing degree days with a base temperature of 50 °F
INRMP	Integrated Natural Resources Management Plan
IPCC	Intergovernmental Panel on Climate Change
ISI-MIP	Inter-Sectoral Impact Model Intercomparison Project
LOCA	Localized Constructed Analogs
MC2	Dynamic Global Vegetation Model
NCAR	National Center for Atmospheric Research
NLCD	National Land Cover Database
OCONUS	Outside the Contiguous United States
PRECIP	Average annual precipitation
RCP	Representative Concentration Pathway
T&E	Threatened and Endangered
TAVE	Annual average temperature
TMAX	Annual average maximum temperature
TMIN	Annual average minimum temperature
USAF	U.S. Air Force
USGS	U.S. Geological Survey

1 BACKGROUND

The Air Force Civil Engineer Center (AFCEC) engaged Colorado State University (CSU) to help U.S. Air Force (USAF) installations meet Department of Defense (DoD) requirements for inclusion of climate change in Integrated Natural Resource Management Plans (INRMPs). These requirements are formalized in the following documents.

- DoD Directive 4715.21, Climate Change Adaptation and Resilience states that DoD Component Heads shall: integrate climate considerations into DoD Component policy, guidance, plans, and operations; assess and manage risks to built and natural infrastructure, including changes to natural resource management; and leverage authoritative environmental prediction sources for appropriate data and analysis products to assess weather and climate impacts.
- DoDM 4715.03, Integrated Natural Resources Management Plan (INRMP) Implementation Manual, Enclosure 5 states that INRMP contents should contain an assessment of natural resource management that include effects of climate change. Enclosure 8, Planning for Climate Change Impacts to Natural Resources, provides data sources and processes for including climate considerations into INRMPs.
- AFI 32-7064, Integrated Natural Resources Management, Sections 3.8.2 states the effects of climate change should be included in plans to restore native ecosystems and Section 3.8.3. Climate Change, states:

  > *Changing climate conditions may significantly affect native ecosystems and require the Air Force to adjust natural resources management strategies to support military mission requirements and address the needs of sensitive species. INRMP goals and objectives for ecosystem management and biodiversity conservation must consider projected climate change impacts, and favor an adaptive ecosystem-based management approach that will enhance the resiliency of the ecosystem to adapt to changes in climate. The INRMP will assess climate change risks, vulnerabilities, and adaptation strategies using authoritative region-specific climate science, climate projections, and existing tools. The INRMP should list, or include by reference, installation-specific climate data and region-specific climate projections from the most current quadrennial National Climate Assessment Report, and include other pertinent Federal climate science documents as appropriate.*

This report is set up to serve two purposes:

1. provide text and appendices to be inserted into an installation INRMP and
2. provide information for installation stakeholder consideration as they evaluate management action options to address natural resource issues.

1.1 What did the CSU Team do?

A team comprising CSU climate scientists, ecologists, environmental planners, military land managers and engineers reviewed the INRMP for the installation, generated site-specific downscaled temperature and precipitation climate projections for two future emission scenarios, and used tools and models to assess impacts of future climate on the installation's natural resources. The CSU assessment is based primarily on publicly available data and augmented with spatial data obtained through AFCEC with appropriate permissions. In addition, the CSU team compiled potential adaptation strategies for installation consideration during goal, objective, and work plan development.

1.2 How was the Climate Data Generated for this Report?

Climate data used in this report were generated originally for international climate assessment reports sanctioned and provided by the Intergovernmental Panel on Climate Change (IPCC-CMIP5) (Hibbard, Meehl, Cox, & Friedlingstein, 2007; Moss et al., 2008, 2010), and subsequently used by the US Fourth National Climate Assessment Report (USGCRP, 2017). Coordinating with AFCEC, a base historical time period was established and two future time horizons and two future emission scenarios were chosen. Emission scenarios are based on assumptions about future worldwide changes in demographic development, socio-economic development, and technological change that result in different greenhouse gas concentrations in the atmosphere. Site-specific temperature and precipitation climate projections were generated.

- Timeframes:
    - 30-year baseline (historical climate between 1980 to 2009 (inclusive) for the bases located in the contiguous United States (CONUS) and 1975 through 2004 (inclusive) outside the contiguous United States (OCONUS) bases
        - The historical climate data represent the 30-year historical reference point used by the IPCC to define climate change scenarios
    - 2030 (climate data from 2026 to 2035 to represent the decadal average for 2030)
    - 2050 (climate data from 2046 to 2055 for the decadal average for 2050)
- Future emission scenarios:
    - Representative Concentration Pathway (RCP) 4.5—moderate emission scenario
    - RCP 8.5—high emission scenario
- Historical climate data source:
    - CONUS: Historical daily climate data used is DAYMET (Thornton, Thornton, & Mayer, 2012) at approximately 1 km spatial resolution. These data were spatially averaged over the base to represent the base average climatology.

  - OCONUS: Historical daily data derived from the HadGEM2-ES dataset provided by the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) archived at the Max Planck Institute for Meteorology (Hempel, Frieler, Warszawski, Schewe, & Piontek, 2013) and are spatially represented at 50 km grid resolution.
- Climate projections:
  - Climate projections do not predict extreme weather events, which are short-term events that are significantly different from the usual weather pattern (hurricanes, flash floods, heat waves). Climate describes trends in temperature and precipitation over a long period of time (usually thirty years) for a given location.
  - Climate projections are based on model runs generated by the U.S. National Center for Atmospheric Research (NCAR) Community Climate Model (CCSM4) simulations prepared for the IPCC-AR5 (Gent, P. R., 2011; Hurrell et al., 2013; Moss et al., 2008, 2010).
  - Scenario generation: daily climate data are derived from the CCSM4 model projections for a 10-year time period covering 2026 to 2035 and 2046 to 2055. Daily differences for each year compared to the historical 30-year average daily climates were computed. Additionally, a daily anomaly for the selected model scenario (projected year – 30-year average daily base year for each variable of interest) over the 10-year period, 2026-2035 for 2030 and 2046-2055 for 2050 was computed to provide daily climate anomaly records representing the decades centered at 2030 and 2050.
  - CONUS projections: The daily data from the CCSM4 projections have been downscaled to approximately 6 km grid resolution over the U.S. and provide daily climate information from 1900 to 2100. The data source for projections is derived from the Localized Constructed Analogs (LOCA) CCSM4 data at approximately 6 km spatial resolution over the US (Pierce, Cayan, & Thrasher, 2014) and used in the US Fourth Climate Assessment Special Report (USGCRP, 2017).
  - OCONUS projections: CCSM4 projections are derived from the ISI-MIP and are spatially represented at 50 km grid resolution. These data are spatially averaged for each installation.

In summary, data and analyses were generated for four climate change scenarios representing two global carbon emissions levels for two different target years. The **emissions scenarios** are medium emissions (RCP 4.5) and high emissions (RCP 8.5). The two **timeframes** are decades around 2030 (2026-2035) and 2050 (2046-2055). Therefore, the climate change scenarios are:

1. RCP 4.5 2030
2. RCP 8.5 2030
3. RCP 4.5 2050
4. RCP 8.5 2050

Climate simulations were conducted to develop site-specific projections for the two potential emission scenarios over each timeframe. Projected climate data were then used to assess potential impacts to the installation's mission and natural resources.

1.3 Report Contents

1. Summaries for incorporation into Installation INRMP with text and appendices that can be modified and incorporated into the USAF standardized INRMP template. The corresponding INRMP section is shown in each section heading.
2. Appendices containing:
   A. Methodology (Appendix A). The methodology appendices will need to be numbered and incorporated with other installation-specific appendices.
   B. Detailed information on climate projections (Appendix B).
   C. Results of hydrological assessment and adaptation strategies (Appendix C).
   D. Details of ecosystem classification and habitat vulnerability (Appendix D).
   E. Discussion of potential impacts and adaptation strategies for threatened and endangered (T&E) species (Appendix E).

Adaptation strategies for projected climate scenarios are also included on the provided DVD for consideration by installations during future planning.

2 SUMMARIES FOR INCORPORATION INTO INRMP TEMPLATE

This document provides an analysis of potential climate impacts derived from downscaled global climate data. It provides summaries of analyses that are intended to be inserted into the U.S. Air Force's (USAF) standardized Integrated Natural Resources Management Plan (INRMP) template. Additional materials, including methodologies and more in-depth analyses, are provided as appendices to this document.

This document focuses on direct and indirect impacts and vulnerabilities associated with climate change. General summaries of climate change and its impacts on the installation's priority resources are provided for inclusion to sections 2.2, 2.3, and 2.4 in the standardized INRMP template; followed by management considerations and adaptation strategies for inclusion in section 7 in the USAF standardized INRMP template.

In contrast to familiar, more linear physical processes, climate models can produce diverse and often counterintuitive projections. The climate system is complex and driven by competing feedbacks and interactions among systems. For example, at a single location, increasing precipitation may be followed by drought and then increasing precipitation over time. Or, a location may experience greater warming in some months than in others. The best-available science is used to develop global climate models from which these downscaled projections are derived. However, there are gaps in data about the influence of phenomena such as changes in globally-significant ice sheets, which add to uncertainty in climate projections (IPCC, 2014). The projections provided here are intended to demonstrate the range of conditions to which a manager may have to adapt.

2.1 Physical Environment (INRMP 2.2)

2.1.1 Climate (INRMP 2.2.1)

Climate projections for The Barry M. Goldwater Range (BMGR) are presented in Table 1 and graphically shown in Appendix B. The results suggest minimum and maximum temperatures will increase over time under two emission scenarios – a moderate carbon emission scenario (Representative Concentration Pathway [RCP] 4.5) and a high emission scenario (RCP 8.5). The potential impact of these two climate change scenarios on the site's natural resources was analyzed using extracted climate data from 2026 to 2035 to represent the decadal average for 2030, and extracted data from 2046 to 2055 for the decadal average for 2050.

<u>BMGR East</u>

For the decade centered around 2030, both of the scenarios project a similar degree of increase in average annual temperature (TAVE) of between 2.1 °F (1.2 °C) and 2.5 °F (1.4 °C) over historic average. The two emission scenario projections show higher warming by 2050, with RCP 4.5 expressing a warming of 3.2 °F (1.8 °C). RCP 8.5 expresses a slightly greater warming of 4.6 °F (2.6 °C) for this period.

Average annual precipitation (PRECIP) varies between emission scenarios and over time due to larger interconnected ocean-atmosphere dynamics associated with the NCAR CCSM model. For 2030, RCP 4.5 scenario projects a large increase in PRECIP of 50% while RCP 8.5 shows an increase of 35%. For 2050 RCP 4.5 projects a moderate increase in PRECIP of 11% while RCP 8.5 shows a greater increase of 24%.

Table 1. Summary climate data, BMGR East.

Variable	Historical	RCP 4.5		RCP 8.5	
		2030	2050	2030	2050
PRECIP (inches)	6.2	9.3	6.9	8.4	7.7
TMIN (°F)	57.5	60.0	60.4	60.2	62.0
TMAX (°F)	87.3	89.0	90.9	89.6	92.0
TAVE (°F)	72.4	74.5	75.6	74.9	77.0
GDD (°F)	7720	8194	8418	8270	8711
HOTDAYS	131.8	137.9	149.9	143.6	154.5
WETDAYS	0.0	0.0	0.0	0.0	0.0

Notes: TAVE ºF = annual average temperature; TMAX ºF = annual average maximum temperature; TMIN °F = annual average minimum temperatures; PRECIP (inches) = average annual precipitation; GDD ºF = Average annual accumulated growing degree days with a base temperature of 50 ºF; HOTDAYS (average # of days per year) = average number of hot days exceeding 90 °F; WETDAYS (average # of days per year) = annual number of days with precipitation exceeding 2 inches in a day.

BMGR West

For the decade centered around 2030, both of the scenarios project a similar degree of increase in average annual temperature (TAVE) of between 2.1 °F (1.2 °C) and 2.3 °F (1.3 °C) over historic average (Table 2). For 2050, RCP 4.5 expresses a warming of 3.2 °F (1.8 °C), while RCP 8.5 expresses a slightly greater warming of 4.6 °F (2.6 °C) for this period.

For 2030, RCP 4.5 scenario projects a large increase in PRECIP of 61% while RCP 8.5 shows an increase of 58%. For 2050 both scenarios project a moderate increase in PRECIP of 24%.

Table 2. Summary climate data, BMGR West.

Variable	Historical	RCP 4.5		RCP 8.5	
		2050	2030	2050	2050
PRECIP (inches)	3.8	6.1	4.7	6.0	4.7
TMIN (°F)	56.2	58.6	58.9	58.6	60.6
TMAX (°F)	87.2	88.9	90.9	89.5	92.0
TAVE (°F)	71.7	73.8	74.9	74.0	76.3
GDD (°F)	7533	7984	8220	8038	8527
HOTDAYS	123.4	131.1	142.6	136.2	147.0
WETDAYS	0.1	0.0	0.0	0.0	0.0

Notes: TAVE ºF = annual average temperature; TMAX ºF = annual average maximum temperature; TMIN °F = annual average minimum temperatures; PRECIP (inches) = average annual precipitation; GDD ºF = Average annual accumulated growing degree days with a base temperature of 50 ºF; HOTDAYS (average # of days per year) = average number of hot days exceeding 90 °F; WETDAYS (average # of days per year) = annual number of days with precipitation exceeding 2 inches in a day.

Understanding changes in daily intensity and total precipitation for multi-day precipitation events is helpful to evaluate precipitation patterns in addition to assessment of annual averages. Three-day storm events (design storms) were generated from projected precipitation data based on RCP 4.5 and 8.5 emission scenarios for the 2030 and 2050 timeframes for two drainage systems at BMGR East (Table 3 and Table 4). Historical precipitation data were used to calculate a baseline storm event for the year 2000 for comparison. Design storms were used to model stream channel overflow in the hydrology assessment.

Table 3. Design storm precipitation for San Cristobal/Growler Wash and Tenmile Wash, BMGR East.

Design Storm		Baseline	RCP 4.5		RCP 8.5	
		2000	2030	2050	2030	2050
Precipitation (inches)	Day 1	0.47	0.67	0.62	0.55	0.53
	Day 2	1.09	1.43	0.77	1.24	1.47
	Day 3	0.56	0.97	0.68	0.77	0.77
	Total	2.12	3.07	2.07	2.56	2.77
Percent change from baseline			45%	-2%	21%	31%

Table 4. Design storm precipitation for Gila Bend AFAF, BMGR East.

Design Storm		Baseline	RCP 4.5		RCP 8.5	
		2000	2030	2050	2030	2050
Precipitation (inches)	Day 1	0.53	0.58	0.61	0.63	0.58
	Day 2	0.82	1.08	0.61	0.92	0.87
	Day 3	0.6	0.77	0.47	0.52	0.63
	Total	1.95	2.43	1.69	2.07	2.08
Percent change from baseline			25%	-13%	6%	7%

2.1.2 Hydrology (INRMP 2.2.4)

2.1.2.1 Stream Channel Modeling

Modeling of stream channel overflow (or flood modeling) was conducted for the BMGR-East along the San Cristobal/Growler Wash System in the San Cristobal Valley and Tenmile Wash to examine the extent of flooding associated with climate projections. Flood modeling was also conducted for the Gila Bend AFAF. Flood modeling was not conducted for the BMGR West because available data was not sufficient to conduct a reliable analysis.

Flood modeling did not consider flooding of independent surface bodies, stormwater systems, or surface ponding. Flood modeling was conducted using local watershed characteristics and the design storms generated from climate projection data. The projected design storms do not represent extreme weather events (e.g., hurricanes, extraordinary storm fronts). Inundation projections were influenced by four variable inputs: (1) variation in total precipitation between design storms, (2) variation between the daily distribution of precipitation over the three-day period, (3) land cover change over the watershed area used in hydrologic modeling, and (4) land cover change in the area within the installation used in hydraulic modeling.

Projected inundation associated with each climate scenario and the relative change from baseline conditions are summarized in Table 5 and Table 6. The spatial extent of projected flooding is depicted in a series of maps included in Appendix C. Projected changes in stream channel overflow can be used to assess potential vulnerabilities to species, habitat, mission, and built and natural infrastructure.

The baseline design storm projected for the San Cristobal/Growler Wash and Tenmile Wash drainage basins was estimated to produce 2.12 in. of precipitation over the three-day period (Table 3). Stream channel overflow associated with the baseline design storm was estimated to inundate nearly 50,000 acres at the BMGR East (Table 5).

The projected design storms vary widely under the RCP 4.5 emission scenario, increasing by 45% to 3.07 in 2030 but reducing to 2.07 inches (a 2% decrease from baseline) in 2050 (Table 3). Projected inundation follows projected changes in total design storm precipitation, increasing by 87.5% in 2030 and then decreasing by 13.8% in 2050 (Table 5). Under the RCP 8.5 emission scenario, design storms are projected to increase by 21% in 2030 and then by 31% in 2050 (Table 3). Projected inundation also follows changes in total design storm precipitation under these scenarios with an estimated increase in total inundation area by 43.6% in 2030 up to a 70.6% increase in 2050 (Table 5).

At Gila Bend AFAF, the baseline design storm was estimated to produce 1.95 in. of precipitation over the three-day period (Table 4). The projected design storms follow the same patterns as the San Cristobal/Growler Wash System and Tenmile Wash design storms, but with lower relative increases and a larger relative decrease for RCP 4.5 in 2050 (Table 4). Inundation, however, is projected to decrease in nearly every scenario, though remaining about the same for RCP 8.5 in 2030 (Table 5).

Table 5. Projected inundation along San Cristobal/Growler Wash and Tenmile Wash, BMGR East.

	Baseline	RCP 4.5		RCP 8.5	
	2000	2030	2050	2030	2050
Projected inundation (acres)	49920	93624	43020	71670	85172
Change in inundation area from baseline (acres)		43704	-6900	21750	35253
Percent change from baseline		87.5%	-13.8%	43.6%	70.6%

Table 6. Projected inundation at Gila Bend AFAF, BMGR East.

	Baseline	RCP 4.5		RCP 8.5	
	2000	2030	2050	2030	2050
Projected inundation (acres)	439.8	31.3	301.3	447.4	397.7
Change in inundation area from baseline (acres)		-408.5	-138.5	7.6	-42.1
Percent change from baseline		-93%	-32%	2%	-10%

2.2 Ecosystems and the Biotic Environment (INRMP 2.3)

2.2.1 Ecosystem Classification (INRMP 2.3.1)

The majority of The BMGR is located within the Dry Domain, Tropical/Subtropical Desert Division, American Semi-Desert and Desert Province (Bailey, 2014). Ecosystems in the majority of Tropical/Subtropical Desert Division are arid and have high air and soil temperatures. Since direct solar radiation ad outgoing radiation are high, there is extreme variations between day and night temperatures (Bailey, 2014).

2.2.2 Vegetation (INRMP 2.3.2)

Five primary natural ecosystems on BMGR were identified using data from the United States Geological Survey (USGS) National Gap Analysis Project (GAP) Land Cover 2011 classification. The ecosystems included creosotebush desert scrub, paloverde-mixed cactus desert scrub, dune complex /dune endemics, desert scrub and woodland / shrubland. Natural ecosystems as well as developed and barren land are summarized in Table 7.

Table 7. Ecosystem coverage by area

Ecosystem Type	Area (acres)	Coverage
Creosotebush Desert Scrub	1024200.5	58.3%
Paloverde-Mixed Cactus Desert Scrub	378900.9	21.6%
Dune complex and Dune Endemics	324208.0	18.4%
Desert Scrub	5183.1	0.3%
Woodland and Shrubland	408.1	0.2%
Developed and Barren Land	24756.8	1.4%

Slight changes in temperature and precipitation can substantially alter the composition, distribution, and abundance of species in these ecosystems, and the products and services they provide. The extent of these changes will also depend on changes in precipitation and fire. Increased drought frequency could also cause major changes in vegetation cover. Losses of vegetative cover coupled with increases in precipitation intensity and climate-induced reductions in soil aggregate stability will dramatically increase potential erosion rates.

Desert habitats are sensitive to climate drivers that exacerbate the already hot and dry conditions, enhancing vulnerability for many species that already exist close to their physiological limits. Climate drivers and disturbances (e.g., changes in precipitation, flooding, wildfire) have the potential to significantly alter species survival and composition. Slow-growing vegetation makes deserts particularly vulnerable to invasive grasses, which provide fine fuels for wildfire; ultimately, the cycle of invasive species and wildfire can cause type conversion to grasslands (EcoAdapt, 2017).

Under future climate conditions, desert habitats are likely to be exposed to increased air temperature, changes in precipitation, decreased soil moisture, more extreme high temperature events, and increased wildfire over the coming century. Although predictions of monsoon activity in North America are highly uncertain (Bukovsky, Gochis, & Mearns, 2013), more frequent and/or more intense tropical storms could alter desert stream geomorphology and riparian vegetation communities, particularly those in dry washes or floodplains. Desert habitat is expected to shift westward and upward in elevation over the coming century (C. W. Barrows, 2011; Cameron W. Barrows & Murphy-Mariscal, 2012), and, in some areas, may replace upslope vegetation that is less suited to increasingly hot and dry conditions (Friggens et al., 2013; Lenihan, Bachelet, Neilson, & Drapek, 2008).

2.2.3 Fish and Wildlife (INRMP 2.3.3)

Wildlife populations on The BMGR will likely experience significant affects due to climate change. Climate change will likely favor newly arriving species which often have the ability to outcompete native species which are already experiencing reduced fitness due to environmental conditions shifting away from historic standards (Hellmann, Byers, Bierwagen, & Dukes, 2008). Though this trend is a global one, it is expected to be far more pronounced in the Southwest (Archer, Predick, Chambers, & Pellant, 2008).

Scarcity of water is already an issue for wildlife populations on post and will continue to be despite projections of increased precipitation, due to the fact that much of the precipitation will fall in the winter during brief, intense convectional storms. Higher frequency and intensity of fires will likely lead to increased habitat destruction in addition to higher erosion and run off rates, which will further compound water scarcity issues for wildlife on BMGR. Higher evapotranspiration rates due to increasing temperatures will also contribute to reduced water availability for wildlife (Archer et al., 2008) and may have particularly negative impacts for amphibians and aquatic macroinvertebrates. Although wildlife communities at The BMGR are highly adapted to hot, arid environments, some may not be able to cope with increases in temperature. More generalist species will likely be better able to acclimate to rising temperatures through behavioral adaptations such as the Gila monster becoming nocturnal on hot days but remaining diurnal on cooler days (Stahlschmidt, DeNardo, Holland, Kotler, & Kruse-Peeples, 2011).

Increasing temperature will likely have a negative impact on water quality, particularly in lentic systems. As water temperatures rise, dissolved oxygen content will lower, decreasing habitat quality particularly for larval amphibians. Increasing water temperature will also raise the chances of algal blooms occurring, further depleting dissolved oxygen content and habitat quality (Paerl, Hall, & Calandrino, 2011).

Density of woody shrubs has increased three fold from the 1970's to the late 1990's in parts of the Sonoran desert due to higher winter precipitation (Brown, Valone, & Curtin, 1997). This trend is likely to continue due to increasing amount of winter precipitation. Changing vegetation communities will likely have a negative impact on specialist wildlife species which have historically depended on specific native plant species for their survival (Dukes & Mooney, 1999). Other wildlife species will change in an unpredictable manner. For example, a common species such as the common chuckwalla is predicted to lose 92% of its suitable habitat in the Sonoran Desert (C. W. Barrows, 2011). Other common species in the Sonoran Desert such as the kangaroo rat (Dipodomys deserti) and silky pocket mouse (Perognathus flavus) have experienced significant declines as a result of changing vegetation induced by climate change. On the other hand, rare species such as the desert pocket mouse (Chaetodipus penicilatus) and Bailey's pocket mouse (Chaetodipus baileyii) have responded positively to changing vegetation (Brown et al., 1997).

2.2.4 Threatened and Endangered Species and Species of Concern (INRMP 2.3.4)

Habitat change and disruption to food availability are two major climate-related threats to all species at The BMGR. Habitat requirements, such as need for refugia, for some species may change as their employ behavioral adaptations. Prey populations or forage abundance may also be affected by changes in temperature and precipitation. Seasonal cues for prey or forage emergence may change resulting in a mis-match between food availability and food needs of T&E species. Populations of some T&E species are further imperiled by life stages that are sensitive to temperature and precipitation changes projected in the climate scenarios.

2.3 Mission Impacts on Natural Resources (INRMP 2.4)

2.3.1 Natural Resource Constraints to Mission and Mission Planning (INRMP 2.4.1)

The large expanses of remote, undeveloped land and airspace that are needed to fulfill the mission of the BMGR do not require specific habitat or vegetation types that may be an integral part of mission readiness at other installations. Climate change will have negligible to no effect on the amount of air and land space available. The climate at The BMGR is expected to get hotter, which could have secondary effects on the mission such as vegetation shifts and species migrations leading to an increased regulatory environment. Infrastructure is not anticipated to be vulnerable to flooding at the BMGR with regard to climate change.

Future impacts to the mission at The BMGR linked to climate change could include:

- increases in temperature and wind velocity leading to unsafe environmental conditions for the launch of current and planned weapons and equipment, resulting in increased maintenance requirements, requirements for new equipment, or decreased launch capacity (DoD, 2014);

- increased dust generation effecting equipment and visibility (DoD, 2014);
- increased wind velocities damaging vital mission infrastructure (Sydeman et al., 2014);
- increased drought potential (Glick, Stein, & Edelson, 2011);
- potential loss of future training areas that may be needed in light of a changing geopolitical landscape and base realignment.

In addition to these direct effects, climate change has the potential to disrupt the acquisition and transportation of materials required for the maintenance, construction, and storage of the equipment required for these systems (DoD, 2014).

2.4 Fish and Wildlife Management (INRMP 7.1)

Fish and wildlife management on the BMGR is not likely to change greatly with respect to climate change. Current fish and wildlife management issues are likely to persist in the future. Fish and wildlife surveys should continue to be conducted on a regular basis. Native species need to continue to be monitored to document changes. Changing climatic conditions also present opportunities for invasive species to flourish and push out native species. Monitoring of invasive species will continue to be important and management plans should be flexible enough to adapt to changing fish and wildlife concerns (Hellmann et al., 2008).

Increasing temperatures could have a negative impact on amphibians and aquatic macroinvertebrate species. As water temperatures rise in lentic systems, dissolved oxygen content decreases, resulting in diminished habitat quality. Increasing water temperatures will also increase the chances of algal blooms, further depleting dissolved oxygen content and habitat suitability (Paerl et al., 2011). Shade trees should be planted around water sources in an effort to prevent excessive heating of water (Poff, Brinson, & Day, 2002).

Erosion, both related and unrelated to wildland fires would potentially have a negative impact on water quality. As a result, wildland fire management will continue to be an important wildlife management tool.

2.5 Outdoor Recreation and Public Access to Natural Resources (INRMP 7.2)

Little changes are expected to occur for outdoor recreation and public access to natural areas at the BMGR with regards to climate change. Activities such as camping, hiking, and target shooting are expected to continue without any changes. Hunting opportunities will need to be frequently assessed. Javelina, mule deer, doves and quail are quite common; hunting opportunities for those species will likely persist. Because big horn populations can vary, opportunities for hunting them will need to be evaluated frequently and be based off population size on the range.

2.6 Management of Threatened and Endangered Species, Species of Concern and Habitats (INRMP 7.4)

Management actions taken to protect T&E species will be influenced by the speed at which the climate changes, the nature of the climatic changes and the ability of the species to respond to those changes. Our understanding of species' response to changing climate is not yet sufficient to be able to predict how an individual species will respond. In addition, the response of sub-populations of a single species may vary. Species can exhibit behavioral, plastic and genetic response to environmental conditions. Genetic variation within a species has been associated with exposure to environmental conditions, however, populations may not be able to undergo selection for preferred traits if environmental conditions change rapidly (Hoffmann & Sgrò, 2011). Behavioral changes, such as host-plant or food source switching, and plastic responses, such as changes in body size associated with longer growing seasons, have already been observed (Iwamura et al., 2013; Ozgul et al., 2010).

Many current T&E management activities are appropriate for increasing resilience or facilitating adaptation to climate change. An ecosystem approach that prioritizes functional diversity, maintenance of habitat, habitat variability and connectivity can help support genetic diversity that may be important for adaptation, and can help species migrate to more favorable habitats. However, when approaching the uncertainty that is inherent with managing species under changing environmental conditions, additional analysis and planning is required.

Research into actionable science used for biodiversity conservation in changing conditions has developed several key principles. Historic patterns used for management decisions are likely to be insufficient for future management challenges (Bierbaum et al., 2013). Proactive approaches that anticipate change can help extend the period over which species can adapt to changing climate and avoid catastrophic declines associated with stochastic events that act on an already stressed ecosystem.

2.7 Wetland Protection (INRMP 7.6)

<u>BMGR East</u>

Highly ephemeral washes include Sauceda Wash, Quilotosa Wash, Daniels Arroyo, Tenmile Wash, and Midway Wash. All are tributaries to the Gila River. These systems have many large and small tributaries that are dry except after rare heavy or prolonged rain events. Ephemeral systems (natural and modified) including clay pans, playas (lakebeds), storm water and evaporation ponds, washes and seeps are only intermittently wet depending on the infrequent and minimal rainfall that occurs in desert environments. Ephemeral systems found at BMGR East are not jurisdictional wetlands because they do not have hydrophytic plant species or a dominance of hydric soil types (Cowardin, Carter, Golet, & LaRoe, 1979).

BMGR West

The Mohawk Valley is a large arroyo that runs along the valley's axis and eventually dissipates into progressively smaller inland deltas. These deltas drain north but never reach the Gila River as coherent channels do (Malusa & Sundt, 2015).

The wetland ecosystems at the BMGR West will be particularly vulnerable to the increase of temperature and changes in precipitation regimes under studied climate scenarios. Summary of climate projections indicate that minimum and maximum temperatures will increase over time under both emissions scenarios. These projections indicate that wetland systems are vulnerable to changes in quantity (increased temperature results in higher evaporation rates and lower freshwater input) and quality of their water supply, and it is expected that climate change will have a pronounced effect on wetlands through alterations in hydrological regimes (Erwin, 2009).

2.8 Wildland Fire Management (INRMP 7.9)

BMGR East

Wildfire activity at the BMGR East will largely be controlled by changes in vegetation rather than climate factors. Invasive species, including fire-adapted grasses and annuals, have invaded parts of the Sonoran Desert. Wherever those species become common, fire is likely to become much more frequent and fires are likely to become much larger, completely upending the current very low fire frequency regime of the desert. Precise estimation of invasive plant extent and intensity is beyond the scope of this study however. The below analysis assumes the absence of large-scale grass or annual invasion.

Wildfires in the Sonoran Desert are generally limited by fuel continuity more than any other single factor. The desert is dry enough to support combustion the overwhelming majority of the time and ignition sources on a live-fire military installation are frequent and widespread. In the Sonoran Desert, much of the land area is too sparsely vegetated to support fire growth at all, and those fires that happen to occur in patches of fuels are isolated and rarely grow larger than a few acres. Though fires may occur, the acreage of any individual fire, or fires in aggregate, is generally quite small.

There are rare occasions when unusually abundant winter rainfall produces a flush of vegetation that may support more robust fire activity, as occurred in the winter of 2004 – 2005 and led to some of the largest fires on record in the Sonoran Desert in the summer of 2005. However, these conditions are rare, and though the climate projections suggest increased moisture in the future, much of the increase is concentrated during the late summer through early winter months, which may not be conducive to vegetation growth on a scale that supports large-scale or more frequent fires. However, the increased overall precipitation likely indicates a higher likelihood of a high winter rainfall event, leading to a slightly higher likelihood of fire seasons like 2005. These can still be expected to be quite infrequent though.

The MC2 vegetation models strongly suggest that climate change will lead to decreased vegetative cover, regardless of the climate scenario. This indicates that while winter flushes of excessive vegetation may become slightly more common, though still rare, in general fire activity is likely to decrease relative to current day due to a decrease in vegetation cover.

<u>BMGR West</u>

Wildfire activity at the BMGR West will largely be controlled by changes in vegetation rather than climate factors. Invasive species, including fire-adapted grasses and annuals, have invaded parts of the Sonoran Desert. Wherever those species become common, fire is likely to become much more frequent and fires are likely to become much larger, completely upending the current very low fire frequency regime of the desert. Precise estimation of invasive plant extent and intensity is beyond the scope of this study however. The below analysis assumes the absence of large-scale grass or annual invasion.

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