

PLANNING FOR A RESILIENT FUTURE

A Climate Vulnerability Preliminary Assessment for Natural and Cultural Resources on Florence Military Reservation

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Photo: AZARNG

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All photos from AZARNG unless otherwise cited.



CONTEXT

As part of the Urban Sustainability Best Practices Fall 2015 Course at Arizona State University, student researchers partnered with the Arizona Army National Guard (AZARNG) to conduct a preliminary vulnerability investigation of climate impacts on operations in relation to natural and cultural resources at Florence Military Reservation (FMR). The FMR training compound includes 19,246 acres of federal, state-owned, and leased property approximately 40 miles southeast of Phoenix and is bordered by Bureau of Land Management Lands, State Trust Lands, and private property (FMR, 2012). The overarching vision of this and subsequent work is to increase the AZARNG's resilience to future climatic impacts on natural and cultural assets to ensure military readiness and overall mission integrity.



INTRODUCTION

The AZARNG recognizes increasingly unpredictable and extreme climatic shifts may introduce threat multipliers and decrease military readiness- endangering political stability on domestic and global levels (FMR, 2012). American military personnel and civilians are, and will continue to be, both directly and indirectly impacted by climate change. If natural and cultural resources are degraded or changed in a way which prevents training or environmental compliance, the AZARNG's mission of national security is at risk of being compromised (FMR, 2012).

Although dynamic and complex systems are impossible to accurately predict, the AZARNG is under Executive Orders to build its resilience to potential future shifts in order to ensure mission success. This report is intended to synthesize FMR-relevant research and identify key strategies for adaptation and resiliency planning. The first of many steps towards increasing FMR's resilience to future climate shifts is to understand the current state of direct and indirect climatic threats. Changing climatic conditions fueling shifts in fauna and flora behavior are of specific interest to the

AZARNG's MISSION:
Ensure national security by responding to domestic emergencies, combat missions, counterdrug efforts, reconstruction missions and more-all with equal speed, strength and efficiency.

FMR due to their location in the Sonoran Desert, a biodiversity hotspot (van Riper, 2014). Experts expect this unique desert ecosystem and its inhabitants are expected to start changing dramatically within the next decade due to climate changes (van Riper, 2014). Since the FMR serves as vital training grounds for AZARNG troops, its operations need to be maintained despite these changes. Therefore, main questions of interest addressed in this report are:

RESEARCH QUESTIONS:

1. What climatic impacts should FMR expect and plan for?
2. How will changes impact current operations?
3. What strategies should be implemented now to mitigate potential future impacts?

CLIMATIC IMPACTS

Climate change is and will increasingly impact natural and cultural systems across all scales from the regional to local (Office of Naval Research et al., 2012). Since modeling is more accurate at the regional level than local, this analysis will frame the problem as such and then discuss implications for FMR operations, training, conservation, compliance, and more.

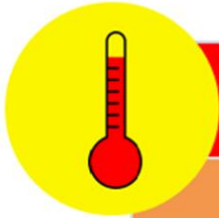
Southwest Climatic Impacts

A dramatic range of elevations and climates creates interconnected and complex environmental and social dynamics in the Southwest region, which spans a large area of the United States from the Rocky Mountains to the east, the Pacific Coast to the west, Northern Utah to the north, and the Mexican border to the south (Karl, Melillo, & Peterson, 2009). Rapid population growth is expected to continue in the region and Arizona's population in particular is anticipated to double by 2050 (Overpeck, et. al, 2013) due to increasingly extreme winters in the Midwest and the number of retirees in the United States. To accurately frame anticipated climatic impacts to FMR, these regional characteristics must be taken into account.



This photo shows a natural desert wash, or path water takes during storms. Flash floods will become increasingly common due to climate.

Southwest Implications of Climate Change Summary



Temperature Changes

INCREASED PROBABILITY OF:

- * Desertification
- * Fire frequency and intensity
- * Transmitting infectious diseases
- * Agricultural failures
- * Heat-related illness/ fatigue

(Karl, Melillo, & Peterson, 2009)



Precipitation Changes

INCREASED PROBABILITY OF:

- * Droughts
- * Damage to infrastructure
- * Death due to flash floods
- * Water insecurity
- * Unhealthy native ecosystems

(Karl, Melillo, & Peterson, 2009)

The Southwest is projected to experience some of the most rapid warming in the nation, with a 6 to 10F increase in average annual temperatures by the end of the 21st century (Karl, Melillo, & Peterson, 2009). As an interconnected result, the quantity of available water is projected to become increasingly scarce creating conflict over the right to use (Karl, Melillo, & Peterson, 2009).

Furthermore, increased evaporation and reduced precipitation (Karl, Melillo, & Peterson, 2009) will increase drought severity and heat waves will become longer and hotter (Overpeck, et al., 2013).

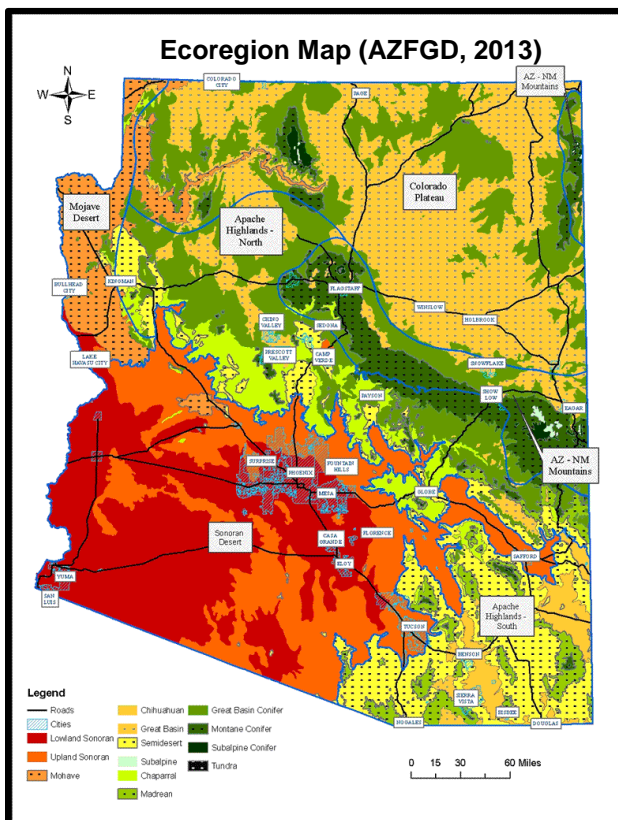
Paradoxically, high temperatures combined with severe precipitation events decrease soil permeability, increasing the risk of flash flooding (Karl, Melillo, & Peterson, 2009).



The mountainous deserts of the Southwest are prone to flash floods during extreme weather events.

Sonoran Desert Impacts

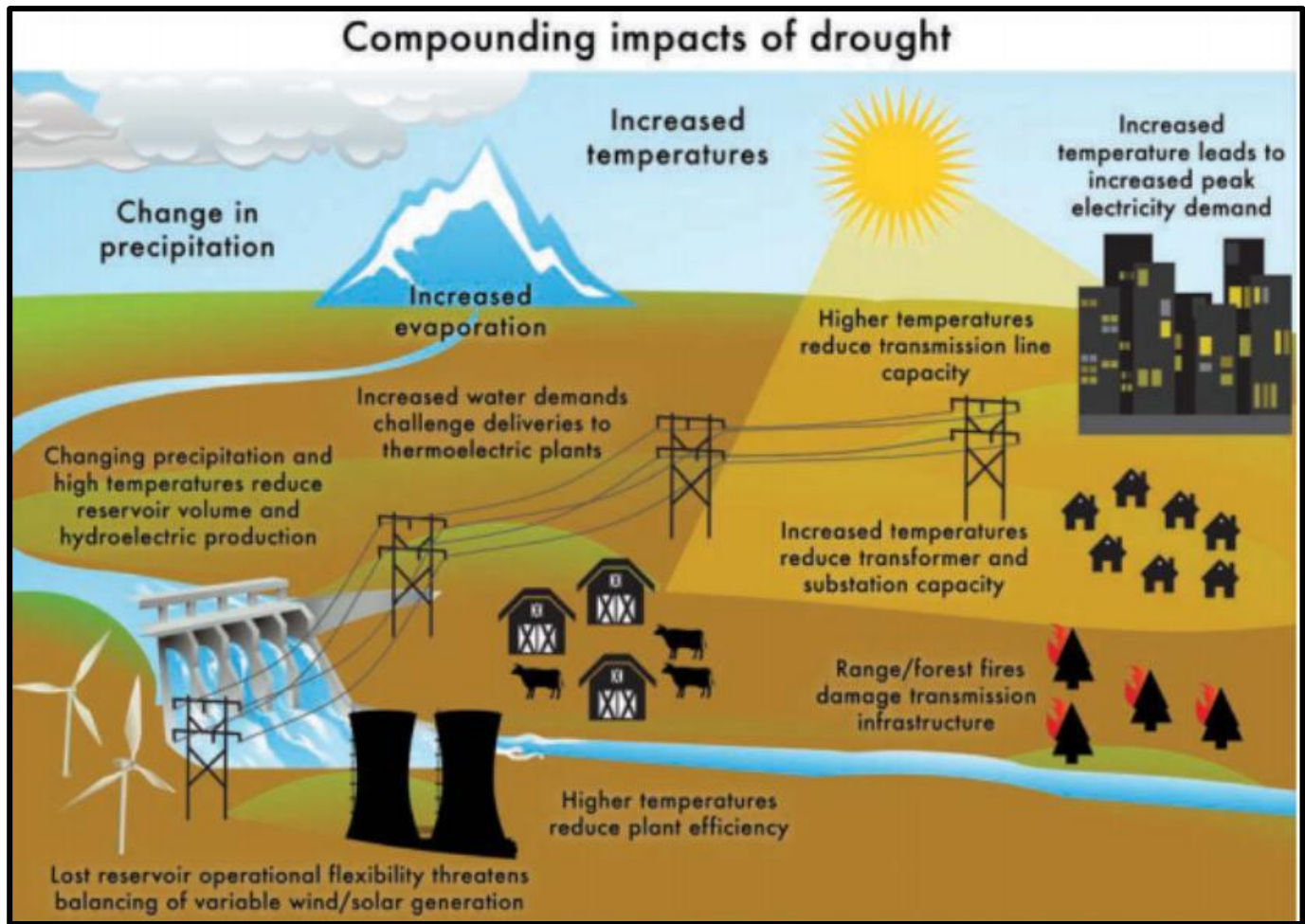
The FMR is located in Pinal County, about an hour southeast of Phoenix. Ecologically, the FMR is located within the Sonoran Desert Ecoregion which is known for Saguaro Cactus (AZGFD, 2013). In FY2015 soldiers reported only four days of rain, 2 of which were only light precipitation. FMR will likely experience less yearly precipitation, resulting in reduced soil moisture (Seager et al. 2007). Soldiers also observed strong winds blow from different directions which shift based on the time of day. Wind associated with haboobs (dust storms) will likely increase due to climate change and the Sonoran Desert Ecoregion is expected to warm more rapidly than many parts of America (Seager et al. 2007).



IMPLICATIONS & MITIGATION TACTICS

Although climate projections do not predict the future, they should be used to inform decision-making now to secure a successful future for FMR. Analysis of the multi-scalar impacts of climate change on FMR's ability to successfully complete their mission is critical to inform intervention strategies.

For example, FMR's future compliance in relation to the National Historic Preservation Act, Archaeological Resources Protection Act, Migratory Bird treaty Act, Clean Water Act, Endangered Species Act (ESA), Clean Air Act, and more is complicated due to the impacts of climate change because it's uncertain how animal and flora ranges will shift or biogeochemical processes will be altered. Climate not only complicates regulatory compliance, but infrastructure integrity as well for FMR. The infographic shown on the next page shows how shifts in climate can have systemic impacts on natural and built infrastructure (2013). In Arizona, energy demand is already at a premium, and many cities experience power outages during the summer due to high temperatures and increased energy demand for AC units. FMR may similarly see an increase in power outages or shortages during the summer which may lead to higher energy bills or negatively impact their ability to perform operations.



With the effects of climate change, operations at FMR may experience several of the effects shown in this infographic (Overpeck et. al, 2013).

Natural Resource Impact

Department of Defense land is ten times as biodiverse as any other department in the nation and FMR is currently a great case study of this phenomenon. However, temperature increases in the Sonoran Desert will push this ecosystem towards even hotter and drier regimes, creating a “self-reinforcing cycle of invasive plants, fire, and erosion” (Karl, Melillo, & Peterson, 2009). Furthermore, species living in the Sonoran Desert are expected to shift in abundance and distribution due to climatic

shifts (Munson, et. al., 2011). Rising temperatures increase evaporative demand and decreased precipitation may challenge many forms of vegetation while boosting cold tolerant species like succulents (Munson, et. al., 2011). Due to the high dependence of species behavior (i.e. migration and mating) on temperature, scientists also expect these cycles to be severely disrupted (Overpeck, et. al, 2013). Each shift within the ecosystem has cascading, unintended effects within the

system which cannot be accurately modeled or predicted. However, understanding shifting species patterns and survival will help FMR prepare by identifying effective management actions and taking a proactive approach to preserve biodiversity (Glick & Stein, 2010).



There are many desert- adapted species of snakes living on the FMR.

Vulnerability and extinction risk assessments are management tools used to help prioritize conservation needs so that actions can be directed in an effective and efficient manner (Glick and Stein 2010). For example, migratory corridors are an excellent conservation tool, if strategically modeled and adaptable as patterns shift. When planning for an uncertain future, decisions must be flexible and continuously re-evaluated.

Although many animals live on FMR which are not listed including the bobcat, gray fox, kit fox, mountain lion, Gila Monster, and more; there are species covered under the Endangered Species Act (ESA) which deserve extra Preliminary Vulnerability Assessment: FMR

addition to ensure compliance. The Fish and Wildlife Service (FWS) survey FMR to monitor the behavior and treatment of species listed with the ESA. While this surveying has not been a substantial disruption to operations and training thus far, increased difficulties with ESA compliance due to climatic shifts may increase the frequency of FWS visits. FWS survey the species in FMR's 'Impact Zone', which is the swath of land soldiers and trainees fire live rounds into. Therefore, these areas must be shut down during inspection. To date, FWS have never found an animal harmed by gunshots. Additionally, vegetation is thriving on FMR and it is very rare for saguaro cactus to be hit during training, despite their abundance.



DoD land is **10x as biodiverse** as land from any other department in the nation.





Planting more vegetation on the FMR may help reduce flooding and runoff while providing habitat for animals.

Species of Special Interest

In order to comply with federal regulations regarding human interactions with Endangered, Threatened or Vulnerable species, troops on the ground at FMR should be aware of updates to the ESA. It would also be beneficial for FMR to stay informed about endemic species that meet the protection criteria from the U.S. Fish and Wildlife Service, through their online resource ECOS (Environmental Conservation Online System) (See Appendix C).

Many species in the Sonoran Desert are uniquely adapted to survive under extreme environmental conditions, but climate change can still prove detrimental for these species.

The desert tortoise, *Gopherus agassizii*, is one of the many species found on the FMR. They are native to the Sonoran Desert and are known for burrowing deep tunnels underground to escape the extreme desert heat. The population of desert tortoises has decreased by up to 90% in some areas due to human activity ("Basic Facts", 2015). This species is currently listed as a threatened species, under the Endangered Species Act, as well as being listed as vulnerable under the IUCN Red List guidelines ("Basic Facts", 2015). Under these protection guidelines, the presence of this species on FMR lands could interfere with training activities and daily operations. Desert tortoises are the most active during their breeding season, from April to July ("Desert

Tortoise”, 2015). Due to their long hibernation period in the winter months, the desert tortoise is less likely to interfere with FMR operations during this time. However, they will need to be conscious of tortoises emerging from hibernation when the temperatures start to increase in the spring.



Desert tortoises are native to the Sonoran Desert and burrow underground to escape the desert heat.

Another species that is reported to live on FMR lands is the Tucson Shovel-Nosed Snake, *Chionactis occipitalis klauberi*. The protection of this species has been a source of debate for the Center for Biological Diversity as well as the Coalition for Sonoran Desert Protection for several years (“Saving the Tucson Shovel-Nosed Snake”, 2011). In 2014, the U.S. Fish and Wildlife Service released a report that declared that the Tucson Shovel-Nosed Snake did not meet the criteria for legal protection under the Endangered Species Act, as either Threatened or Endangered (U.S. Fish and Wildlife, 2014). The reasons cited for this decision were based upon geographical range

Preliminary Vulnerability Assessment: FMR

and genetic testing; the Tucson Shovel-Nosed Snake is one of four major subspecies of the Western Shovel-Nosed Snake, and the combined range and suitable habitat for these subspecies was deemed large enough to sustain the population for the foreseeable future (U.S. Fish and Wildlife, 2014). However, human activities are still acknowledged as a possible threat for this subspecies, especially as suitable habitat is lost as a result of land conversion for human use (Hammerson, Frost, and Gadsden, 2007).

While the presence of these species should not interfere with FMR operations, FMR troops and Florence residents should be aware sightings will likely be more frequent if habitat range is restricted by further development. The Tucson Shovel-Nosed snake is not a venomous species, but its coloration mimics another highly venomous species, the Arizona Coral Snake, which is also found in the Sonoran Desert (“Arizona Coral Snake”, 2015). Because of the physical similarities of these two species, troops training should be advised to take caution when approaching any snake found on the grounds, until the species can be verified.

The Tucson Shovel-Nosed Snake may go under ESA protection in the future.



Infrastructure

FMR troops already experienced the destructive and expensive impacts of flooding on infrastructure- a disruption expected to become more extreme and frequent due to climate change (Karl, Melillo, & Peterson, 2009). Flash floods destroy roads and trails while also negatively impacting training facilities. During 2015, two major monsoons hit FMR and both required intensive repairs. Since re-grating is expensive, FMR is looking into asphalt replacements. However, this solution has its own consequences, including holding more heat and increased runoff. Investing in road and building infrastructure designed for more intense storms and higher temperatures will help decrease long-term costs of repairs and lost training hours. For example, adding culverts and natural/ 'green' infrastructure to the main service road will provide a channel for water during monsoons. Standing structures like the tower, parking structures, flags, and office space below will also need to be strengthened for high winds.



Solar canopy photo taken by researchers.

The solar shade canopy depicted below covers the shooting range while providing energy. This shade project and other non-solar canopies provide relief from the hot sun and rain for

trainees. New shade structures built on FMR include angled roofs and a French Drain system directing water to Riparian areas. One shade structure was not built with enough support and was thus uprooted during the last monsoon in 2015. This lesson must be considered when planning future projects.



Existing structures will need to be analyzed and strengthened accordingly to increase the probability of surviving a large storm. Photo taken by researchers.

Based on climatic impacts previously summarized, decision makers must plan for stronger winds, rains, storms, and heat intensity within an environment with less water overall. Recognizing the need for cooling technology, FMR started to install misters for trainees. However, facing a future where precipitation will likely decrease and become continuously scarcer in the Southwest, questions about future water availability must be considered. Energy and water sources for future operations on FMR should be strategically analyzed now, since the access to both will become increasingly difficult to attain and yet vital to life in a warming desert. If water

availability data is not available, AZARNG should pressure stakeholders who manage water assets to provide data and enter into a conversation around water stewardship.



One tool for identifying, analyzing, and addressing water risks was recently developed by the Alliance for Watershed Stewardship (AWS). Although the [Standard](#) developed by AWS has been adopted by many corporations including Coca Cola and Nestle, it has not been utilized by any military reservations yet. However, using AWS' Standard would help the FMR understand and mitigate operational risks due to shifts at both watershed and site levels. Even if this Standard isn't implemented in full at FMR, the process and guidance detailed will likely prove invaluable.



Trainees are in full uniform during all activities and currently utilize both well and trucked-in water for drinking.

Training Location and Timing

FMR is hot (actively used for firing range/training) seven days a week. During monsoons everything except the shooting range shuts down, but lightning causes all operations to cease. No training is halted due to heat, although training schedules are adjusted based on Heat Index requirements for water and rest (see Appendix D for chart).



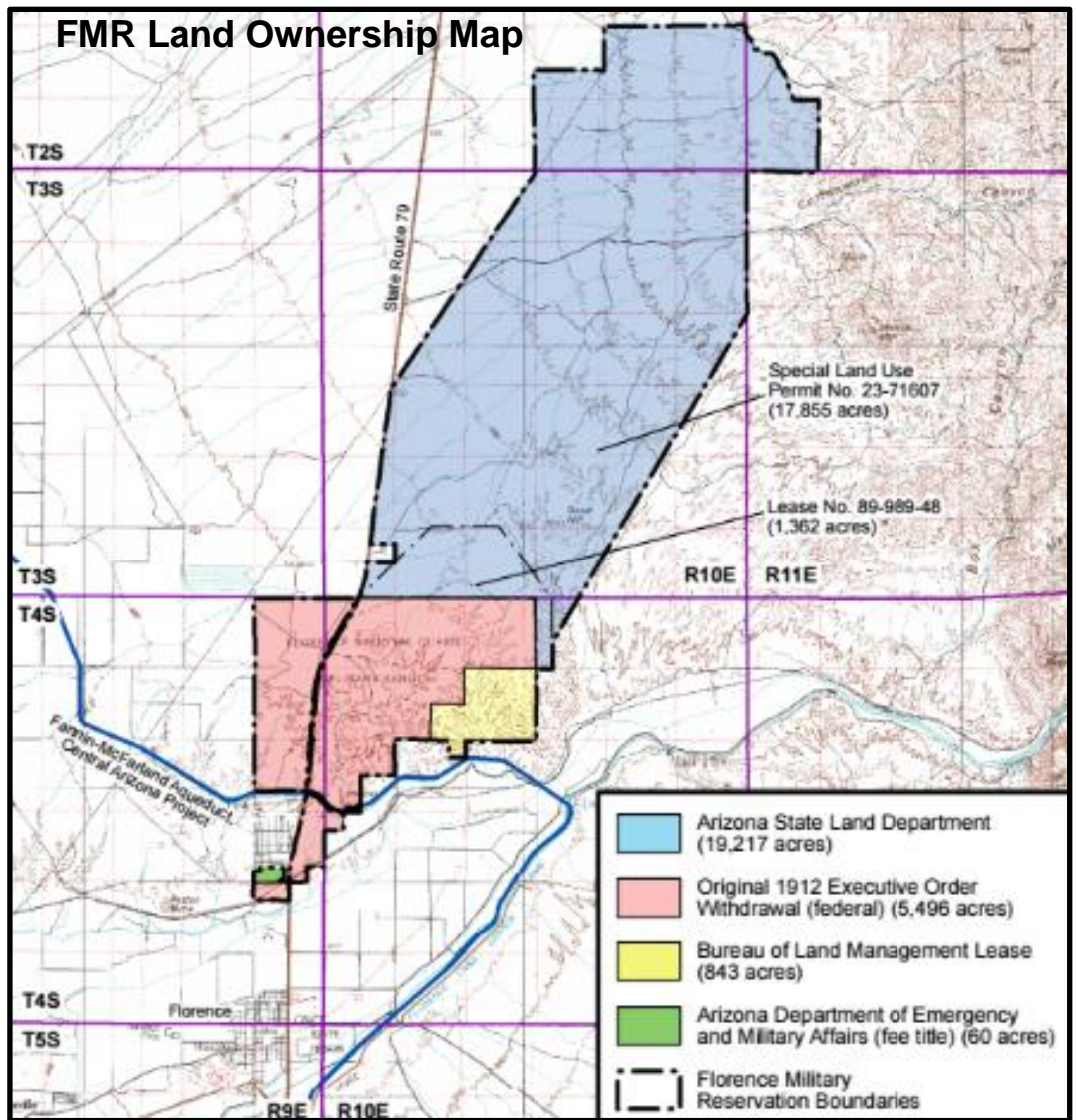
This Mesquite shaded area located by the training facilities provides a cooler place for soldiers to camp out overnight. The information board depicted provides a shady spot for troops to learn about wildlife on the FMR during breaks and overnight stays.

Land

Part of the FMR's Impact Area is on land leased from the Bureau of Land Management (BLM). FMR is also bordered by land owned by the State Trust. This land may be sold at any time to the highest bidder, which could pose a risk to FMR operations. After the recession in 2008, real estate development in the area decreased, but the recent economic recovery may renew interest in this land. Since State Trust Land earnings are invested in schools, the recent reduction in funding may add more

pressure for the State Department to sell this land. If this occurs, the encroachment of residential buildings may result in increased traffic, the migration of more species onto FMR seeking refuge, and potentially more complaints from nearby residents about noise-pollution.

A potential residential development that may be built upon the State Trust Land is Superstition Vistas. This 275-acre planned development would be located along the northern portion of Pinal County, north of the FMR (“Superstition Vistas”, 2013). It is expected to house over half a million residents which may increase traffic, urban heat island effect, and water demand.



If development bordered the FMR, how would this impact endangered and threatened species?



Future scenarios of encroachment and potential adaptation methods should be considered in current planning.

Public Engagement

Further recommendations include incorporating these suggestions into Cultural and Natural Resource Management Plans and engaging stakeholders to ensure a comprehensive understanding of the situation and solutions. For example, discussing potential impacts and solutions with drill leaders and machine repair personnel may lend insight into the ways increased temperatures and decreased precipitation will impact operations. Also, flexibility must be built into decision-making since this is critical in developing effective tools to adapt to uncertain climate impacts (Office of Naval Research et al., 2012).

CONCLUSION

The widespread, imminent, and threatening implications of climate change and variability impact all aspects of the DoD including “...military readiness, maintaining infrastructure to support the mission, compliance, and stewardship” (2012). As summarized by the Office of Naval Research et al, the “complexity of climate change and the potential costs of risk management actions, or even no action, compel an adaptive decision making framework that includes establishing and sustaining a process and dialogue” (2012).



This report is intended to help launch this strategic planning and investigation effort focused on enhancing the resiliency of the FMR and the AZARNG as a whole in order to ensure mission success.

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Tucson Shovel Nosed Snake:

http://www.werc.usgs.gov/OLDSitedata/pubbriefs/images/Tucson_Shovel_nosed%20web.jpg

Photo of shooter: <http://www.aznationalguard.com/media.shtml>

Photo of soldier with flags: <http://archive.azcentral.com/commphotos/azcentral/12276/1#2>

APPENDIX B: Glossary

Definitions from Office of Naval Research, et al., 2012

Adaptation: adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects (NRC 2010).

Adaptive capacity: ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Parry et al. 2007)

Built infrastructure: basic equipment, utilities, productive enterprises, installations, and services essential for the development, operation, and growth of an organization, city, or nation (based on

Parry et al. [2007] definition of infrastructure). All building and permanent installations necessary for the support, redeployment, and military forces operations (e.g. barracks, headquarters, airfields, communications, facilities, stores, port installations, and maintenance stations (based on JP1-01 [2001] definition of infrastructure)

Climate change: Refers to any change in climate over time, whether due to natural variable or as a result of human activity. [Anthropogenic] climate change, as defined by the United Nations Framework Convention on Climate Change, refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over

comparable time periods (based on Parry et al 2007).

Extreme weather event: Event that is rare within its statistical reference distribution at a particular place. Definitions of 'rare' differ, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile. By definition, the characteristics of what is called 'extreme weather' may differ from place to place. Extreme weather events may typically include floods and droughts (Parry et al. 2007).

Impact assessment: Practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change [and climate variability] on natural and human systems (Parry et al. 2007).

Mitigation: Intervention to reduce the causes of changes in climate, such as reducing emissions of greenhouse gases to the atmosphere (NRC 2010). An anthropogenic intervention to reduce the anthropogenic forcing of the climate system, which includes strategies to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks (Parry et al. 2007).

Resilience: Capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment (NRC 2010). Ability of a social or ecological system to absorb disturbances while retaining the same basic

structure and ways of functioning, capacity to self-adapt to stress and change (Parry et al. 2007).

Risk: Combination of the magnitude of potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur (NRC 2010).

Sensitivity: Sensitivity is the degree to which a system can be affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise (Parry et al. 2007).

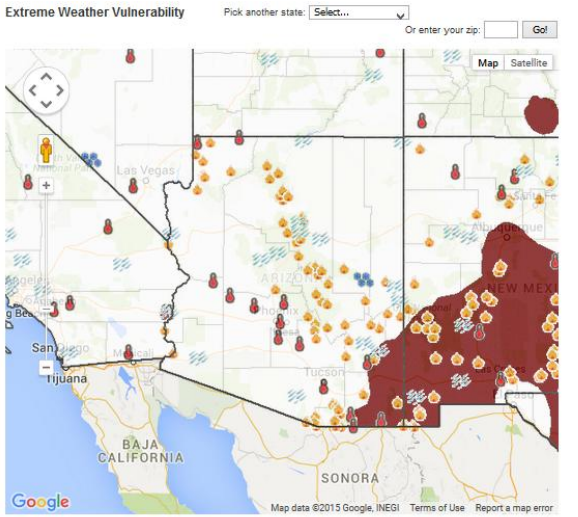
Vulnerability: Degree to which a system is susceptible to, or unable to cope with, the adverse effects of climate change, including climate variability and extremes (NRC 2010). Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (Parry et al. 2007).

Vulnerability assessment: Practice of identifying and evaluating the impacts of climate change and climate variability on natural and human systems so as to understand system sensitivities and capacity to adapt (Office of Naval Research et al., 2012)

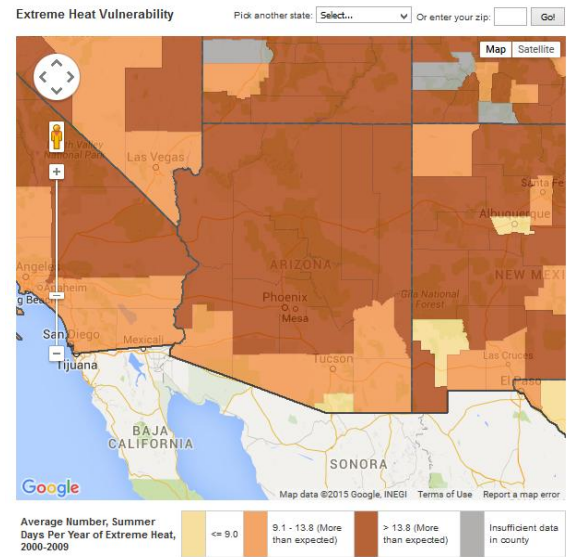
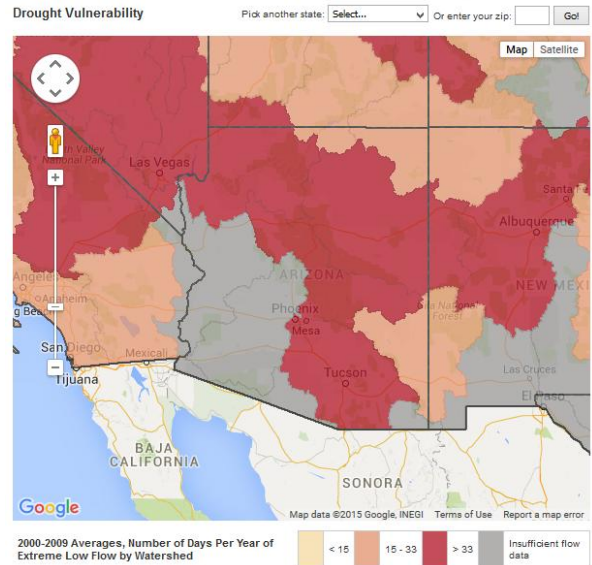
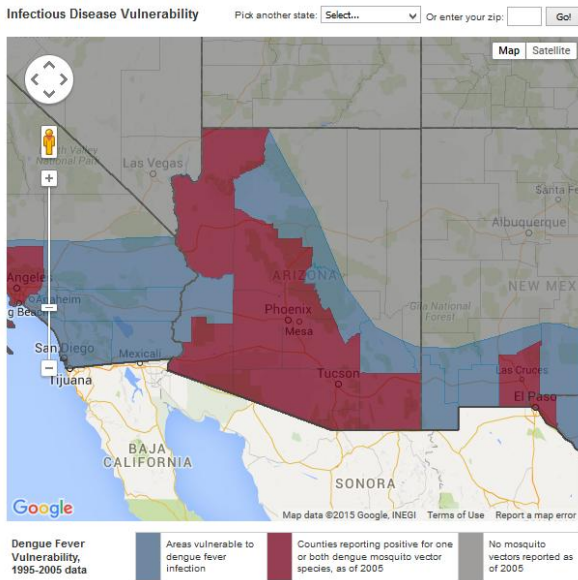
APPENDIX C: Links

U.S. Fish and Wildlife Service - Environmental Conservation Online System (ECOS)

http://ecos.fws.gov/tess_public/reports/species-listed-by-state-report?state=AZ



- Extreme Weather Events**
- Record Rainfall
 - Record temperature
 - Extreme drought
 - Record Snowfall
 - Wildfire
 - Extreme flooding



Link to NRDC Climate Change Health Threats Maps - <http://www.nrdc.org/health/climate/az.asp>

APPENDIX D: Work/ Rest & Water Consumption

Work/Rest and Water Consumption Table

Applies to average sized, heat-acclimated soldier wearing BDU, hot weather. (See TB MED 507 for further guidance.)

Easy Work	Moderate Work	Hard Work
<ul style="list-style-type: none"> • Weapon Maintenance • Walking Hard Surface at 2.5 mph, < 30 lb Load • Marksmanship Training • Drill and Ceremony • Manual of Arms 	<ul style="list-style-type: none"> • Walking Loose Sand at 2.5 mph, No Load • Walking Hard Surface at 3.5 mph, < 40 lb Load • Calisthenics • Patrolling • Individual Movement Techniques, i.e., Low Crawl or High Crawl • Defensive Position Construction 	<ul style="list-style-type: none"> • Walking Hard Surface at 3.5 mph, ≥ 40 lb Load • Walking Loose Sand at 2.5 mph with Load • Field Assaults

- The work/rest times and fluid replacement volumes will sustain performance and hydration for at least 4 hrs of work in the specified heat category. Fluid needs can vary based on individual differences ($\pm \frac{1}{4}$ qt/hr) and exposure to full sun or full shade ($\pm \frac{1}{4}$ qt/hr).
- **NL** = no limit to work time per hr.
- **Rest** = minimal physical activity (sitting or standing) accomplished in shade if possible.

Heat Category	WBGT Index, F°	Easy Work		Moderate Work		Hard Work	
		Work/Rest (min)	Water Intake (qt/hr)	Work/Rest (min)	Water Intake (qt/hr)	Work/Rest (min)	Water Intake (qt/hr)
1	78° - 81.9°	NL	$\frac{1}{2}$	NL	$\frac{3}{4}$	40/20 min	$\frac{3}{4}$
2 (GREEN)	82° - 84.9°	NL	$\frac{1}{2}$	50/10 min	$\frac{3}{4}$	30/30 min	1
3 (YELLOW)	85° - 87.9°	NL	$\frac{3}{4}$	40/20 min	$\frac{3}{4}$	30/30 min	1
4 (RED)	88° - 89.9°	NL	$\frac{3}{4}$	30/30 min	$\frac{3}{4}$	20/40 min	1
5 (BLACK)	> 90°	50/10 min	1	20/40 min	1	10/50 min	1

- **CAUTION: Hourly fluid intake should not exceed 1½ qts.**
- **Daily fluid intake should not exceed 12 qts.**
- If wearing body armor, add 5°F to WBGT index in humid climates.
- If doing Easy Work and wearing NBC (MOPP 4) clothing, add 10°F to WBGT index.
- If doing Moderate or Hard Work and wearing NBC (MOPP 4) clothing, add 20°F to WBGT index.

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