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Integrated Climate Assessment for Army Enterprise Planning

Effects of Climate Change, Urban Development, and Threatened and Endangered Species Management on Army Training Capabilities

Firing Ranges

Juliana Wilhoit, Scott Tweddale, Matt Hohmann, David Delaney, Michelle E. Swearingen, and James Westervelt

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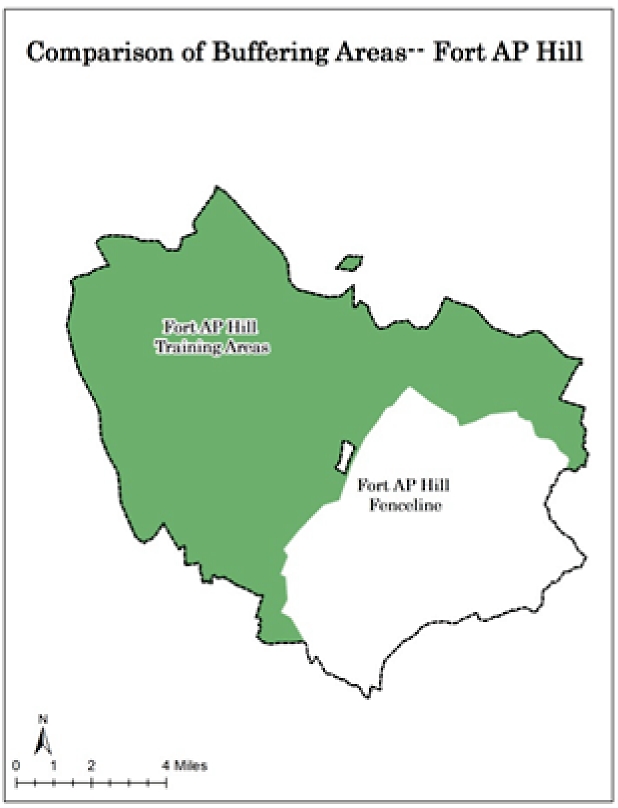

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Abstract

Army stationing analyses have historically been conducted under the assumption that conditions at and around installations will remain static. In reality, the natural, social, and built infrastructure changes over time, and this non-stationarity should be considered in stationing analyses to ensure continuation of each installation's mission. This work documents efforts completed in Fiscal Year 2015 that addressed the temporal aspects of population growth and its potential for negatively impacting an installation's training areas, and the potential impact of currently listed and species at risk of being listed to the endangered species list. A modified method for estimating population impact and a new method for estimating the impact of listed and at-risk species are described.

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Preface

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQUSACE) under project 622720A896, "Environmental Quality Guidance," Work Package "Integrated Climate Assessment for Army Enterprise Planning," Work Item 8D07G1, "Firing Range Capacity." The technical monitor was Sarah Harrop, Headquarters, Department of the Army (HQDA).

The work was performed by the Ecological Processes Branch (CNN) of the Installations Division (CN), U.S. Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, Chris Rewerts was Chief, CEERD-CNN; Michelle J. Hanson was Chief, CEERD-CN; and Alan B. Anderson was the Technical Director for Environmental Quality/Sustainable Lands and Ranges. The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

COL Bryan Green was Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

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1 Introduction

1.1 Background

1.1.1 U.S. Army stationing

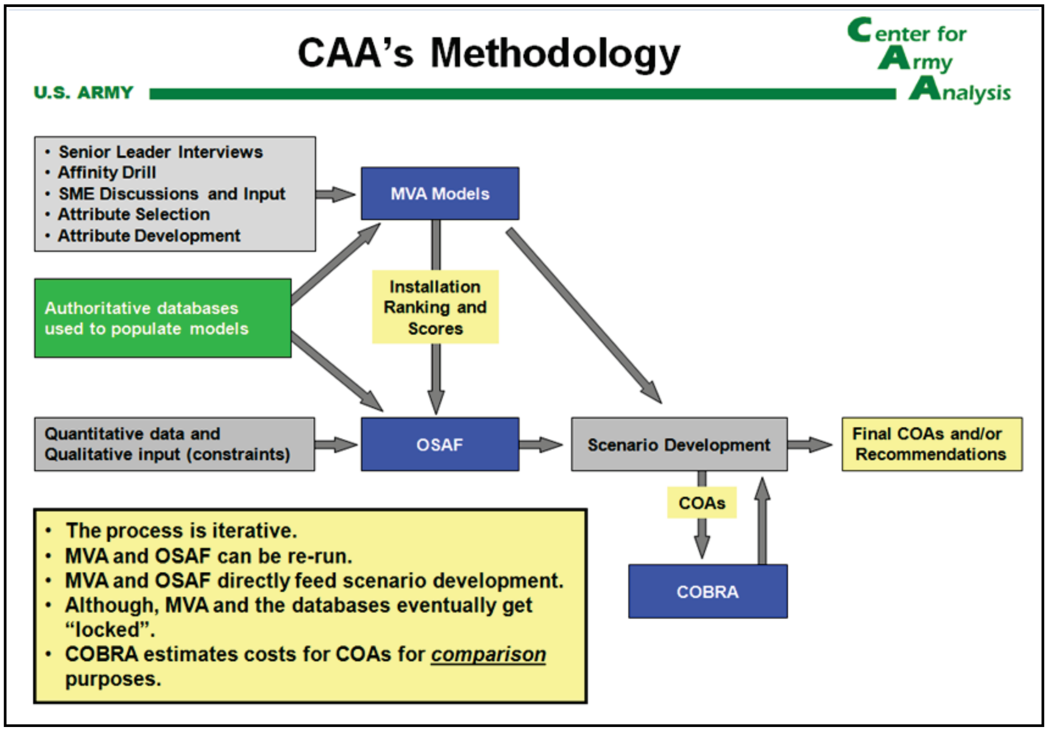
U.S. Army stationing is a constant multi-scale process. Army personnel are in a constant state of flux and changing stations. Army Regulation (AR) AR 10-5, *Organization and Functions* (HQDA 1992) guides most stationing processes. However, large scale stationing, which is identified with strategic realignments, also requires some level of modeling to determine whether the movement of tactical equipment and large numbers of personnel continues to meet future long-term strategic requirements written in the Army Campaign Plan, and to save money. The Center for Army Analysis (CAA) researchers are the experts on large scale modeling and analysis and are often requested to participate in large scale personnel realignments as part of the AR 10-5 process. The largest stationing efforts conducted in the Department of Defense in which CAA participates is the congressionally approved Base Realignment and Closure (BRAC).

To address the scope of stationing analysis required for BRACs, CAA has developed and regularly updates analytical processes that optimize stationing decisions based on costs and military value. Currently, CAA's process for BRAC (Figure 1-1) is composed of four sub-processes:

1. Military Value Analysis(MVA) modeling
2. Evaluation of the Optimal Stationing of Army Forces (OSAF)
3. Evaluation of the Cost of Base Realignment Actions (COBRA)
4. Formulation of final Courses of Action (COAs) and/or recommendations.

This iterative process builds on MVA models that are based on a set of attributes that define the military value of installations. The MVA models result in installation rankings and scores that provide input to the OSAF model. OSAF and MVA outputs are combined to produce potential scenarios, which are then input to the COBRA tool, which ultimately narrows the potential scenarios to yield final COAs and recommendations.

Figure 1-1. Current CAA stationing decision analysis process.



The analysis outlined above is not limited to a BRAC. Many of these tools are used in other large stationing processes, depending on the scope and budget of the process in question. Opportunities for process improvement are available as new technologies are adopted and as data formats evolve that will allow more efficient modeling and improved data standards.

Although CAA's stationing decision analysis process has worked well in the past, the organization has expressed a desire to improve the method for use in future stationing analyses. Climate change can be expected to have an impact on the Army's costs and ability to fulfill its missions. Therefore inserting environmental analysis into stationing decisions is in the interest of the U.S. Army so that it will be better able to predict and prepare for a changing climate. Army installations will be affected by climate change. It behooves the Army to understand how major military realignments may further exacerbate or may be affected by existing and potential future climate-related problems on any one facility. Stationing analysis done with climate forecasting in mind recognizes an unpredictable future, while striving to best prepare for the consequences of climate change on installations through holistic consideration of various climate factors. The inclusion of these factors will result in a stationing analysis process that will allow for more informed MVA modeling and cost analysis.

1.1.2 Climate change vulnerability

The U.S. Department of Defense (DoD), which manages over 25 million acres of land across 425 major military installations, is the third largest federal land managing agency in the United States. DoD has the highest density of federally listed species under the U.S. Endangered Species Act (ESA), more than any other federal land management agency (Benton 2004, 2011). The Army manages nearly half of the total acreage under the management of DoD, across 120 major installations. The Army in particular, has more than twice the number of threatened and endangered species (TES) and at-risk species than other branches of the military (Benton 2004, 2011; Stein, Scott, and Benton 2008).

Military lands are managed primarily for military training and testing purposes to support combat readiness; military land management practices differ from those of other land management agencies. Natural Resource Programs on military installations support the military mission by ensuring access to realistic training lands, while managing for the long-term sustainability of natural resources. Climate change is anticipated to negatively impact the ability of installation Natural Resource Programs to effectively manage listed and at-risk species, increasing the likelihood that the presence of those species will pose additional restrictions on military access to training lands.

Atmospheric temperatures have increased significantly over the last century, causing substantial changes in local precipitation and temperature patterns, which are likely to have widespread effects on military lands, especially in coastal areas and cold climate regions (Hayden et al. 2013, SERDP 2013). It is estimated that more than 30 DoD installations are already at risk due to climate change factors. The effects of climate change on DoD installations is increasing in significance and has the potential to impact the military mission (Daggett 2010). To understand these effects, it is important for the DoD to assess the potential risks and vulnerabilities associated with climate change on its installations and missions globally. A number of environmental impacts from climate change need to be considered in future management plans on military lands, such as: changes in phenology, rising sea levels, alteration of disturbance regimes (i.e., fire, drought, and flooding), disruption of ecological processes, and shifts in species' ranges and distribution. New DoD natural resources guidance, delineated in DoD instruction [DODI] 4715.03 (DoD 2011), requires that the Military Services consider climate change in their Integrated Natural Resources Management Plans (INRMPs) to help mitigate for impacts on military lands.

It is anticipated that another round of military BRAC determinations will occur in 2017 and beyond. Given their ability to generate restrictions on training land use and the likely increase in these restrictions under climate change, listed and at-risk species are a potentially important consideration for the BRAC process. However, environmental factors have only received minimal consideration in the past as part of the decision-making process. While environmental impacts such as cost of potential environmental restoration, waste management, and environmental compliance have been considered in previous BRAC determinations (i.e., BRAC 2005), climate change impacts have not been addressed to date. Potential areas of concern where climate change might impact military capability include: (1) plans and operations, (2) training and testing, (3) built and natural infrastructure, and (4) acquisition and supply chain (DoD 2014). A recent report by the CNA Corporation Military Advisory Board (2014) recommended that climate change be included in future BRAC considerations.

Climate change vulnerability assessments have been applied across different land management agencies to identify current and future climate change priorities on different assessed factors of interest. Climate change vulnerability assessments are coarse-filter approaches for developing qualitative categorization of vulnerability and sensitivity factors. A number of different approaches have been developed to assess the vulnerability and sensitivity of wildlife species to climate change on federal (e.g., Bagne, Friggens, and Finch 2011), state (e.g., Gardali et al. 2012), and tribal lands (e.g., Mawdsley and Lamb 2013). The most widely used and available assessment tool is the NatureServe Climate Change Vulnerability Index (CCVI, Young et al. 2015).

1.2 Objectives

The overall objective of this work is to document the analysis methods developed to estimate the impact of two attributes on an installation:

1. Population growth in an installation's surrounding area
2. New and/or shifting listings of TES.

1.3 Approach

The objectives of this work were met in two principal activities:

1. To estimate the impact of population growth in an installation's surrounding area:
   a. First, existing methods for evaluating these factors were examined.
   b. The methods were then modified and/or updated to better capture the true impact. For the population impact case, the initial method examined was the Military Value Attribute named "Population Impact."
   c. Subject Matter Experts (SMEs) were consulted to reveal heretofore ignored factors of interest, such as Army Compatible Use Buffers (ACUB) and satellite training locations. These factors were included in the analysis of population impact.
   d. An updated methodology, including realistic urban growth projections and graded distance buffer zones, was developed to replace or supplement the existing Population Impact MVA.
2. To estimate the impact of new and/or shifting listings of TES:
   a. Since the impact of already listed and species at risk had no formal evaluation procedure, a new, high-level screening method was developed to estimate the potential impact of such species on an installation's ability to perform its mission.
   b. A rapid, easy process was proposed for assessing the vulnerability of Army installations to impacts of climate change on listed and at-risk species, which could be used to guide a decision matrix for future BRAC and restationing evaluations.
   c. A weighting scheme was proposed that can be applied to all Army facilities and installations, and that generates a single TES impact score for each location of interest.

1.4 Scope

This work explored the ability of U.S. Army installations in the Continental United States (CONUS) to support firing range and maneuver area training in light of how current capacities are likely to change (expand) over the next 3 decades. Drivers to those changes were limited to direct and indirect consequences of changes to climate and to urban growth. This study focused on a limited set of installations distributed across several geographical and climatological regions. While the focus of this project is notionally on the firing range capacity, it is anticipated that these two factors will impact the entire installation.

1.5 Mode of technology transfer

It is anticipated that the results of this work will provide a foundation for follow-on research in support of Army stationing analyses.

2 Population Impact: Current Practices

2.1 Population Impact MVA attribute

CAA recognizes the impact that encroachment may have on an installation, and measures this in the MVA. Population Impact (formerly termed “Urban Sprawl”) examines the population density within a 10-mile buffer zone around the installation and uses a growth factor based on the change in population over the 10 years between 2000 and 2010. This methodology, updated in February 2015, is a revision of the Urban Sprawl MVA attribute used in BRAC ’05. For reference, this definition is included in Appendix A. The Urban Sprawl attribute was “a measure of local changes in land use based on changes in land cover data from non-urban to urban-like features over a 10-year period.” The analysis for this attribute in BRAC ’05 was conducted by ERDC-CERL.

The Population Impact MVA attempts to “address potentially negative impacts on an installation and the nearby communities created by changes in population of the surrounding area over time.” Furthermore, the attribute is an indicator of encroachment issues that is used to assess the impact of population and population growth on the installation and that serves as “an indicator of potential encroachment issues relating to noise complaints, reduction of natural buffer land surrounding installation boundaries, light pollution effects on nighttime training operations, and other potential impacts to operations on installations” (CAA 2015).

The metric uses a 10-mile buffer around an installation to assess the growth rate and thereby possible new encroachment hazards. This metric assumes that the growth rate for the 10-mile buffer is equal across the area, since it is the average of the growth rates of each block within the buffer. However, this assumption could lead to erroneous or deceptive predictions of growth since growth may vary widely in the study area. For example, the area just outside of the main gate of an installation could be growing rapidly while areas closer to the training ranges may not be growing at such a high rate. An assessment that averages the growth rates over the entire buffer area and assumes that growth is happening at that rate through the entire region may erroneously identify a potential problem area. Conversely, if the areas near the training ranges grow rapidly, but growth in the more densely populated areas has slowed significantly, a potential problem area could be overlooked. Identifying the growth rate at distances under 10 miles will greatly improve the assessment of the impact of population growth on the installation.

2.1.1 Current population impact methodology

For the Population Impact MVA, population data are gathered using the most recent decennial census geospatial data at the census block level. Growth factors are derived from the change in census block level data from the most current decennial census and the one immediately previous to it. For example, an assessment performed in 2015 would use the 2010 data as the current set and 2000 as the preceding set. Using a Geographic Information System (GIS), blocks with their centers within 10 miles of an installation boundary are selected.

Installation boundary data are gathered from Army Mapper, the Army's geospatial dataset of record for installations. The boundaries used are notional (not the legal boundaries maintained by the U.S. Army Corps of Engineers). The use of the notional boundaries makes the process easily reproducible because of the accessibility of these boundaries. Furthermore, the boundaries are generalized, providing a resolution adequate for this analysis and significantly reducing processing times. Averaged population density and population growth rates are then calculated using the census block data. These values are normalized across the entire set of installations in the study set so that the Population Impact Score (normalized population density + normalized percent change in population) can be calculated.

2.1.2 Challenges with the current methodology

The methodology presented in the MVA attribute definition provides a generalized indicator of the potential for future encroachment issues. While it is useful to have information regarding population densities around military installations as an encroachment indicator, the methods used do not adequately relate significance to the locations and projected growth rates of the population centers. Encroachment factors include noise, dust, radio frequency availability, and light pollution, all of which are dependent on the locations of the residential centers. Synchronizing the encroachment factors and projected urban growth would result in a more meaningful assessment of the impact of Urban Sprawl.

Using a linear growth model, based on the previous 10 years of growth does not adequately portray the potential urban growth in an area. Multiple factors, such as availability of space for housing, economic resiliency, and desirability of a location all influence the actual growth in an area. Additionally, long-term growth tends to level off when an area reaches a saturation point, an effect not captured in a linear growth model. A linear model also fails to capture the effects of a significant influx or outflow of population due to external drivers, such as a major restationing decision. Finally, if a significant population event occurred within or just after the timeframe, the growth rate could be skewed.

2.1.3 Proposed solution

The current attribute does not couple population location or growth to encroachment factors such as noise, dust, TES habitat, and light pollution. This work proposes the use of an urban growth model to project future areas of development that are expected to cause encroachment. The initial plan was to couple this model with noise contours that could be used as a "worst case" encroachment factor due to the distances to which noise can propagate beyond the fenceline. Noise contours could be overlaid on the population map and areas of greater impact identified. Locations experiencing high growth rates that are also within the high impact region of a noise contour would indicate a stronger potential impact on the installation training mission. However, as that analysis was conducted, it was found that there were few instances of noise propagating outside of the installations fenceline at the case study sites. Instead, a distance-weighted assessment of population growth around the training areas was implemented.

3 Population Impact: Proposed Changes to the Population Impact MVA

In response to the challenges of aggregated linear growth this work proposes six changes to the Population Impact MVA attribute:

1. *Use of Urban Growth Modeling*. An urban growth model is a spatial model that predicts what land will develop in the future. The use of an urban growth model lets the user better assess future encroachment hazards because the model makes it possible to assess the hazards' proximity to an installation.
2. *Use of LandScan Population Data*. It is recommended to change the population data from U.S. Census block data to the LandScan population estimates from Oak Ridge National Laboratory (ORNL). This dataset, which is provided free of charge to the Federal government, reduces processing time and, because it provides population estimates at 30-meter resolution, allows population estimations to be developed at scales below 10 miles.
3. *Use of Areas Less than 10 Miles*. Changing data sources to LandScan for population and for urban growth modeling makes it possible to provide population estimates at a resolution finer than 10 miles.
4. *Measurement from Ranges*. The current population impact attribute uses a 10-mile buffer from the installations fenceline to calculate population. A 10-mile area was selected by SMEs, based on factors such as noise, road infrastructure, and a comparison of the population densities around the installations (CAA 2015). Because the greatest impact of urban growth surrounding an installation comes from growth near the training areas (as opposed to near the cantonment area), this work used training land proximity (as opposed to the entire fenceline) as the buffering point.
5. *Incorporate Satellite Training Areas into Analysis*. The current population impact attribute only measures from the installations main fenceline. This analysis includes non-adjacent training areas associated with an installation. From conversations with the Army Environmental Command, researchers were not able to locate an official list pairing satellite training areas to installations. In the event of a stationing event, it is recommended that a data call be used to obtain satellite training areas from the affected installation(s). Section 3.1 provides a summary of these training areas.
6. *Give Weight to Installations with ACUB Land*. The ACUB Program is a tool to protect an installation's accessibility, availability, and capability for training, testing, and operations by sustaining natural habitats, open space, working lands, cultural resources, and communities. ACUB land shapefiles were obtained from the ACUB team. These were made into "no-

growth" areas in this urban growth model. Installations with ACUB programs therefore will not have development projections in these parcels. It is also proposed that a weighting scheme be devised for the final MVA score that provides a bonus point for installations with ACUB programs.

This project initially planned to assess urban growth in relationship with components of range sustainability defined by the Army Sustainable Ranges Program (growth of urban areas, noise abatement, air quality, demand for use of airspace, maritime sustainability, frequency encroachment, unexploded ordnance and other constituents, endangered species protection and critical habitat designations) (USD[P&R] 2014). After searching for data and a method to produce an easily scalable solution, growth of urban areas and noise abatement were selected as factors to assess. It was initially proposed that noise contours could be used as a "worst case" encroachment factor, due to the distances to which noise can propagate beyond the fenceline. However, when assessment of noise contours began, it was found that in many instances, noise of significant levels did not leave installations. Furthermore, there was a higher requirement on runs of the urban growth model to have confidence in the results of development within certain areas, thereby increasing the runtime significantly.

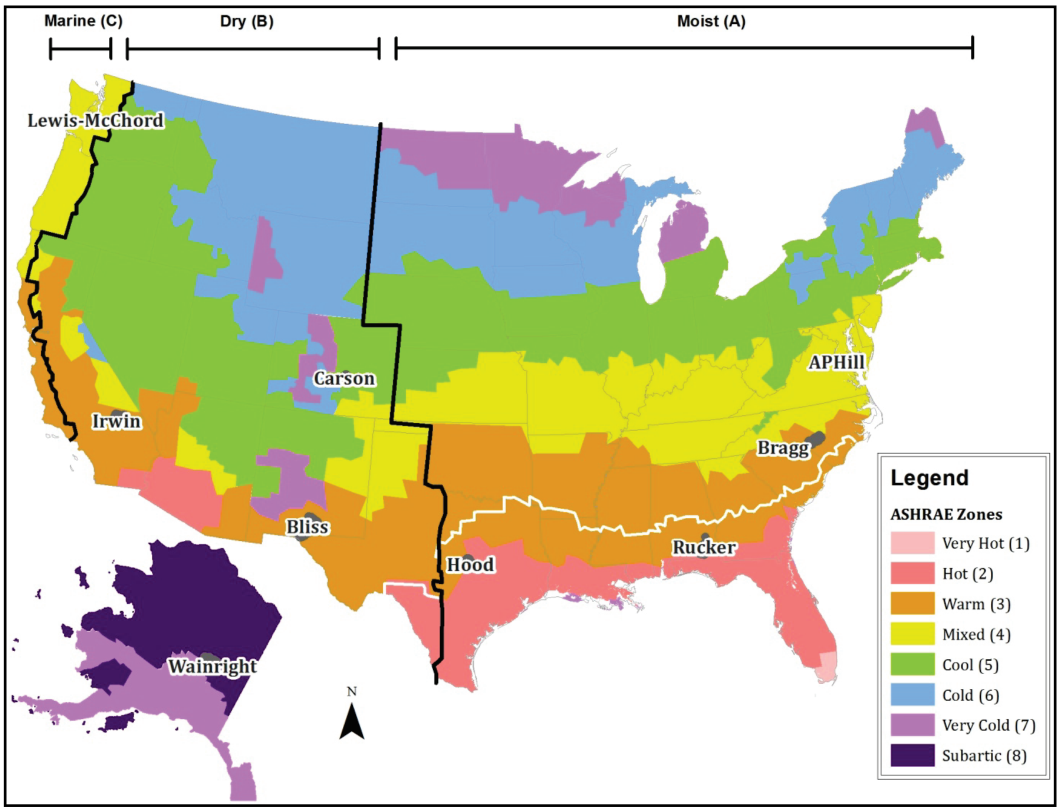
3.1 Case study areas

A subset of Army installations were selected as case studies in this proof of concept analysis. In the initial selection, the primary criterion was the existence of large weapon training ranges. This criterion was based on the original concept of using noise contours as a surrogate for encroachment. Large weapon noise propagates much farther into the surrounding communities than small arms range noise. Because the initial proposal was to assess urban growth in relation to noise contours, the second criterion was the availability of noise contours from the installation. Not all of the installations on the initial list had approved noise contours that they were able to share with the research team. Once the initial set was obtained, the urban growth rates around the installations were examined. In a small number of cases, the growth was so small (<1%) that an analysis including urban growth potential was not considered useful. Ultimately, the set was reduced to nine installations that contain examples from multiple geographical and climatological regions (Figure 3-1):

- Fort AP Hill, VA
- Fort Bliss, TX

- Fort Bragg, NC (included satellite Camp Mackall)
- Fort Carson, CO (satellite Piñon Canyon not included)
- Fort Hood, TX
- Fort Irwin, CA
- Joint Base Lewis-McChord, WA (satellite Yakima Training Center not included)*
- Fort Rucker, AL (included multiple un-named satellites)
- Fort Wainwright, AK (included satellites Donnelly Training Area, Gerstle River Artic Test Site, and Black Rapids Training Area).

Figure 3-1. Map of Case Study sites in relation to their climate zones, illustrating the geographic diversity.



3.2 Regional Urban Growth model (RUG)

The current CAA methodology uses a normalized growth rate from 2000-2010 for the region. As previously discussed (Section 2.1) linear growth models do not necessarily adequately portray the potential urban growth

* After the analysis, stakeholder feedback indicated that Yakima Training Center was considered to be a satellite location of Joint Base Lewis-McChord. This was previously unknown because no dataset pairing training areas with main installations was available. If this method is applied to restationing, it is recommended that a data call be implanted to ascertain the training areas associated with each installation.

in an area where housing, economics, and desirability of a location are all drivers of growth. A linear growth model may significantly skew growth in areas where there has been an influx or loss of population between the two times. For military installations affected by BRAC ’05, future estimations may produce a skewed future growth projection.

There are multiple methods and tools available for creating more detailed projections of future population densities over variable time periods. These include the ERDC-CERL-maintained Regional Urban Growth model (RUG) (Westervelt, BenDor, and Sexton 2011), the Landuse Evolution and Impact Assessment Model (LEAM) (Deal and Pallathucheril 2009) and the U.S. Environmental Protection Agency’s (USEPA’s) Integrated Climate and Land Use Scenarios (ICLUS) model (Bierwagen and Morefield 2014). Using any of these methods presents a significant improvement to the growth rate estimates currently used by CAA.

The RUG model was used to produce estimates of growth. The RUG model produces a spatially explicit estimate of future urban growth based on data and user input to the model. The goal of the RUG model is to generate residential attractiveness maps and growth projections that are based on nationally available datasets and require little human intervention to produce. The RUG model is a software tool intended to be rapidly implemented by a planner with reasonable GIS knowledge, or a GIS technician with little requisite simulation expertise. Because RUG is DoD owned and managed software, it has the greatest potential for reliable access and adaptability. RUG can be rapidly installed, parameterized, calibrated, and run on almost any several-county region within the United States (Westervelt, BenDor, and Sexton 2011).

There are two primary components to the RUG model. The first component assesses the relative attractiveness for urban growth for every location in a rasterized landscape within a region. The urban attractiveness map produced from the first component of the RUG model is then used as input to the second component of the RUG model, which forecasts future urban growth patterns based on this attractiveness. The two components of the RUG model and their data input requirements are described in more detail below.

3.2.1 RUG component #1 – Estimating attractiveness to development

The first component of the RUG model estimates development attraction for every location in a rasterized landscape on the basis of proximity and travel time to development attractors. First, each of the development attractors (driving times to road intersections, driving time to highways, driving time to interstate ramps, driving time to three different categories of urban density, slope, distance to forest, and distance to water) were identified and mapped in a GIS. Minimum travel times for every grid cell location to each of the nearest individual attractors of growth were calculated.

This resulted in a set of minimum-travel-time maps from each grid cell to all sets of attractors. The travel-time maps were then converted to "attractiveness" maps using a conversion function based on the "training" map layer. The training map layer identifies areas that have recently developed and therefore are assumed to reflect the land's current attractiveness for development. A final step in the estimation of attractiveness element of RUG was to use the R statistical package to calculate logistic regression to combine the attractiveness values of the individual attractors at each cell location. The resulting equation was captured and applied using raster math in a GIS; each grid cell is assigned the logit probability of development, resulting in a combined urban attractiveness map (Westervelt, Ben-Dor, and Sexton 2011).

3.2.2 RUG component #1 – Data Inputs

Six GIS datasets (five raster and one vector) are required as inputs to develop the attractiveness map. All of the raster data layers must have the same spatial resolution, projection, and geographic extent. These six datasets, as well as their sources, are described in the following sections.

3.2.2.1 Region

This is a raster map outline of the region of analysis. For this study, this was the boundary of counties in the vicinity of the case study installations. There are many ways to define a region, and there is not a comprehensive national dataset of regional councils or other regional boundaries. Many installations support a regional council comprising surrounding counties. Lacking a dataset, the region for each Army installation was defined as those areas bounded by the counties adjacent to it. These counties are listed in Appendix C. These counties were manually selected based on projected growth rates, proximity to installations, and location of urban areas. The tools outlined in this paper can be easily transferred to other regional definitions including the housing market area, the members of a local regional council, or sources of water.

Areas within the study area were coded with a value of "1" and the remainder of the area with a value of 0 (zero). All other GIS data layers were clipped to this boundary of the study area. Vector GIS data of U.S. counties is available for free download from the national map viewer.*

3.2.2.2 Elevation

Elevation was further used as an input to the RUG model. A raster digital elevation model (DEM) was obtained with values in meters above sea level. The DEM was used to calculate slope, which is one of the attractors considered in the RUG model. Raster DEM's are also available for free download from the national map viewer. Elevation is computed at some point into slope.

3.2.2.3 Landcover

The National Land Cover Database (NLCD), developed by United States Geological Survey's Multi-Resolution Land Characteristics Consortium (MRLC) was obtained. The landcover map is used to identify dense urban centers, which is one of the attractors to urban growth. It is also used to calculate distance to forest and distance to water, both of which are attractors in the model. In addition, the landcover map is used to identify areas where projected growth can occur. The NLCD is available for free download from the national map viewer or MRLC.†

3.2.2.4 Roads

A vector map of roads for the study area was obtained from the national map viewer. By using the integer value in the "ROAD_CLASS" field, it was possible to distinguish between road types and to assign appropriate travel speeds for the different types of roads. The travel speeds for different road

* http://viewer.nationalmap.gov/viewer/

† www.mlrc.gov

types were used to estimate travel time to road intersections, highways, interstate ramps, and urban areas.

3.2.2.5 Training

The training map, which is a raster map delineating where urban development has recently developed, was therefore assumed to reflect the lands current attractiveness for development. This map is used to calibrate the equations used to calculate the attractiveness of every grid cell across the study area. The *NLCD 2006 to 2011 Land Cover Change* map was used to create the training map and is available for free download from MRLC. Any locations in this change map that had changed to an urban landcover type between 2006 and 2011 were coded with a value of “1” and all other values were coded to “0.”

3.2.2.6 NoGrowth

The final input to the attractiveness map calculations is a raster map identifying cells where development is not permitted. The NoGrowth raster was compiled from two data sources. The first data source was *the Protected Areas Database* available for free download by state from the National Gap Analysis Program/Protected Areas Data Portal.* Protected areas that are delineated in this dataset represent any type of land where development would not be permitted, such as federal or state-owned land, parks, natural areas, wetlands, and military installations.

The second source of data used to compile the NoGrowth map was the boundary of ACUB areas in the vicinity of installations (Table 3-1). The ACUB program is a tool used to protect an installation’s accessibility, availability, and capability for training, testing, and operations by sustaining natural habitats, open space, working lands, cultural resources, and communities. ACUB land development right acquisitions generally work through cooperative agreements that place restrictions on the development of land outside of an installation boundary. Managed by the U.S. Army Environmental Command (USAEC), a subcommand of the Installation Management Command (IMCOM), the ACUB program supports soldier combat readiness training through partnerships with public and private landowners and organizations.

* http://gapanalysis.usgs.gov/padus/data/download/

Table 3-1. Summary of ACUB Programs for Case Study Sites.

Installation	ACUB Program Status
AP Hill	Yes
Fort Bliss	Yes, but no parcels acquired as of June 2015.
Fort Bragg	Yes
Fort Carson	Yes
Fort Hood	Yes
Fort Irwin	No. ACUB program expired in 2008, but no land was acquired.
Fort Rucker	No
Fort Wainwright	Yes
Joint Base Lewis-McChord	Yes

ACUB acquisitions are formalized through cooperative agreements, and are representative of a positive relationship among the community and a base. ACUB data were obtained from the U.S. Army Environmental Command ACUB Team and combined with the Protected Areas Database to produce the NoGrowth map. Areas where growth is prohibited were assigned a value of "1" and background areas where growth was possible were assigned a value of "0."

3.2.3 RUG Component #2 – Forecasting Urban Growth

The second component of RUG actually places patterns of urban growth over a user-specified time interval, resulting in a realization of a potential landcover map for some future date. This was accomplished by calculating the number of new growth locations needed, identifying the grid cells that could be developed, and then creating a sorted list of those locations based on attractiveness to growth. Attractiveness for each grid cell was based on the attractiveness value in the input map and the amount of randomness (see randomness coefficient below) specified by the user, which for this project was set to the minimum. The random-factor accounts for randomness in decision making, and for the fact that a knowledge of past growth patterns is not a full predictor of future growth. The top grid cell in the list is then developed, followed by the second most attractive, followed by the third and so on. Depending on whether the Neighborhood-size coefficient is set,* either the adjacent grid cells are developed to create a neighborhood up to a specified size, or the grid cell with the next highest attractiveness value is developed without considering adjacency to the previously

* Also see Section 3.2.4.4, Neighborhood-size below.

developed patch. This process is completed until the simulation time frame is completed (Westervelt, BenDor, and Sexton 2011).

3.2.4 RUG Component #2 – Data Inputs

3.2.4.1 Urban attractiveness

This is the map of the attractiveness of each cell to urban development, which is produced in Step #1 (see description above)

3.2.4.2 Landcover

This is the baseline landcover map from which to initiate the simulation. It determines where growth can and cannot occur. The original source for this map is the NLCD landcover map used as input to the first component of RUG. The original NLCD landcover map has roads misclassified as urban. A roads mask is used to mask out the road category so that the only remaining urban landcover types are residential.

3.2.4.3 Runtime

The user must specify the number of years to run the simulation. In this project, the simulation was run for 30 years. Thirty years was selected based on professional opinion of how long into the future the model results are useful before construction of new roads make the model results inaccurate.

3.2.4.4 Neighborhood-size

The Neighborhood-size coefficient determines how dispersed or clustered the projected new urban growth pixels should be in the resulting landcover map. This value was set to zero, allowing projected growth to be allocated to isolated pixels rather than forcing new development to occur in clusters or neighborhoods of pixels.

3.2.4.5 Random-factor

A coefficient denoting the weight of random or spontaneous growth. In this project, the randomness factor was set to the minimum possible value of 1%, which specified that urban development was allocated to grid cells in the order of their calculated attractiveness to growth with a small (1%) amount of randomness factored into the allocation. The random-factor accounts for the element of human choice, which impacts how development occurs

3.2.4.6 Population growth

An annual percent growth rate is used for projecting urban growth. Central to the urban growth model are population projections. Population projections require localized knowledge of development trends, economic activity, and local social factors like household size. Due to the importance of these local factors, the Census Bureau stopped publishing county-level population projections. After evaluating national data sources including ICLUS (Bierwagen and Morefield 2014) and the Water Supply Stress Index (WaSSI) [Ecosystem Services Model] (Caldwell et al. 2013), it was determined that these population projections were not sufficient for this work. In many instances, these projections were based on data recorded before the completion of BRAC '05 stationing in 2011. In the evaluated sites, these projections provided inaccurate current regional population, reducing the validity of the future projections.

Historical data were used to estimate future regional growth, feeding annual percent growth into RUG. Annual population estimates for counties (BEA 2014) were obtained using table "CA1" from the U.S. Department of Commerce Bureaus of Economic Analysis. Using the BEA data made it possible to view population estimates from 1969 to 2013 in one spreadsheet, reducing data conversion errors. Using data from the U.S. Census would have meant combining multiple sheets to get this extent of data. These data were used to calculate the annual percentage growth rate as:

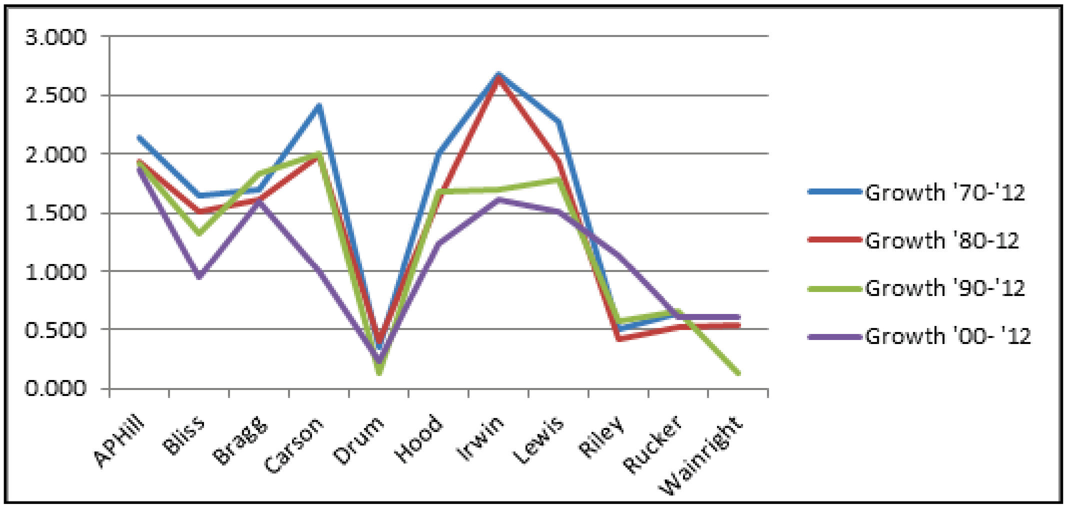
$$P = \left(\frac{f}{s}\right)^{\frac{1}{y}} - 1 \qquad (3\text{-}1)$$

where:

f = final value or population
s = starting value or population
y = number of years.

Calculating growth starting at different decades ('70, '80, '90, '00) and calculating the annual percentage change to 2012 revealed that there were general consistencies within annual percent changes. However, as Figure 3-2 demonstrates, both 1980 and 1990 had fewer outliers. The time period from 1980 to 2012 was selected to estimate annual growth because it gave a longer period of time for estimating and because this period was before the first round of BRAC in 1988.

Figure 3-2. Annual percent population growth for study sites.



These annual averages were rounded to the nearest whole number and used in RUG to estimate growth. Annual percent growth rate for each installation was calculated as the mean of annual percent growth rate for each county in the installation region. Table 3-2 lists annual percent growth for each installation region.

The RUG outputs provided estimates that a cell would develop between 2011 and 2041. Rather than calculating a population growth rate, as is done in the current metric, the growth rate was calculated in the number of developed cells between 2011 and 2041. As this was calculated as a raster in 30x30-meter resolution, it was possible to estimate the growth rate for various distances from ranges.

Table 3-2. Annual percent population growth for study sites.

Installation	Annual Percent Growth, 1980-2012
AP Hill	1.9
Fort Bliss	1.5
Fort Bragg	1.6
Fort Carson	2.0
Fort Hood	1.6
Fort Irwin	2.6
Fort Rucker	0.5
Fort Wainwright	1.3
Joint Base Lewis-McChord	1.9

3.3 Population estimates from LandScan

CAA currently uses U.S. census block data to produce estimates of population for the attribute. Census blocks are the smallest geographic units where data are collected and distributed by the census. Blocks vary significantly in size. In an urban area, a census block will generally look like a city block bounded by streets. In more rural areas, blocks can be large and irregular in shape, and are bounded by a variety of features such as roads, streams, and transmission lines. In very remote areas, a census block may encompass hundreds of square miles.

The variability in the size of the blocks makes it difficult to assess population within a small area. For example, in the 10 miles surrounding Fort Bliss, there are over 19,000 census blocks (Figure 3-3). The smallest block has an area of under a quarter square mile, while the largest is nearly 287 square miles. LandScan™ U.S. population estimates developed by Oak Ridge Laboratory were used to improve the estimation of population. Using U.S. census data, satellite imagery, night time lights, and other factors, LandScan provides population estimates for 60x60-meter cells. To produce the estimates, the LandScan apportions census counts to grid cells based on likelihood coefficients, which are based on proximity to roads, slope, land cover, nighttime lights, and other information (ORNL 2015). For the United States, there are both day and night population estimates. This analysis used night estimates on the assumption that most people will be in their place of residence at night. The scale of the data allows researchers to access more highly refined data than would be possible using block level census information, thereby allowing greater confidence to produce population estimates at a smaller scale.

One of the reasons why a 10-mile buffer was selected by CAA in its initial assessment was in recognition that population is not evenly distributed within a census block. Population may be clustered in one area, with the remaining area being occupied by industrial, office, open space, or agricultural land. By selecting a smaller buffer, CAA was concerned that they may be inappropriately accounting for population. The resolution of the LandScan data made it possible to produce population estimates at smaller scales—0.5, 1, 2, 5, and 10 miles. There were no significant differences in the population density estimates produced using a 10-mile buffer around an installation using census or LandScan data (Table 3-3). At scales below 10 miles, however, there were differences.

Figure 3-3. Demonstration of the variety of sizes of census blocks surrounding Fort Bliss, TX.

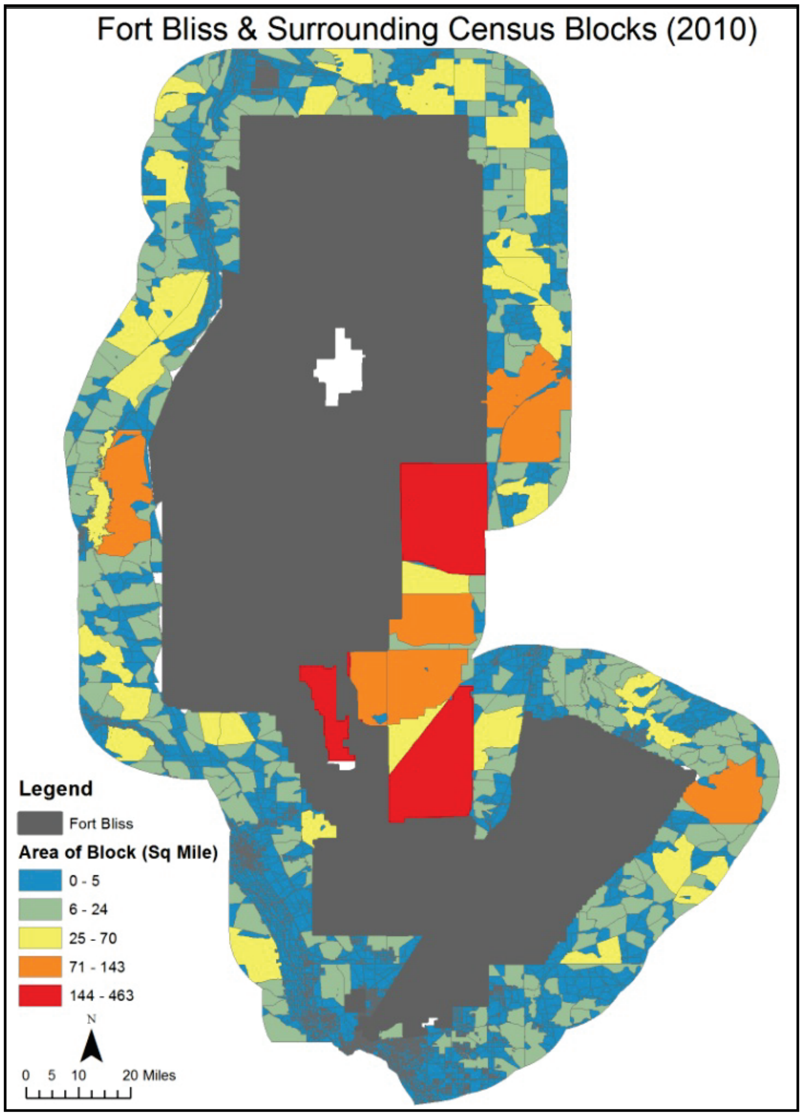


Table 3-3. Population estimation for 10-mile buffer around training areas using census 2010 and LandScan.

Location	Population 2010 Census Estimate	Population Density-2010 Census	LandScan Population Estimate	LandScan Pop Density
AP Hill	153,286	187.86	158,462	194.20
Bliss	813,442	200.60	832,353	205.26
Bragg	467,263	286.09	478,487	292.97
Carson	320,040	293.63	331,254	303.92
Hood	374,195	245.22	385,653	252.72
Irwin	9,713	4.08	9,957	4.18
Lewis-McChord	838,425	799.35	865,936	825.58
Rucker	209,398	92.68	211,814	93.75

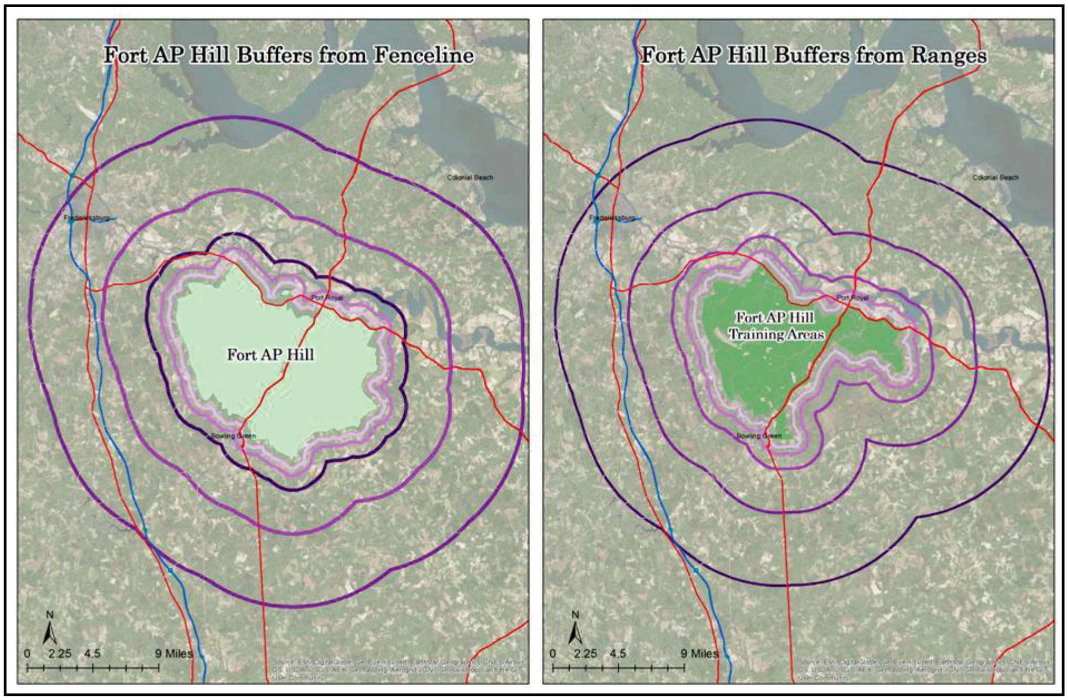
While census data are considered to be the authoritative source of population counts in the United States, census counts can often be incorrect. For example, undocumented populations or non-English speakers are less likely to fill out census forms because they do not understand the process. By looking at the urban footprint along with census estimates, LandScan can produce more robust estimates. LandScan is available freely within the federal government, and is included in the widely distributed annual release of GIS data from the Homeland Security Infrastructure Program (HSIP) (Booz Allen Hamilton 2012). Furthermore, LandScan data is packaged in a way that requires less processing capacity and time to produce population estimates than do census data. Regardless of the method that is selected, LandScan or Census, the use of buffers that do not correlate to the units in which the data was collected will result in errors. However, the use of reliable data available at a higher resolution reduced the number of errors.

3.4 Post-processing of the data for the updated attribute

The first step in determining the impact of population on the installation was to select the buffer distance around the installation to investigate. Currently, CAA uses a 10-mile buffer from the installations fenceline. This buffer was selected by SMEs, based on factors such as noise, road infrastructure, and a comparison of the population densities around the installations. The boundaries for buffering were the notional boundaries provided through the Army Mapper program. As the greatest impact of urban growth surrounding an installation results from growth near the training areas, as opposed to near the cantonment area, this work proposes using training lands as opposed to the fenceline as the buffering point. Distances of 0.5, 1, 2, 5, and 10 miles from ranges were buffered using the *Training Areas Dataset* from the Sustainable Range Program. The goal was that, by having a variety of distances, it would be possible to weight the impact of development on the installation based on its proximity to the base. Figure 3-4 shows the differences in buffer areas based on the point of buffering. Because footprint of the ranges is smaller than the installations fenceline, the buffer area is smaller.

Simply measuring 10 miles does not fully capture the population density and its possible impact on an installation. For example, within 0.5 miles of ranges at Fort AP Hill the population density is 25.4. However the density is six times larger when calculated for a 10-mile area. Figure 3-5 shows that the population is concentrated in the Fredericksburg area and may have less impact on training capacity than development closer to the base.

Figure 3-4. Buffer areas from buffering from the installation's fenceline (left) and ranges (right) for Fort AP Hill.



3.4.1 Population calculation post-processing

Population Densities were calculated using the 2013 LandScan U.S. nighttime. As discussed in Section 3.3, these data allow researchers to create population estimates at a finer resolution than they could create using census block data. Using the buffers of 0.5, 1, 2, 5, and 10 miles the raster population estimates layer was summarized using zonal statistics. Zonal statistics provide a summary of the data that intersect or are contained within another layer (ESRI 2014). Cells that are on the edge of two buffer zones may be included in multiple buffers. If a cell is within both the 0.5- and 1-mile buffer that cell's population is reflected in both estimates. To reduce this double counting the population for each buffer calculated individually (i.e., using 0.5 mile as a base and adding subsequent buffers onto that). Table 3-4 summarizes the population estimates for these case study sites. For comparison with the current metric, the figures provided are estimates as measured from the installations fenceline, rather than from the ranges.

Figure 3-5. Map of urban development in relation to distance from ranges at Fort AP Hill.

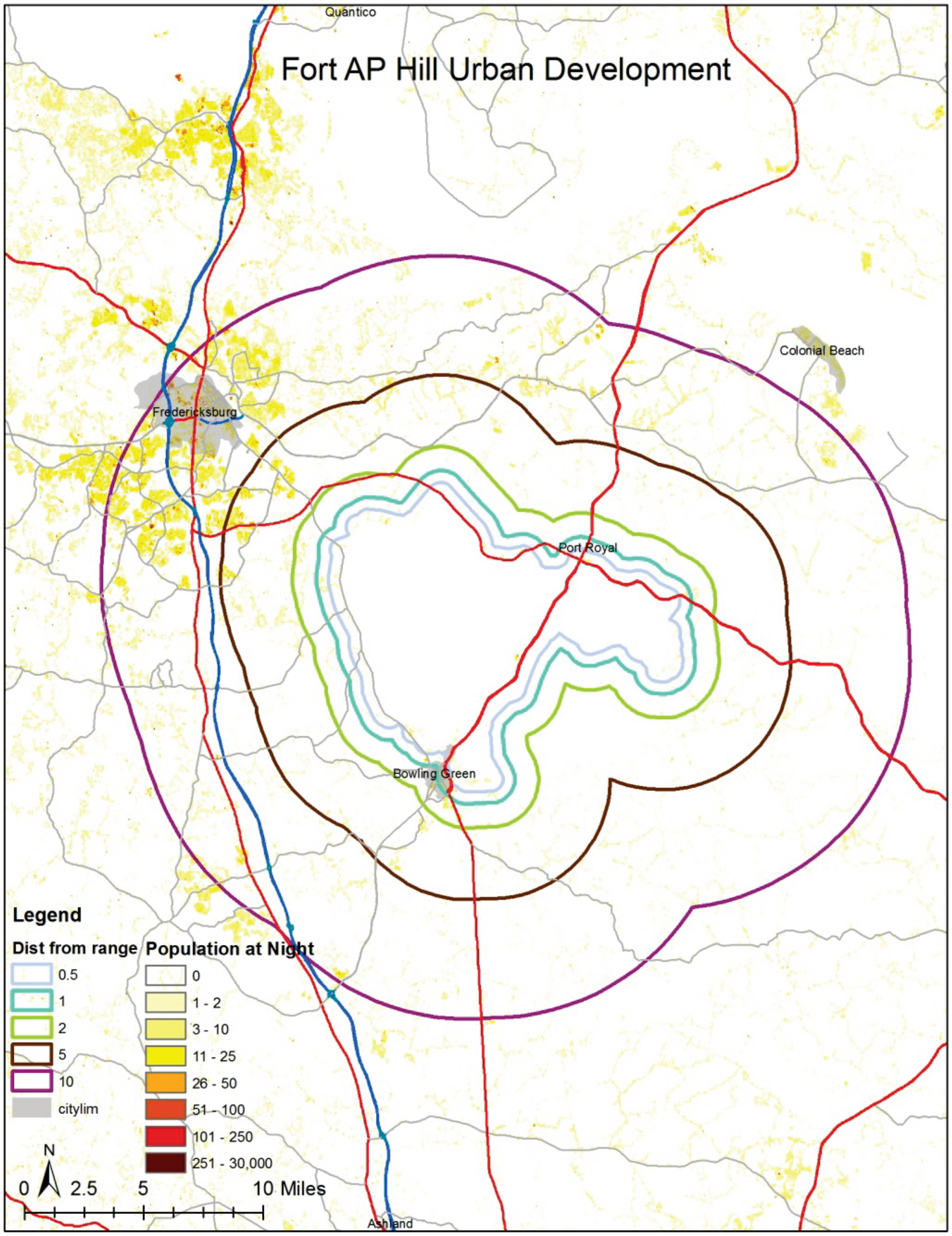


Table 3-4. Population estimates for case study sites using LandScan data and measuring from ranges.

Location	0.5 miles	1 mile	2 miles	5 miles	10 miles	10 miles current method
AP Hill	2,697	4,499	7,262	27,332	159,883	155,515
Bliss	99,703	187,297	326,690	621,205	884,838	890,860
Bragg	70,025	98,482	165,076	320,710	468,924	450,813
Carson	26,687	47,489	99,456	211,233	448,385	433,232
Hood	71,795	114,891	178,204	279,609	361,697	352,369
Irwin	9,071	9,096	9,100	9,106	9,978	9,727
Lewis-McChord	57,742	88,943	150,435	410,005	863,021	834,826
Rucker	13,029	23,618	42,103	105,843	211,700	208,848
Wainwright	114	991	6,769	70,297	94,416	95,796

3.4.2 Growth rate

Growth rate was calculated as the total increase in urban landcover over a 30-year period as projected by the RUG model. First, the total area of urban landcover in the 2011 NLCD was tabulated for buffers of 0.5, 1, 2, 5, and 10 miles around the installations fenceline and from the ranges. This established a baseline from which to calculate growth. A projected land cover map for 2041 was obtained using the outputs of a 30-year simulation from RUG. A decision was made to continue to use the percent growth calculation used by CAA currently for simplification. However, using a compounded annual percentage growth, such as the one outlined in Equation 3-1, would be recommended. Percent growth was then calculated as:

$$\frac{\frac{2041\ Developed\ Area - 2011\ Developed\ Area}{2011\ Developed\ Area}}{30\ (Years)} \qquad (3\text{-}2)$$

Table 3-5. Yearly growth rate by distance from ranges.

Range Buffer Growth Rate/yr.						
	0.5	1	2	5	10	10 mile growth rate Feb. 2015 version
AP Hill	0.0043	0.0051	0.0078	0.010	0.0187	0.02834
Bliss	0.0068	0.0064	0.0060	0.004	0.0047	0.02243
Bragg	0.0115	0.0136	0.0119	0.011	0.0116	0.01303
Carson	0.0058	0.0067	0.0092	0.008	0.0073	0.01223
Hood	0.0187	0.0163	0.0139	0.013	0.0132	0.00391
Irwin	0.0000	0.0000	0.0000	0.0000	0.0178	0.02518
Lewis-McChord	0.0101	0.0105	0.0105	0.010	0.0084	-0.00887
Rucker	0.0072	0.0063	0.0066	0.007	0.0074	0.01404
Wainwright	0.0000	0.0048	0.0081	0.008	0.0077	0.01642

4 Population Impact: Results and Courses of Action

This chapter outlines a methodology for calculating the Population Impact MVA through a specific weighting scheme. This weighting scheme can be altered based on feedback that CAA may receive from installations. As previously discussed, the current methodology used by CAA uses a 10-mile buffer from an installations boundary to calculate growth rate (2000-2010) and population density (2010). This proposed methodology keeps the intent of the current methodology by keeping the components growth rate and population density. In addition to changing the sources of data from the U.S. census to LandScan and the outputs of the RUG model, the following changes are also proposed:

- Provide bonuses to installations with ACUB programs.
- Create buffers from training areas, rather than from the installation fenceline.
- Calculate population density and growth rates at distances less than 10 miles from the installation.

4.1 Updated data shifts results

Using updated data with the current methodology changes the results of the Population Impact MVA. Table 4-1 lists two scores of the Population Impact MVA. The left-hand column lists the results of the analysis using the current Population Impact MVA scoring mechanism (as of February 2015). This score uses census data for both the population density and the growth rate. Population density is standardized on a 0-9 scale and growth rate is standardized on a 0-1 scale. The data in the right-hand column use a 10-mile buffer from ranges to calculate population density and the growth rate. Instead of using census data, however, these scores use LandScan data for the population density and the growth rate generated from the RUG output.

Under the current methodology and with the updated data sources Joint Base Lewis-McChord has the highest score, meaning it has the greatest possible effects of population. Fort Irwin, which ranks best using the current method, demonstrates slightly less value in the new calculation.

Table 4-1. Current Population Impact MVA score (left) and the modified MVA score (right).

Location	Current Population Impact Score 10-mile population density (9), 10-mile growth rate (1)	Current Population Impact Methodology with updated data 10-mile population density (9) 10-mile growth rate (1)
AP Hill	3.00	4.28
Bliss	3.23	1.95
Bragg	4.63	2.66
Carson	4.75	4.15
Hood	3.56	1.88
Irwin	0.00	0.94
Lewis-McChord	9.62	9.26
Rucker	1.47	1.08
Wainwright	0.92	0.63

This is because the RUG model projects that there will be development within the 10 miles surrounding the Fort in the next 30 years, while there was negligible growth between 2000 and 2010. Fort AP Hill demonstrates the greatest shift: 3.00 to 4.28. This is a result of measuring from the ranges, rather than the entire installation. If the same weights were applied to data calculated from the installation boundary, AP Hill's score would drop from 3.00 to 2.99.

4.2 Proposed update

The current methodology gives a weight of "9" to the population density and weight of "1" to the growth rate. Assessment done in the initial attribute creation found that there was little impact on the overall score by shifting the weights given to population density and growth rate. Within these assessments, it was found that there were significant changes in scores depending on whether population density or growth rates were given more weight. Furthermore, it was found that the largest impact on shifting the scores of an installation was weighting buffers.

It is proposed to update the Population Impact MVA attribute to use the following weights (Table 4-2):

- 10-mile Population Density: 2
- 5-mile Population Density: 1
- 1-mile Population Density: 2
- 10-mile Growth Rate: 2
- 5-mile Growth Rate: 1
- 1-mile Growth Rate: 2.

Table 4-2. Updated Population Impact MVA comparison with current ca.

Location	Current Population Impact Score 10-mile Population Density (9), 10-mile Growth Rate (1)	Update to Population Impact 10-mile Population Density (2), 5-mile Population Density (1), 1-mile Population Density (2), 10-mile Growth Rate (2), 5-mile Growth Rate (1), 1-mile Growth Rate (2)
AP Hill	3.00	4.37
Bliss	3.23	1.95
Bragg	4.63	5.15
Carson	4.75	3.20
Hood	3.56	5.70
Irwin	0.00	1.90
Lewis-McChord	9.62	7.58
Rucker	1.47	2.46
Wainwright	0.92	1.77

Using this methodology shifts scores and presents an improved way to calculate the impact of population on an Army installation. While still having the highest score, and thus the highest likelihood of increased encroachment, Joint Base Lewis-McChord's total score drops from 9.62 to 7.58. This drop is attributed to the use of multiple buffer areas. The installation has a population density of 211 people per square mile within 1 mile of ranges and 438 within 10 miles from the ranges. The encroachment hazards generated 10 miles away from the installation will have impacts on the installation, as will development (or lack thereof) in proximity to an installation. Using a combination of 1, 5, and 10 miles in calculating impact allows greater nuance in the results.

4.3 Integrating ACUB

Conversations with SMEs and stakeholders identified the importance of integrating the ACUB into the population impact analysis. Installations and the surrounding community collaborate in the ACUB program to protect land from development, thereby ensuring that training can still occur. ACUB acquisitions are formalized through mutual agreements, and are illustrative of a positive relationship among the group and a base. ACUB programs are integrated in this analysis through the no-growth map input to RUG, as these are areas where development cannot occur (Section 3.2.2.6). Integrating ACUB does influence an installation's ranking and score, especially with the updated methodology as there are fewer areas for development to occur.

ACUB can be given additional weight in the MVA ranking process by giving bonus points to installations with an ACUB program. An initial test of the population impact attribute summed all factors to “9” and then added a point to installations that did not have an ACUB program. Feedback received indicated that was too punitive, that, instead of penalizing installations that lack an ACUB program, installations with programs should receive a bonus (Table 4-3). If CAA desires to include ACUB in the Population Impact MVA, it is recommended that one point be subtracted from installations with ACUB programs. While one point may seem very high for one component (10% of the total score), ACUB programs are a valuable indication of installations and communities working together. Installations with ACUB programs have fewer issues with encroachment.

4.4 Required processing time

As mentioned earlier, the goal of the RUG model is to generate residential attractiveness maps and growth projections that are based on nationally available datasets and that require little human intervention to produce. The RUG model is a software tool intended to be rapidly implemented and run on almost any several-county region within the United States. In this study, the processing time to complete a RUG analysis ranged from 45 minutes to an hour, depending on the installation region size. This processing time does not include the time required to download and prepare the national level datasets required as input. Future work will include automation of the process of preparing the national level datasets for input.

Table 4-3. Population Impact MVA score with "bonus" point given to installations with ACUB programs.

Location	Current Population Impact Score 10-mile Population Density (9), 10-mile Growth Rate (1)	Update to Population Impact 10-mile Population Density (2), 5-mile Population Density (1), 1-mile Population Density (2), 10-mile s Growth Rate (2), 5-mile s Growth Rate (1), 1-mile Growth Rate (2)
AP Hill	3.00	3.37
Bliss	3.23	0.95
Bragg	4.63	4.15
Carson	4.75	2.20
Hood	3.56	4.70
Irwin	0.00	1.90
Lewis-McChord	9.62	6.58
Rucker	1.47	2.46
Wainwright	0.92	0.77

5 Impact of Listed and At-Risk Species

5.1 Method

A spreadsheet of listed and at-risk species was compiled for seven regionally distinct installations of interest based on information taken from environmental and installation documents (INRMP, Environmental Assessments, Environmental Impact Statement, etc.), as shown in Appendix D. Currently listed species impose known impacts to installations, but at-risk species generally impose fewer impacts because their presence imposes fewer restrictions on training land use, and because installations have greater flexibility in management of these species. Despite installation efforts to proactively manage at-risk species, some are ultimately listed.

Sperry, Wall, and Hohmann (2015) developed a logistic regression model of the probability that species proposed for listing under ESA will in fact be listed. Variables included in the model were the species taxonomic group and the percentage of the species range lost to intensive human land use (e.g., urbanized or agricultural). The former variable to weight at-risk species and species under ESA review was used by multiplying the number of species in each taxonomic group by the probabilities listed in Table 5-1.

For at-risk species, an additional weighting was applied wherein the value obtained in the former step was multiplied by 0.25. This was done to approximate the uncertainty in future listing of at-risk species, which have not yet been petitioned for listing under the ESA. The derived numbers were then summed for each taxonomic group and added to the number of listed species on each of the seven case study installations. Because the magnitude of impact is expected to vary as a function of available training area, these values were divided by installation area (km^2) to generate a single non-normalized impact score for each installation (Table 5-2).

Table 5-1. Probability of federal listing by taxonomic group used to weight species at-risk and species currently under USFWS review for federal listing. Numbers in parentheses represent number of species used to develop the model. Derived from Sperry et al 2015.

Taxonomic Group	Probability of Listing
Arthropod (24)	0.29
Birds (18)	0.72
Fish (14)	0.64
Mammal (20)	0.65
Plants (35)	0.63
Reptile (10)	0.60

Table 5-2. Installation impact score for vulnerability to climate change based on weighting scheme applied to listed and at-risk species on seven Army installations (Appendix D). Installations with green colors had the lowest projected vulnerability to climate change based on the estimated metric, while those in yellow had moderate risk, and those that were red colored had the highest risk.

Installation Name	Impact Score	
Schofield Barracks	1.51	
Joint Base Lewis-McChord	0.01	
Fort Bragg	0.01	
Fort Riley	0.01	
Fort Bliss	0.00	
Fort Drum	0.00	
Fort Wainwright	0.00	

5.2 Findings

The TES impact scores generated for the case study installations ranged from 1.51 to 0.00. Based on this range of scores and a three tier grouping strategy, one installation was assigned to a high vulnerability category (red) and three installations to both moderate (yellow) and low (green) vulnerability categories (Table 5-2). Schofield Barracks, the single installation in the high vulnerability category had more listed (86) and at-risk species and species under review (49) than all of the other six installations combined (135; see Appendix D). It also is two orders of magnitude smaller than the largest installation (Fort Bliss). In contrast, installations within the lowest vulnerability category had relatively fewer listed and at-risk species, as well as larger areas.

This approach for generating a metric (Table 5-2) to characterize the potential for climate change instigated impacts of listed and at-risk species within a BRAC decision-making process has several desirable features. Firstly, it is based on a simple, straightforward process that uses readily available information. Secondly, it not only incorporates the potential impacts of existing listed species, but also the anticipated impacts of future listings. Although it does not contain any specific information about differing climate change vulnerabilities of species, or the regional variation in projected climate change that will likely affect installations in different portions of the country in varied ways, these two considerations are feasible and will be the focus of on-going efforts discussed in the following chapter.

6 Future Work

This chapter outlines the way forward for both population impact assessment and listed and at-risk species impact assessment, which includes:

1. *Improvements in Data Processing*. It is proposed to automate the data pre-processing elements of RUG outlined in Section 3.2.2. The research team will compile all of the data required to run RUG nationally. Furthermore, the team will develop scripts to automate the clipping and extraction process. This will allow RUG to be run quickly for all Army installations.
2. *Integrate Climate Factors into RUG*. Climate change will impact habitation patterns in the United States. It is proposed to integrate climactic factors into this research. One inclusion would be integrating 100- and 500-year flood plains as areas that are less attractive to development.
3. *Integrate Species Vulnerability Assessment Information into a Scoring System to Predict the Overall Impact of Climate Change on Army Installations*. The NatureServe CCVI was created to provide land managers a way to rapidly assess species vulnerability to climate change, as well as to provide input to key planning documents (Young et al. 2015). The index assesses a species exposure to climate change based on its sensitivity (e.g., dispersal ability, temperature and precipitation requirements, habitat specificity); exposure, both direct (e.g., drought and heat stress) and indirect (e.g., land use changes, effects of barriers); and response. These factors are then weighed against the adaptive capacity of the species to determine the overall vulnerability to climate change. The index scores each species' level of vulnerability based on user-provided expert opinion, available data, and information drawn from the literature.

   It is proposed to apply the NatureServe CCVI to all of the listed and at-risk species identified for the seven Army installations of interest in Appendix D, to develop an overall impact score for each installation based on the level of vulnerability that species on each installation exhibit. These scores will then be ranked according to a red-yellow-green scorecard to show the level of vulnerability that species on each installation have in relation to the others. Output from the index will be used to refine the initial impact scores shown above.

Acronyms and Abbreviations

Term	Definition
ACUB	Army Compatible Use Buffer
AR	Army Regulation
BEA	U.S. Department of Commerce, Bureau of Economic Analysis
BRAC	Base Realignment and Closure
CAA	Center for Army Analysis
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
COA	Course of Action
COBRA	Cost of Base Realignment Actions
CONUS	Continental United States
DEM	Digital Elevation Model
DoD	U.S. Department of Defense
DODI	Department of Defense Instruction
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESA	US Endangered Species Act
ESRI	Environmental Systems Research Institute, Inc.
GIS	Geographic Information System
GIST	Geographic Information Science and Technology
HQDA	Headquarters, Department of the Army
HQIIS	(Army) Headquarters Installation Information System
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HSIP	Homeland Security Infrastructure Program
ICLUS	Integrated Climate and Land Use Scenarios
IMCOM	US Army Installation Management Command
INRMP	Integrated Natural Resources Management Plans
LEAM	Landuse Evolution and impact Assessment Model
LLC	Limited Liability Company
MRLC	Multi-Resolution Land Characteristics Consortium
MVA	Military Value Analysis
NLCD	National Land Cover Data
OACSIM	Office of the Assistant Chief of Staff for Installation Management
OMB	Office of Management and Budget
ORNL	Oak Ridge National Laboratory
OSAF	Optimal Stationing of Army Forces
POC	Point of Contact
RMRS	Rocky Mountain Research Station
RUG	Regional Urban Growth model

Term	Definition
SAR	Same As Report
SAVS	System for Assessing Vulnerability of Species
SERDP	Strategic Environmental Research and Development Program
SF	Standard Form
SME	Subject Matter Expert
TES	Threatened and Endangered Species
TR	Technical Report
UR	Under Review
USAEC	US Army Environmental Command
USD(P&R)	Under Secretary of Defense for Personnel and Readiness
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
WaSSI	Water Supply Stress Index

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Appendix A: Current Population Impact MVA Definition

1. **Date.** Proposed Population Impact (as of: 09 Feb 2015).

2. **Definition.** The impact of population density and growth rate in a 10-mile buffer outside the installation.

3. **Purpose.** The population impact attribute attempts to address potentially negative impacts on an installation and the nearby communities created by changes in population of the surrounding area over time. It also serves as an indicator of potential encroachment issues relating to noise complaints, reduction of natural buffer land surrounding installation boundaries, light pollution effects on nighttime training operations, and other potential impacts to operations on installations. Thus, the higher the Population Impact Score, the lower the potential value to the military.

4. **Point of contact (POC).** U.S. Army Environmental Command (USAEC): Mr. Jeff Salmon (jeff.a.salmon.civ@mail.mil)

5. **Data source(s).** U.S. Census, Army Mapper, (Army) Headquarters Installation Information System (HQIIS)

6. **Methodology.**

   a. Obtain the most recent decennial census geospatial data (with population statistics at the census block level) and the decennial data from 10 years before the most recent dataset. Decennial census data are used because they are more accurate than population estimates developed in the interim years and because they are collected down to the census block level.

   b. Use the buffer tool in ArcGIS software to create a 10-mile buffer area around the installation. See Figure A-1. Per guidance for this version of the MVA, data for non-contiguous training areas are not included for this attribute in this time.*

* AEC ran an analysis that included sub-installations, administered by the main installation according to HQIIS data. This information is available on request. An improved version of the MVA may consider non-contiguous training areas when evaluating population impacts.

i. A standardized set of geospatial data for installation boundaries is required. Currently, USAEC uses installation boundaries from Army Mapper, the Army's geospatial dataset of record for installations.
ii. The installation boundaries maintained in Army Mapper are the notional site boundaries, not the legal boundaries that are maintained by the U.S. Army Corps of Engineers.
iii. Ten miles was chosen as the buffer area by SMEs, based on factors such as noise, road infrastructure, and a comparison of the population densities around the installations.

c. Add decennial census block data to the project. (See Figure A-1.)

d. Select census block polygons where the polygon centroid of the census blocks is within the polygon representing the 10-mile buffer of the installation. See Figure 3.

i. The location of the centroid of the census block polygon is used to determine if the census block is included in the population total for the 10-mile buffer. If the census block polygon centroid lies outside the 10-mile buffer, the entire polygon is excluded from the analysis.
ii. Create a new data layer with the census blocks selected from the overlay analysis.

e. Determine the total population for all of the census blocks that were selected from the overlay analysis. The best way to do this is by opening the attribute table for the census blocks data layer and summarizing the population data field for the total population.

f. Determine the square miles of the 10-mile buffer zone surrounding the installation being analyzed. The best way to do this is by adding a new field to the attribute table for the buffer data layer and using the "calculate geometry function" to determine the total square mileage and automatically add that information to the new data field.

g. Divide the total population of the selected census blocks by the square mileage of the buffer area (Step f) to calculate the current population density per square mile.

h. Normalize the current population density and scale the range of values to a score that ranges from zero (0) to 9.

i. Calculate the percentage change in population between the most current census population (i.e., 2010) by the census population from 10 years prior (i.e., 2000) to determine the rate of population change.

j. Normalize the percentage changes in population and scale the range of values to a score that ranges from zero (0) to 1.

7. Equations.

2010 Population Density per Square Mile =
population / 10-mile buffer area (in sq. mi.) (A-1)

Normalized Population Density =
$b + [(X - X_{min}) (a\text{-}b) / (X_{max} - X_{min})]$ (A-2)

where:

a represents the highest score for the dataset
b represents the lowest score for the dataset
X is population density per square mile.
(For the population density, $a = 9$, $b = 0$.)

Growth Rate/yr = ([2010 population – 2000 population] / [2000 population])/10 (years) (A-3)

Normalized Growth Rate = $b + [(X - X_{min}) (a\text{-}b) / (X_{max} - X_{min})]$ (A-4)

where:

a represents the highest score for the dataset
b represents the lowest score for the dataset
X is growth rate/yr. For the growth rate/yr, $a = 1$; $b = 0$.

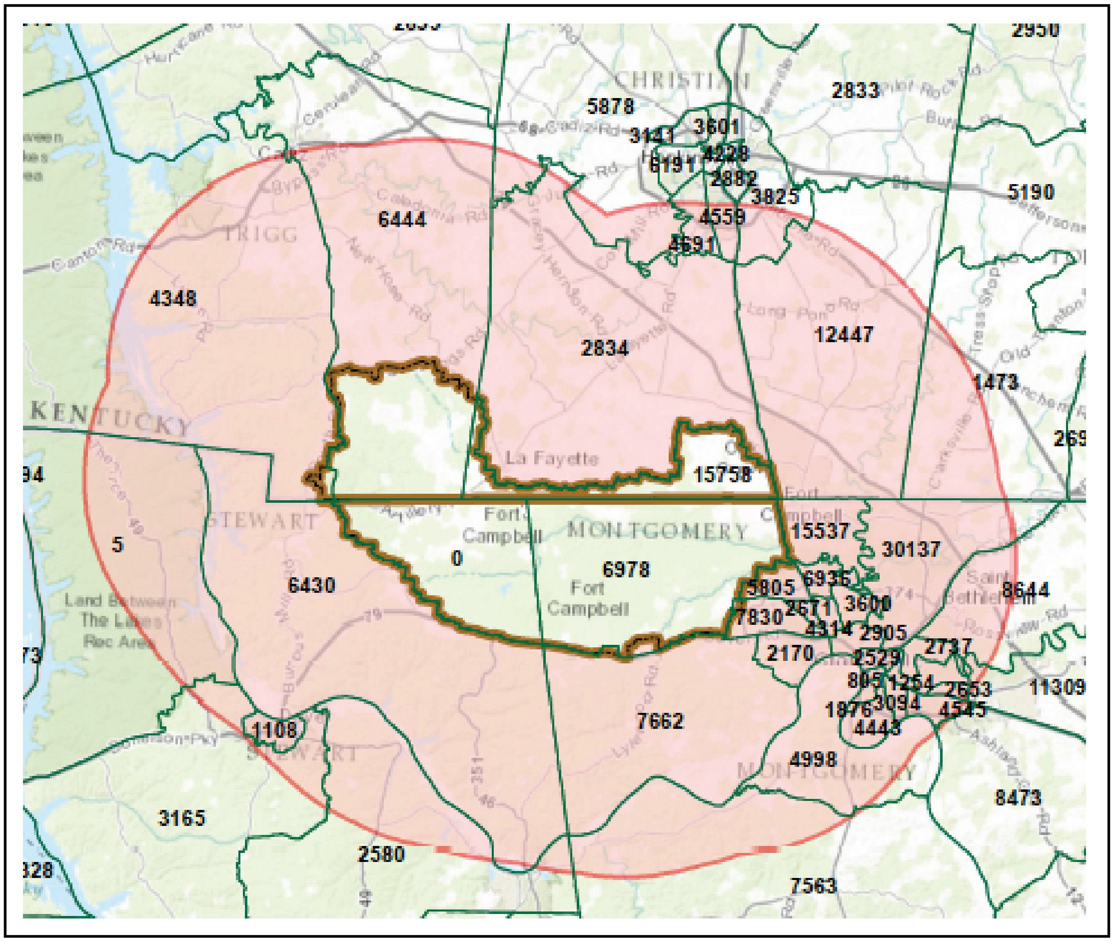
Population Impact Score = Normalized Population Density +
Normalized Growth Rate (A-5)

Note: 10 is the maximum score for any installation and zero (0) is the minimum score.

The normalized population density and normalized growth rate, being unitless, are added together for the Population Impact Score. This results in a weight factor of 90% on current population density and 10% on growth rate over last 10% years.*

Figure A-1 shows a snapshot of a 10-mile buffer (red) surrounding Fort Campbell with **census tract** geography (green polygons) overlaid. Census tract geography is too large to obtain accurate population statistics for the area within the 10-mile buffer area alone.

Figure A-1. Ten-mile buffer with census tracts overlaid.



* The sensitivity of the model to the relative weights of density and growth was tested at ratios of 8:2, 7:3, and 5:5. It was determined that the results are not sensitive to these weights and that the relative rankings changed little with different weighting schemes.

Figure A-2 shows a snapshot of a 10-mile buffer (red) surrounding Fort Campbell with **census block** geography (black polygons) overlaid. Census block geography is nested within census tracts and block groups. It is the lowest level of census geography available. Geospatial analysis at this level of census geography provides for the most accurate population statistics.

Figure A-2. Ten-mile buffer with census blocks overlaid.

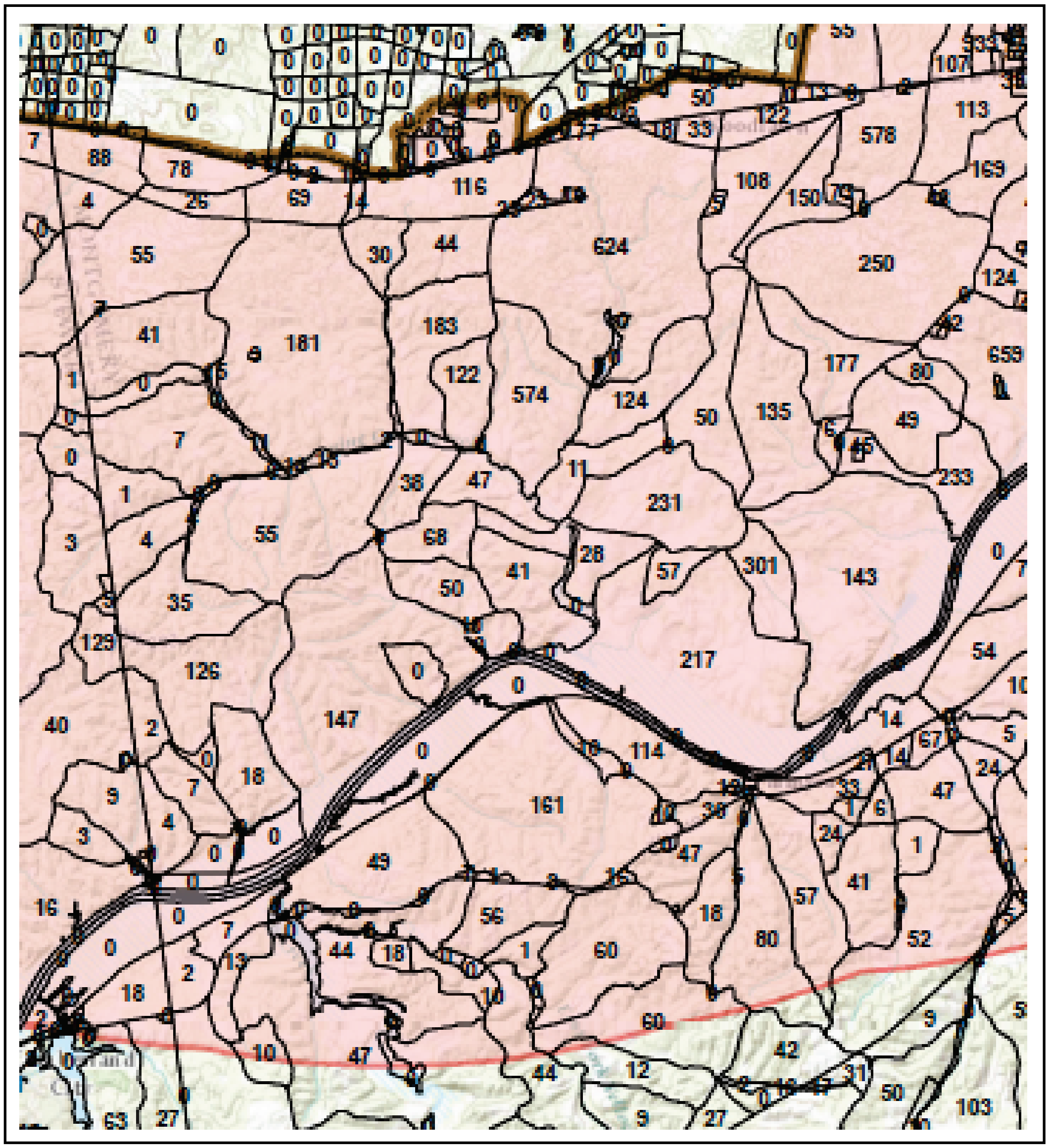
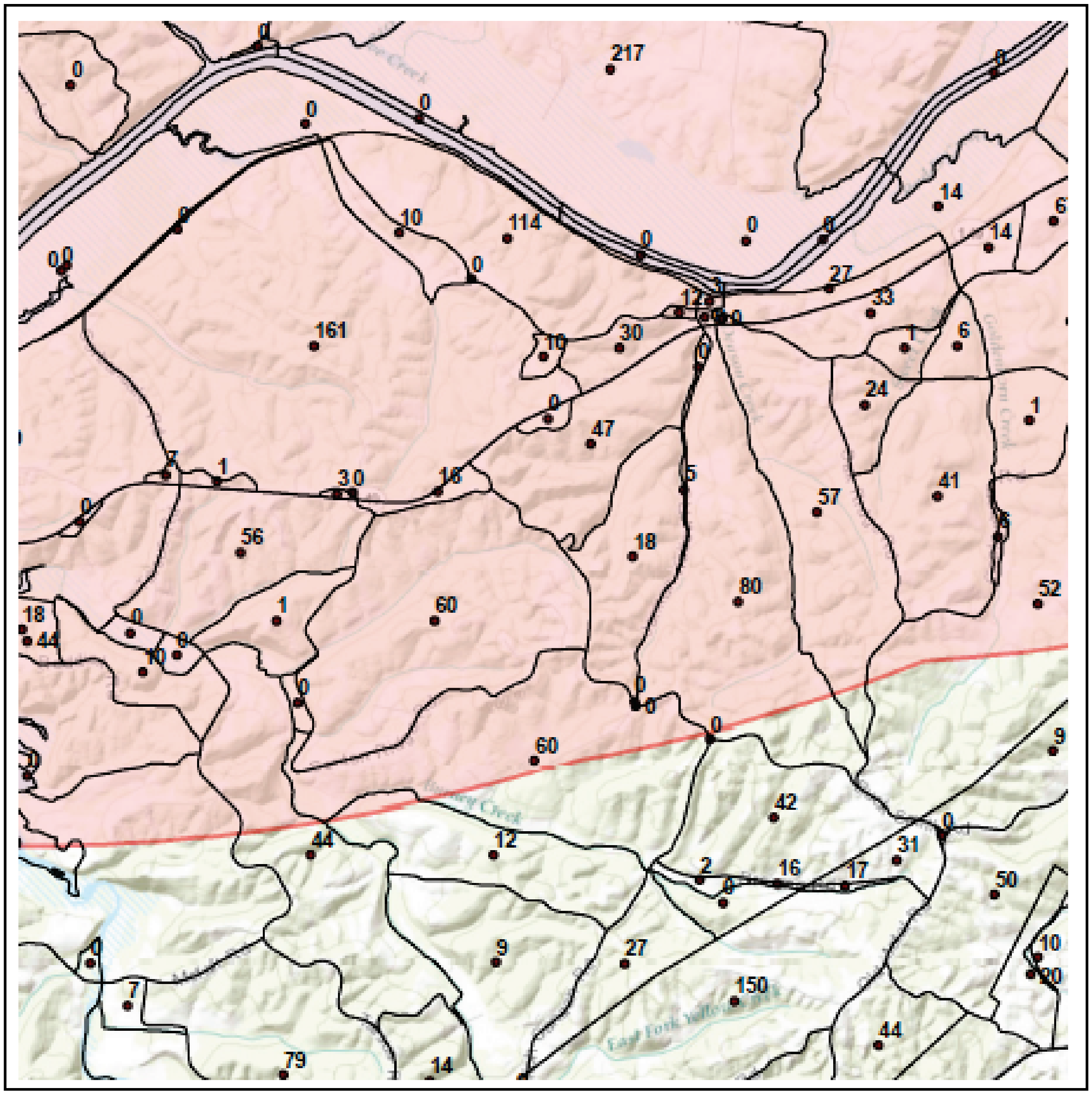


Figure A-3 shows a snapshot of a 10-mile buffer (red) surrounding Fort Campbell with **census block** geography (black polygons) and **census block centroids** (points) overlaid. ArcGIS software is used to geospatially select only the census blocks with their centroids within the 10-mile buffer. Census blocks with their centroids outside of the buffer area are entirely eliminated from the selection and not included in the population statistics.

Figure A-3. Ten-mile buffer with census blocks and census block centroids overlaid.



Appendix B: Proposed Population Impact MVA Definition

1. **Date.** Proposed Population Impact (as of: 30 September 2015).

2. **Definition.** The impact of population density and growth rate in a 10-mile buffer outside the ranges on the installation.

3. **Purpose.** The population impact attribute attempts to address potentially negative impacts on an installation and the nearby communities created by changes in population of the surrounding area over time. It also serves as an indicator of potential encroachment issues relating to noise complaints, reduction of natural buffer land surrounding installation boundaries, light pollution effects on nighttime training operations, and other potential impacts to operations on installations. Thus, the higher the Population Impact Score, the lower the potential value to the military.

4. **POC.** U.S. Army Environmental Command (USAEC): Mr. Jeff Salmon (jeff.a.salmon.civ@mail.mil)

5. **Data source(s).** Landscan, Sustainable Ranges Program, output of RUG model

6. **Methodology.**

   a. Obtain the most recent LandScan night population data for CONUS, Alaska, and Hawaii.

   b. Use the multi-ring buffer tool in ArcGIS software to create a buffers of 1, 5, and 10 miles around the training areas of an installation.

      i. A standardized set of geospatial data for installation ranges is required. The Sustainable Ranges Program maintains a national dataset of training areas. Furthermore, as this analysis seeks to assess the impact of population growth not just on the main installation but also on non-contiguous areas a list of training areas will have to be obtained. The Army Environmental Command does not have such a list, so this would need to be obtained through a data call.

   ii. Buffers of 1, 5, and 10 miles were chosen as the buffer areas by SMEs, based on factors such as noise, road infrastructure, and a comparison of the population densities around the installations.

c. Add LandScan night population data. Use the “zonal statistics as table” tool to calculate the population located within each buffer ring.

d. Determine the square miles of the buffer zones surrounding the ranges. The best way to do this is by adding a new field to the attribute table for the buffer data layer and by using the “calculate geometry function” to determine the total square mileage and to automatically add that information to the new data field.

e. Divide the total population of the buffer zone by the square mileage of the buffer area to calculate the current population density per square mile.

f. Normalize the current population density to have a minimum of zero (0) and a maximum of the value listed below:

   i. 10-mile Population Density: 2
   ii. 5-mile Population Density: 1
   iii. 1-mile Population Density: 2.

g. In ArcGIS, bring the NLCD 2011 into the map. Use the “tabulate area” tool to calculate the area of land type developed open space, developed low density, developed medium density, and developed high density for buffers of 1, 5, and 10 miles from the ranges.

h. In ArcGIS, bring the projected landcover map produced by a regional urban growth model into the map. Using tabulate area, tabulate the area of projected new urban growth for buffers of 1, 5, and 10 miles from the ranges.

i. Calculate the percentage change in development between 2011 and 2041. Normalize these values to have a minimum of zero (0) and a maximum of the value listed below:

   i. 10 miles Growth Rate: 2
   ii. 5 miles Growth Rate: 1
   iii. 1 mile Growth Rate: 2.

j. Sum Normalized Population Density and Normalized Growth Rate. If an installation has an ACUB program, subtract one (1) from the total.

7. Equations.

2010 Population Density per Square Mile =
population / 10-mile buffer area (in sq. mi.) (B-1)

Normalized Population Density = $b + [(X - X_{min})(a-b) / (X_{max} - X_{min})]$ (B-2)

where:

a represents the highest score for the dataset
b represents the lowest score for the dataset
X is population density per square mile.
(For the population density, *a* = value listed in 5.f , *b* = 0.)

Growth Rate/yr = ([2041 Developed Area – 2011 Developed Area] /
[2011 Developed Area])/30 (years) (B-3)

Normalized Growth Rate = $b + [(X - X_{min})(a-b) / (X_{max} - X_{min})]$ (B-4)

where:

a represents the highest score for the dataset
b represents the lowest score for the dataset
X is growth rate/yr.
(for the growth rate/yr, *a* = value listed in 5.i; *b* = 0.)

Appendix C: Supplemental Information for Population Impact

Table C-1. Counties used to define installation regions.

Installation	Counties
Fort AP Hill	Stafford, VA King and Queen, VA Essex, VA Westmoreland, VA Spotsylvania, VA King George, VA Caroline, VA
Fort Bragg	Cumberland, NC Hoke, NC Moore, NC Scotland, NC Harnett, NC Lee, NC
Fort Carson	Pueblo, CO Fremont, CO El Paso, CO Teller, CO
Fort Drum	St. Lawrence, NY Jefferson, NY Lewis, NY
Fort Hood	Bell, TX Coryell, TX Lampasas, TX

Installation	Counties
Fort Irwin	San Bernardino, CA
Joint Base Lewis-McChord	Pierce, WA Thurston, WA
Fort Rucker	Pike, AL Barbour, AL Geneva, AL Dale, AL Houston, AL Coffee, AL
Fort Riley	Riley, KS Pottawatomie, KS Geary, KS Clay, KS Dickinson, KS
Fort Wainwright	Southeast Fairbanks, AK Yukon-koyukuk, AK Fairbanks North Star, AK
Fort Bliss	Otero, TX Doña Ana, TX Hudspeth, TX El Paso, TX

Appendix D: Lists of Threatened, Endangered, and At-Risk Species by Installation

Table D-1. List of threatened, endangered, and at-risk species found on Fort Bliss, NM (U.S. Army Garrison Fort Bliss 2015). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Northern goshawk	*Accipiter gentilis*	Bird	On site	SAR
Baird's sparrow	*Ammodramus bairdii*	Bird	On site	SAR
Sprague's pipet	*Anthus spragueii*	Bird	On site	UR
Cliff brittlebush	*Apacheria chiricahuensis*	Plant	On site	UR
Sacramento prickly-poppy	*Argemone pleiacantha ssp. pinnatisecta*	Plant	Contiguous	E
Boulder Canyon Woodland snail	*Ashmunella auriculata*	Terrestrial Snail	On site	SAR
Goat Mountain Woodland snail	*Ashmunella harrisi*	Terrestrial Snail	On site	UR
Organ Mountain Woodlands snail	*Ashmunella organensis*	Terrestrial Snail	On site	SAR
Maple Canyon Woodlands snail	*Ashmunella todseni*	Terrestrial Snail	On site	SAR
Western burrowing owl	*Athene cunicularia*	Bird	On site	SAR
Zone-tailed hawk	*Buteo albonotarus*	Bird	On site	SAR
Ferruginous hawk	*Buteo regalis*	Bird	On site	SAR
Costa's hummingbird	*Calypte costae*	Bird	On site	SAR
Organ Mountain paintbrush	*Castilleja organorum*	Flowering Plant	On site	SAR
Piping plover	*Charadrius melodus*	Bird	On site	T
Mountain plover	*Charadrius montanus*	Bird	On site	T
Sandhill goosefoot	*Chenopodium cycloides*	Flowering Plant	Contiguous	SAR
Black tern	*Chlidonias niger*	Bird	On site	SAR
Samalayuca Dune Grasshopper	*Cibolacris samalayucae*	Grasshopper	On site	UR
	Cicindela nevadica	Beetle	Contiguous	SAR
Yellow-billed Cuckoo [western distinct population]	*Coccyzus americanus*	Bird	On site	T
Townsend's pale big-eared bat	*Corynorhinus townsendii*	Bat	On site	SAR
Sneed pincushion cactus	*Coryphantha sneedii var. sneedii*	Plant	On site	E
Mottled rock rattlesnake	*Crotalus lepidus lepidus*	Snake	On site	SAR
Arizona black-tailed prairie dog	*Cynomys ludovicianus arizonensis*	Mammal	On site	SAR
Standley's Whitlow-Grass	*Draba standleyi*	Flowering Plant	Contiguous	SAR
Kuenzler hedgehog cactus	*Echinocereus fendleri var. kuenzleri*	Plant	Contiguous	E

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Southwestern Willow flycatcher	*Empidonax traillii extimus*	Bird	Contiguous	E
Organ Mountain Pincushion cactus	*Escobaria organensis*	Flowering Plant	On site	SAR
Spotted bat	*Euderma maculatum*	Bat	On site	SAR
Northern Aplomado Falcon	*Falco femoralis septentrionalis*	Bird	On site	E*
Peregrine falcon	*Falco peregrinus anatum*	Bird	On site	SAR
Bald eagle	*Haliaeetus leucocephalus*	Bird	On site	SAR
Crested coral-root	*Hexalectris spicata var. arizonica*	Flowering Plant	On site	SAR
Gray-banded king snake	*Lampropeltis alterna*	Snake	On site	SAR
Loggerhead shrike	*Lanius ludovicianus*	Bird	On site	SAR
Western red bat	*Lasiurus blossevillii*	Bat	On site	SAR
Anthony Blister beetle	*Lytta mirifica*	Beetle	Contiguous	SAR
Occult little brown bat	*Myotis occultus*	Bat	On site	SAR
Fringed myotis	*Myotis thysanodes*	Bat	On site	SAR
Long-legged myotis	*Myotis volans*	Bat	On site	SAR
Yuma myotis	*Myotis yumanensis*	Bat	Contiguous	SAR
Gray-footed chipmunk	*Neotamias canipes sacramentoensis*	Mammal	On site	SAR
Big free-tailed bat	*Nyctinomops macrotis*	Bat	On site	SAR
Organ Mountain evening primrose	*Oenothera organensis*	Flowering Plant	On site	SAR
Sand prickly pear	*Opuntia arenaria*	Plant	Contiguous	SAR
Oscura Mountain land snail	*Oreohelix socorroensis*	Terrestrial Snail	On site	UR
Desert bighorn sheep	*Ovis canadensis mexicana*	Mammal	On site	SAR
Varied bunting	*Passerina versicolor*	Bird	Contiguous	SAR
Desert night blooming cereus	*Peniocereus greggii var. greggii*	Flowering Plant	On site	SAR
Organ beardtongue	*Penstemon alamosensis*	Flowering Plant	On site	SC
Lanceleaf beardtongue	*Penstemon ramosus*	Flowering Plant	On site	UR
Nodding rock daisy	*Perityle cernua*	Flowering Plant	On site	SAR
Hueco Mountains rockdaisy	*Perityle huecoensis*	Flowering Plant	On site	SAR
New Mexico rockdaisy	*Perityle staurophylla homoflora*	Flowering Plant	On site	UR
Texas horned lizard	*Phrynosoma cornutum*	Lizard	On site	SAR
Mountain short-horned lizard	*Phrynosoma hernandezii*	Lizard	On site	SAR
White-faced ibis	*Plegadis chihi*	Bird	On site	SAR
Mescalero milkwort	*Polygala rimulicola mescalerorum*	Flowering Plant	On site	UR
Smooth figwort	*Scrophularia laevis*	Flowering Plant	On site	SAR
Franklin Mountain Talus snail	*Sonorella metcalfi*	Terrestrial Snail	On site	SAR

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Interior least tern	*Sterna antillarum athalassos*	Bird	Contiguous	E
Mexican spotted owl	*Strix occidentalis lucida*	Bird	Contiguous	T
Organ Mountains Colorado chipmunk	*Tamias quadrivittatus australis*	Mammal	On site	SAR
Texas lyre snake	*Trimorphodon biscutatus vilkinsoni*	Snake	On site	SAR
Bell's vireo	*Vireo bellii*	Bird	On site	SAR
Gray vireo	*Vireo vicinior*	Bird	On site	SAR
New Mexico meadow jumping mouse	*Zapus hudsonius luteus*	Mammal	Contiguous	E
* This population has been designated as a nonessential experimental population within the states of NM and AZ, carrying 10(j) status under ESA. Thus, the species is designated as threatened within these designated geographic confines and is separated from other populations' federal listing status.				

Table D-2. List of threatened, endangered, and at-risk species found on Fort Bragg, NC (U.S. Army Garrison Fort Bragg 2001). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Dusky roadside-skipper	*Amblyscirtes alternata*	Butterflies and Skippers	On site	SAR
Georgia leadplant	*Amorpha georgiana georgiana*	Vascular plant	On site	UR
Sandhills milk-vetch	*Astragulus michauxii*	Plant	On site	SAR
Savanna campylopus	*Campylopus carolinae*	Moss	On site	SAR
Star-nosed mole-eastern NC	*Condylura cristata Pop. 1*	Mammal	On site	UR
Thinlip chub	*Cyprinella Sp. 1*	Freshwater and Anadromous Fish	On site	SAR
Hidden-flower witchgrass	*Dichanthelium cryptanthum Sp. 9*	Flowering Plant	On site	SAR
Septima's clubtail	*Gomphus septima*	Insect	Contiguous	UR
Southern hog-nosed snake	*Heterodon simus*	Reptile	On site	SAR
Winter quillwort	*Isoetes hyemalis*	Vascular plant	On site	UR
Sandhills lily	*Lilium pyrophilum*	Plant	On site	SAR
Bog spicebush	*Lindera subcoriacea*	Vascular plant	On site	UR
Boykin's lobelia	*Lobelia boykinii*	Vascular plant	On site	UR
Rough-leaved loosestrife	*Lysimachia asperulifolia*	Plant	On site	E
Spur throat grasshopper	*Melanoplus nubilus*	Grasshoppers	On site	SAR
Northern long-eared bat	*Myotis septentrionalis*	Mammal	Contiguous	T
Saint Francis' satyr butterfly	*Neonymphamitchellii francisci*	Insect	On site	E
Cape Fear spatterdock	*Nuphar lutea sagittifolia*	Vascular plant	On site	UR
Bachmann's sparrow	*Peucaea aestivalis*	Bird	On site	SAR
Red-cockaded woodpecker	*Picoides borealis*	Bird	On site	E
Crested fringed orchid	*Pteroglossaspis ecristata*	Flowering Plant	On site	SAR
Well's pixie-moss	*Pyxidanthera brevifolia*	Plant	On site	SAR
Michaux's sumac	*Rhus michauxii*	Plant	On site	E
Alabama beaksedge	*Rhynchospora crinipes*	Vascular plant	On site	UR

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
American chaffseed	*Schwalbea americana*	Plant	On site	E
Pickering's morning-glory	*Stylisma pickeringii Var. pickeringii*	Plant	On site	SAR

Table D-3. List of threatened, endangered, and at-risk species found on Fort Drum, NY (U.S. Garrison Fort Drum 2011). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Indiana bat	*Myotis sodalis*	Mammal	On site	E
Northern long-eared bat	*Myotis septentrionalis*	Mammal	On site	T

Table D-4. List of threatened, endangered, and at-risk species found on Joint Base Lewis-McChord, WA (OACSIM 2009). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Streaked Horned Lark	*Eremophila alpestris strigata*	Bird	On site	T
Taylor's checkerspot butterfly	*Euphydryas editha taylori*	Insect	On site	E
Water howellia	*Howellia aquatilis*	Plant	On site	T
Steelhead (Puget Sound DPS)	*Oncorhynchus mykiss*	Fish	On site	
Chinook salmon (naturally spawned populations from rivers and streams flowing into Puget Sound)	*Oncorhynchus tshawytscha*	Fish	On site	T
Mardon skipper	*Polites mardon*	Insect	On site	SAR
Oregon spotted frog	*Rana pretiosa*	Amphibian	On site	T
Bull trout	*Salvelinus confluentus*	Fish	On site	T
Bocaccio rockfish	*Sebastes paucispinis*	Fish	Contiguous	E
Canary rockfish	*Sebastes pinniger*	Fish	Contiguous	T
Yelloweye rockfish	*Sebastes ruberrimus*	Fish	Contiguous	T
Northern Spotted Owl	*Strix occidentalis caurina*	Bird	Contiguous	T
Roy prairie pocket gopher	*Thomomys mazama glacialis*	Mammal	On site	T
Olympia pocket gopher	*Thomomys mazama pugetensis*	Mammal	Contiguous	T
Tenino pocket gopher	*Thomomys mazama tumuli*	Mammal	Contiguous	T
Yelm pocket gopher	*Thomomys mazama yelmensis*	Mammal	On site	T
Small-flowered trillium	*Trillium parviflorum*	Plant	On site	SAR

Table D-5. List of threatened, endangered, and at-risk species found on Fort Riley, KS (U.S. Army Garrison Fort Riley 2010). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Henslow's sparrow	*Ammodramus henslowii*	Bird	On site	SAR
Piping Plover	*Charadrius melodus*	Bird	On site	T
Rusty blackbird	*Euphagus carolinus*	Bird	On site	SAR
Northern long-eared bat	*Myotis septentrionalis*	Mammal	Contiguous	T
Topeka shiner	*Notropis topeka*	Fish	On site	E
Texas horned lizard	*Phrynosoma cornutum*	Lizard	On site	SAR
Salina dewberry	*Rubus hancinianus*	Plant	On site	SAR
Regal fritillary butterfly	*Speyeria idalia*	Butterfly	On site	SAR
Least Tern	*Sterna antillarum*	Bird	On site	E

Table D-6. List of threatened, endangered, and at-risk species found on Fort Wainwright, AK (U.S. Army Garrison Fort Wainwright 2013). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Field locoweed	*Oxythropis tananensis*	Plant	On site	SAR
Alaska starwort	*Stellaria alaskana*	Plant	On site	SAR
Rusty blackbird	*Euphagus carolinus*	Bird	On site	SAR

Table D-7. List of threatened, endangered, and at-risk species found on Schofield Barracks, HI (U.S. Army Garrison Hawai'i 2010, OACSIM 2009). Species are designated by either E = endangered, T = threatened, UR = under review, or SAR = species at risk. Species are considered to be located on site if they reside within a 2 km distance of the installation (NatureServe 2011).

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Green-flower Indian-mallow	*Abutilon sandwicense*	Plant	on site	E
Pupu kuahiwi	*Achatinella mustelina*	Snail	on site	E
Pupu kuahiwi	*Achatinella byronii*	Snail	on site	E
Pupu kuahiwi	*Achatinella decipiens*	Snail	on site	E
Oahu tree snail	*Achatinella mustelina*	Snail	on site	E
Pupu kuahiwi	*Achatinella sowerbyana*	Snail	on site	E
Mahoe	*Alectryon macrococcus var. macrococcus*	Plant	on site	E
Three-Nerved Alsinidendron	*Alsinidendron trinerve (syn. Schiedea trinervis, and S. trinerve)*	Plant	on site	E
Amastrid land snail	*Amastra cylindrica*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Amastra micans*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Amastra rubens*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Amastra spirizona*	Terrestrial Snails	contiguous	SAR

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Hawaiian short-eared owl	*Asio flammeus sandwichensis*	Bird	on site	SAR
Amastrid land snail	*Auriculella AFF. Castanea N. SP. 1*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Auriculella ambusta*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Auriculella malleata*	Terrestrial Snails	contiguous	SAR
Amastrid land snail	*Auriculella tenella*	Terrestrial Snails	contiguous	SAR
Ko`oko`olau	*Bidens amplectens*	Vascular plant	contiguous	E
`Ahakea	*Bobea sandwicensis*	Flowering Plants	contiguous	SAR
Uhiuhi	*Caesalpinia kavaiensis*	Plant	contiguous	E
Kamanomano	*Cenchrus agrimonioides var. agrimonioides*	Plant	on site	E
`Akoko	*Chamaesyce rockii*	Plant	on site	E
Oahu `Elepaio	*Chasiempis sandwichensis ibidus*	Bird	on site	E
Boyd's maidenfern	*Christella boydiae*	Vascular plant	contiguous	UR
Pauoa	*Ctenitis squamigera*	Plant	on site	E
Haha	*Cyanea acuminata*	Plant	on site	E
Haha	*Cyanea calycina (syn. Cyanea lanceolata ssp. calycina)*	Plant	on site	E
Koʻolau Range Rollandia	*Cyanea crispa*	Flowering Plants	contiguous	E
Koʻolau Range Rollandia	*Cyanea grimesiana ssp. grimesiana*	Flowering Plants	on site	E
Haha	*Cyanea grimesiana ssp. obatae*	Flowering Plants	on site	E
Oʻahu Rollandia	*Cyanea humboldtiana*	Flowering Plants	contiguous	E
Haha	*Cyanea koolauensis (syn. Rollandia angustifolia)*	Flowering Plants	on site	E
Lanceleaf Cyanea	*Cyanea lanceolata*	Flowering Plants	on site	E
Papery cyanea	*Cyanea membranacea*	Flowering Plants	contiguous	SAR
Haha	*Cyanea st-johnii*	Plant	on site	E
Koʻolau Range Rollandia	*Cyanea superba*	Plant	contiguous	E
Ha'iwale	*Cyrtandra kaulantha*	Vascular plant	contiguous	E
Windy-ridge Cyrtandra	*Cyrtandra sessilis*	Vascular plant	contiguous	E
Ha`iwale	*Cyrtandra subumbellata*	Plant	on site	E
Ha`iwale	*Cyrtandra viridiflora*	Plant	on site	E
Douglas' bladderfern	*Cytopteris douglasii*	Ferns and relatives	contiguous	SAR
Oha	*Delissea waianaensis (syn. Delissea subcordata)*	Plant	on site	E
Sickle island-spleenwort	*Diellia falcata*	Plant	on site	E
Molokai twinsorus fern	*Diplazium molokaiense*	Ferns and relatives	on site	E
Hawaii false bristle grass	*Dissochondrus biflorus*	Flowering Plants	contiguous	SAR
Lyon's hacksaw ferm	*Doodia lyonii*	Ferns and relatives	on site	SAR
Takeuch's lip fern	*Doryopteris takeuchii*	Vascular plant	contiguous	E
Pomace fly, [no common name]	*Drosophila aglaia*	Insect	contiguous	E

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Pomace fly, [no common name]	*Drosophila montgomeryi*	Insect	on site	E
Pomace fly, [no common name]	*Drosophila obatai*	Insect	contiguous	E
Pomace fly, [no common name]	*Drosophila substenoptera*	Insect	on site	E
Sherff railliarndia	*Dubautia sherffiana*	Flowering Plants	contiguous	SAR
Fosberg's lovegrass	*Eragrostis fosbergii*	Plant	contiguous	E
Gaudichaud's exocarpus	*Exocarpos gaudichaudii*	Flowering Plants	contiguous	SAR
Mehamehame	*Flueggea neowawraea*	Plant	on site	E
Nanu	*Gardenia mannii*	Plant	on site	E
Oahu chewstick	*Gouania vitifolia*	Plant	contiguous	E
(Moth)	*Hedylepta monogramma*	Moth	on site	SAR
Water bluet	*Hedyotis fluviatilis*	Vascular plant	contiguous	UR
Lanai hesperomannia	*Hesperomannia arborescens*	Plant	on site	E
Maui island-aster	*Hesperomannia arbuscula*	Plant	on site	E
Ma'o hau hele	*Hibiscus brackenridgei ssp. mokuleianus*	Plant	contiguous	E
Aupaka	*Isodendrion longifolium*	Plant	on site	E
\`Ohe	*Joinvillea ascendens ascendens*	Plant	on site	UR
No common name	*Kadua degeneri var. coprosmifolia*	Plant	contiguous	E
No common name	*Kadua degeneri var. degeneri*	Plant	contiguous	E
Degener Korthalsella	*Korthalsella degeneri*	Vascular plant	contiguous	E
Kamakahala, Ko'olau Range labordia	*Labordia cyrtandrae*	Plant	on site	E
Waianae range labordia	*Labordia kaalae*	Flowering Plants	contiguous	SAR
Amastrid land snail	*Laminella sanguinea*	Terrestrial Snails	contiguous	SAR
\`Anaunau	*Lepidium arbuscula*	Plant	on site	E
Amastrid land snail (Oahu)	*Leptachatina Sp. 8*	Terrestrial Snails	contiguous	SAR
Nehe	*Lipochaeta lobata var. leptohylla*	Plant	on site	E
Lobed nehe	*Lipochaeta lobata var. lobata*	Flowering Plants	contiguous	SAR
Remy's nehe	*Lipochaeta remyi*	Flowering Plants	contiguous	SAR
Slender-leaved nehe	*Lipochaeta tenuifolia*	Plant	on site	E
Slender nehe	*Lipochaeta tenuis*	Flowering Plants	contiguous	SAR
Gaudichaud's lobelia	*Lobelia gaudichaudii ssp. koolauensis*	Plant	on site	E
Niihau lobelia	*Lobelia niihauensis*	Plant	on site	E
Oahu lobelia	*Lobelia oahuensis*	Plant	on site	E
Panaunau	*Lobelia yuccoides*	Flowering Plants	contiguous	SAR
Pupillid land snail (Lyropupa or lyropupilla)	*Lyropupa Sp. 1*	Terrestrial Snails	contiguous	SAR
Hawaiian crimson damselfly	*Megalagrion leptodemus*	Dragonflies and Damselflies	on site	E

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Blackline megalagrion damselfly	*Megalagrion nigrohamatum nigrolineatum*	Dragonflies and Damselflies	contiguous	E
Oceanic megalagrion damselfly	*Megalagrion oceanicum*	Dragonflies and Damselflies	contiguous	SAR
Alani	*Melicope christophersenii*	Plant	on site	E
Manena	*Melicope cinerea*	Flowering Plants	contiguous	SAR
Alani	*Melicope hiiakae*	Vascular plant	contiguous	E
Makaha Valley Melicope	*Melicope makahae*	Plant	contiguous	E
Gray's pelea	*Melicope sandwicensis*	Flowering Plants	contiguous	SAR
Maui fern	*Microlepia strigosa mauiensis*	Vascular plant	contiguous	UR
Kolea	*Myrsine fosbergii*	Vascular plant	contiguous	UR
Angular-fruited neraudia	*Neraudia angulata*	Plant	on site	E
Ma'aloa	*Neraudia melastomifolia*	Plant	on site	SAR
Big Island ma'aloa	*Neraudia ovata*	Flowering Plants	contiguous	SAR
Island nesoluma	*Nesoluma polynesicum*	Flowering Plants	contiguous	SAR
`Aiea	*Nothocestrum latifolium*	Plant	on site	UR
Kulu‘i, ka‘ala rock wort	*Nototrichium humile*	Plant	on site	E
No common name	*Omiodes monogramma*	Moth	on site	UR
Beechey's panicgrass	*Panicum beecheyi*	Flowering Plants	contiguous	SAR
Wawae‘iole, nodding club moss	*Phlegmariurus nutans (Huperzia nutans)*	Plant	on site	E
Hairy phyllostegia	*Phyllostegia hirsuta*	Plant	on site	E
Kaala phyllostegia	*Phyllostegia kaalaensis*	Plant	contiguous	E
Velvety phyllostegia	*Phyllostegia mollis*	Plant	on site	E
Ale	*Plantago princeps var. princeps*	Plant	on site	E
Oahu pilo kea	*Platydesma cornuta cornuta*	Plant	on site	E
Oahu pilo kea	*Platydesma cornuta decurrens*	Plant	on site	E
Hala pepe	*Pleomele forbesii*	Vascular plant	on site	SAR
Helicinid land snail	*Pleuropoma sandwichiensis*	Terrestrial Snail	contiguous	SAR
Lo’ulu	*Pritchardia kaalae*	Plant	on site	E
`Ena`ena	*Pseudognaphalium sandwicensium molokaiense*	Vascular plant	contiguous	UR
Oahu wild coffee	*Psychotria hexandra oahuensis*	Vascular plant	contiguous	E
Kaulu	*Pteralyxia macrocarpa*	Plant	on site	E
Lydgate's brake	*Pteris lidgatei (syn. Pteris lydgatei)*	Plant	on site	E
Makou	*Ranunculus mauiensis*	Flowering Plant	contiguous	SAR
Purple-flowered sanicle	*Sanicula purpurea*	Flowering Plant	on site	E
Hooker's schiedea	*Schiedea hookeri*	Plant	on site	E
Ma'oli'oli	*Schiedea kaalae*	Plant	on site	E
Privet-leaf schiedea	*Schiedea ligustrina*	Flowering Plant	contiguous	SAR

Common Name	Scientific Name	Taxonomic Group	On Site/Contiguous	Status
Mann's schiedea	*Schiedea mannii*	Flowering Plant	on site	UR
Valley Schiedea	*Schiedea nuttallii*	Plant	on site	E
Hairy schiedea	*Schiedea pentandra*	Plant	on site	UR
Ma`oli`oli	*Schiedea pubescens Var. purpurascens*	Flowering Plant	contiguous	SAR
Kauai bur cucumber	*Sicyos lanceoloideus*	Flowering Plant	contiguous	SAR
`Aiakeakua, popolo	*Solanum sandwicense*	Flowering Plant	on site	E
Oahu Stenogyne	*Stenogyne kanehoana*	Plant	on site	E
ridge top tetramolopium	*Tetramolopium filiforme*	Plant	on site	E
Waianae Range Tetramolopium	*Tetramolopium lepidotum ssp. lepidotum*	Plant	on site	E
`Ohe`ohe	*Tetraplasandra gymnocarpa*	Plant	on site	E
Lava slope false lobelia	*Trematolobelia singularis*	Plant	contiguous	E
Opuhe	*Urera kaalae*	Plant	on site	E
ʻIʻiwi	*Vestiaria coccinea*	Bird	contiguous	UR
Pamakani	*Viola chamissoniana ssp. chamissoniana*	Plant	on site	E
Forbe's Violet	*Viola oahuensis*	Plant	on site	E
Oʻahu prickly-ash	*Zanthoxylum oahuense*	Vascular plant	on site	E

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Army stationing analyses have historically been conducted under the assumption that conditions at and around installations will remain static. In reality, the natural, social, and built infrastructure changes over time, and this non-stationarity should be considered in stationing analyses to ensure continuation of each installation's mission. This work documents efforts completed in Fiscal Year 2015 that addressed the temporal aspects of population growth and its potential for negatively impacting an installation's training areas, and the potential impact of currently listed and species at risk of being listed to the endangered species list. A modified method for estimating population impact and a new method for estimating the impact of listed and at-risk species are described.

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