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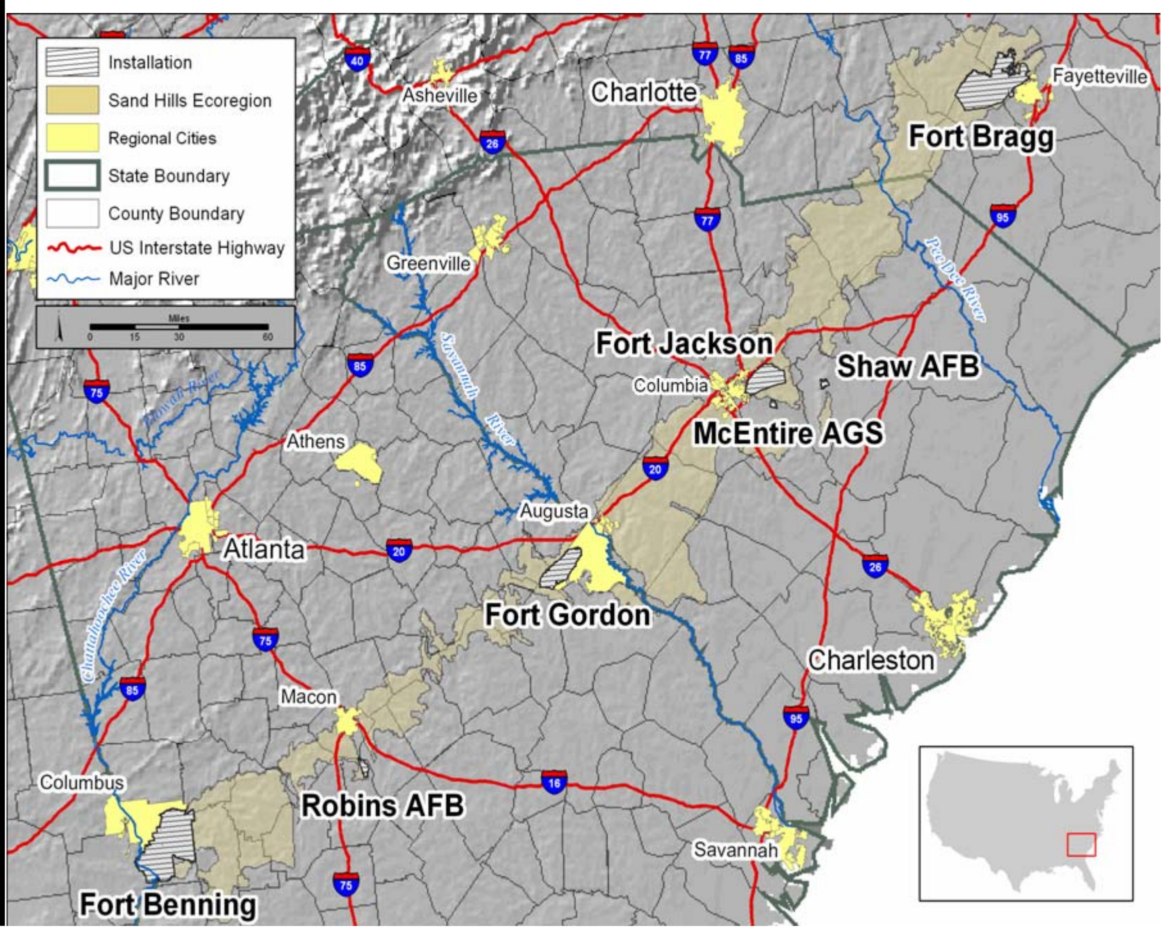
Considerations for the Development of the Strategic Sustainability Assessment Program

Elisabeth M. Jenicek, Donald F. Fournier, Natalie R. Downs, and Brad Boesdorfer

June 2005



Construction Engineering
Research Laboratory

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Considerations for the Development of the Strategic Sustainability Assessment Program

Elisabeth M. Jenicek

Construction Engineering Research Laboratory, Champaign, IL

Donald F. Fournier

Building Research Council, University of Illinois at Urbana/Champaign, IL

Natalie Downs

The PERTAN Group, Champaign, IL

Brad Boesdorfer

University of Illinois at Urbana-Champaign, IL

Final Report

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ABSTRACT: *The Army Strategy for the Environment* policy document establishes a long-range vision for enabling the Army to meet its mission today and into the future. The Strategy is based on the concept of "Sustainability," which focuses the Army's thinking on addressing both present and future needs while strengthening community partnerships that improve the Army's ability to organize, equip, train, and deploy as part of a joint force. The Strategic Sustainability Assessment (SSA) is a long-term project sponsored by the Army Environmental Policy Institute (AEPI). The Institute will use a variety of models and research tools to provide strategic analyses that will provide the Army with a fact-based visualization of future trends and issues critical to sustainability. The envisioned product is a series of ongoing, regular studies and reports that focus on specific regions or issues, and that enable the development of implementation plans and concepts for the Army Strategy for the Environment. This project defined and analyzed key forces, outcomes, and trends related to SSA as it applies to Army installations over a 20- to 30-year time horizon.

Executive Summary

The recently published *Army Strategy for the Environment: Sustain the Mission. Secure the Future.* (ASA–I&E 2004) establishes a long-range vision for enabling the Army to meet its mission today and into the future. Sustainability is the foundation of the Strategy and a paradigm that focuses the Army's thinking to address both present and future needs while strengthening community partnerships that improve the Army's ability to organize, equip, train, and deploy as part of a joint force. The Strategic Sustainability Assessment (SSA) is a long-term project sponsored by the Army Environmental Policy Institute (AEPI). The Institute seeks to provide a fact-based visualization of trends and issues that allows the Army to see the future in terms of the issues that are critical to sustainability.

Sustainability is always contextual in process and outcome. What may support the well-being of one community may not support the well-being of another. The definition of sustainability must encompass the relationships between economy, society, and environment. Knowledge of how these three elements interact with one another is needed to identify sustainable conduct for a particular region. Therefore, if sustainable development is to be achieved, sustainable decisionmaking and planning must be integrated across these three areas in a regional context. Also, regions impact those around them so interaction among regions is a key component to forecasting and trending. It is important to examine some of the key issues that are likely to change over the next 20 to 30 years to determine or predict the impact of future stressors on a regional basis. The likely key forces or critical factors are land use change (driven by population change and development patterns), climate change, and the availability and cost of energy resources. These forces will impact the region resulting in outcomes that affect sustainability. Key outcomes are air quality in the region, the availability and quality of water (along with health of watersheds) and habitat and biodiversity (including impacts on threatened and endangered species). This report discusses each of these key forces and outcomes. It is the goal of later research to focus on specific regions and develop scenarios that inform how these issues might impact sustainability and the outcomes as related to that region.

Trends or forecasts allow for characterization of the future, but are limited in nature as they do not define the policy framework or interventions necessary to attain a sustainable future. The most accurate forecasting/trending methodologies use

both statistical and judgmental research to model relationships between the current and future social, economic, and physical environment. Understanding the relationships between the environment, economy, and society is the key to effective forecasting and trending analyses.

There is a significant range of possible relationships between the environment, economy, and society. Advances in computer modeling have aided in exploring many of these relationships, although it is still expensive and time consuming to model all of the possible relationships. These models produce scenarios based on a set of assumptions and, therefore, it is critical for forecasters to select and use a well-defined list of informative indicators and well correlated drivers when modeling the future.

Bridging between projected scenarios and some desired future state is complex. "Backcasting" is a technique where the desired future state is defined. Working backwards from that particular desirable future to the present determines the feasibility of that future and the policy measures that would be required to reach that point. Backcasting and forecasting are, therefore, complementary. The difference between the desired end state and the forecast scenarios defines the fertile ground for policy change and course correction. This is especially true in situations where great change is needed and other considerations and externalities influence the future in unexpected ways that require mid-course corrections.

The Army recognizes that military installations are often the catalyst for actions and developments occurring "outside the fence." Today's military installations are struggling with ever-increasing readiness requirements involving training more soldiers on less land. In addition to time and spatial constraints, installation Commanders are facing challenges of environmental factors and growing encroachment issues that can seriously restrict, and in some cases shut down the training ability of an installation. This report provides descriptions of strategies and ongoing efforts to help mitigate these challenges. It also contains information on resources and models for forecasting and scenario building that are generally and commercially available and have been used by regions and municipalities to address some of the same issues.

The key forces and outcomes noted above indicate that serious consideration must be given to defining a more sustainable path for the nation in general and military installations, in particular. These forces drive much of the encroachment and the adverse environmental outcomes being experienced. Development patterns and population dynamics continue to exert increasing pressure on habitat and aquatic ecosystems while contributing to high energy consumption. Both high energy consumption and land-use change have major effects on the carbon cycle leading to global climate change. The key forces are interrelated and complex, as are the outcomes. Significant progress has been made in developing tools and conceptualizing ways to approach these complex regional scale problems. A fact-based visualization of trends will allow the Army to see the future in terms of the environmental issues that are critical to sustainability. Determining the desired end state and backcasting to the present will help to formulate guidance for policy change and adaptation to future trends. The variety of models and research tools available will provide for ongoing analyses to inform policy and guide the Army in its efforts to increase sustainability. A series of ongoing, regular studies and reports that focus on specific regions or issues will illuminate the way forward.

In summary, AEPI and ERDC intend to use a variety of models and research tools to provide strategic analyses to help the Army increase its sustainability. The envisioned product is a series of ongoing, regular studies and reports that focus on specific regions or issues and that enable the development of implementation plans and strategic concepts to achieve the *Army Strategy for the Environment*. The initial study area is the fall line ecoregion that extends from Alabama, across Georgia and South Carolina, and into North Carolina. This fall line ecoregion contains four Army installations and several other Department of Defense (DOD) and government facilities. The project has several byproducts, for example, building beneficial partnerships with organizations also working on sustainability, as well as creating opportunities for further dialogue with internal and external stakeholders.

Contents

List of Figures and Tables

Figures

Tables

Conversion Factors

Non-SI* units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

* *Système International d'Unités* ("International System of Measurement"), commonly known as the "metric system."

Preface

This study was conducted for the Army Environmental Policy Institute (AEPI) under reimbursable project “Strategic Environmental Appraisal,” Military Interdepartmental Purchase Request (MIPR) Nos. 4GERDC0020 and 4GERDC0021/PO. The technical monitor was Karen Baker, AEPI.

The work was performed by the Energy Branch (CF-E) and the Business Processes Branch the CF-N of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Elisabeth Jenicek. Thomas Hartranft is Chief, CF-E, Donald Hicks is Chief, CF-N, and L. Michael Golish is Chief, CF. The associated Technical Directors are Michael Case and William Goran. Part of this work was done by Donald Fournier of the University of Illinois at Urbana-Champaign under contract No. DACA88-99-D-002, Delivery Order 0031, and Natalie Downs of the PERTAN Group, contract No. DACA42-01-D-0002, Delivery Order 11. The technical editor was William J. Wolfe, Information Technology Laboratory. The Acting Director of CERL is Dr. Ilker K. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL James R. Rowan, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

The new *Army Strategy for the Environment: Sustain the Mission. Secure the Future.* (ASA–I&E 2004) establishes a long-range vision for enabling the Army to meet its mission today and into the future. Sustainability is the foundation of the Strategy and a paradigm that focuses the Army's thinking to address both present and future needs while strengthening community partnerships that improve the Army's ability to organize, equip, train, and deploy as part of a joint force. The Strategic Sustainability Assessment (SSA) is a long-term project sponsored by the Army Environmental Policy Institute (AEPI). The Institute seeks to provide a fact-based visualization of trends and issues that allows the Army to see the future in terms of the issues that are critical to sustainability. AEPI intends to use a variety of models and research tools to provide strategic analyses for the Army in its journey to increasing sustainability. The envisioned product is a series of ongoing, regular studies and reports that focus on specific regions or issues that enable the development of implementation plans and concepts for the *Army Strategy for the Environment*. The project has several byproducts, for example, building beneficial partnerships with organizations also working on sustainability, as well as creating opportunities for further dialogue with internal and external stakeholders.

The goals of the SSA project are:

1. To provide Army leadership with an assessment of the state of the Army's sustainable future and offer recommendations for policy development and new initiatives as the Army works to achieve the goals of the *Army Strategy for the Environment*.
2. To bridge the gap between short-term planning to implement the Strategic Plan and identify actions needed in the long term to ensure that the Strategy goals are met within the 20- to 30-year timeframe set by the Strategy.
3. To create a forum for ongoing dialogue among Army leadership and other partners working toward sustainability.

Objective

The objective of this project is to define and conduct specific analyses of key forces, outcomes, and trends related to the SSA as it applies to Army installations using the 20- to 30-year time horizon. The specifics of the project objectives are somewhat flexible and will evolve in a more concrete manner as research progresses and concepts are developed.

Approach

This initial stage of research consisted of:

1. Performing an initial literature survey
2. Conducting scoping meetings to define appropriate methodologies and tools
3. Determining the key long term sustainability issues
4. Putting this information in a context that can inform the implementation of the *Army's Strategy for the Environment*.

Once the initial research and survey work is accomplished, a preliminary study area will be selected for specific demonstration projects apply and demonstrate the concepts. Trending analyses and modeling concepts will also be evaluated and introduced in the SSA framework.

Scope

This report documents the initial efforts for the project, which included reviewing concepts and establishing the methodologies that will be used to look at environmental issues in a strategic context as they apply to military installations and Army transformation. The initial scope has also determined the first demonstration area or focus region in which to apply the concepts and ideas.

Mode of Technology Transfer

The results of this research will start with a special report and evolve into a series of ongoing, regular reports that focus on specific regions or issues. The reports will be presented at workshops, symposia, and will be available through the World Wide Web (WWW) at either (public or secure, respectively) URLs:

http://www.cecer.army.mil
https://websps1.battelle.org/aepi/StrategicSustainabilityIAST/default.aspx

2 Overview of Previous Work

Introduction

This chapter provides an overview of the concepts of sustainability and a summary of research into forecasting and trending methods and models. It introduces the concepts of forecasting and backcasting as methods that complement one another in the effort to define a path to a more sustainable future. The literature on the topic is summarized and discussed and the forecasting model chosen for the project is recommended.

Definitions and Concepts of Sustainability

The Army is concerned with understanding those factors that impact an installation's ability to sustain its operations and the assigned mission. Crucial to this concern is an understanding of the definition of sustainability and the determination of implementations strategies. The seminal work that defined sustainability in the modern context was the report *Our Common Future* (World Commission on Environment and Development 1987), which defined sustainable development as development that "ensure[s] that it meets the need of the present without compromising the ability of future generations to meet their own needs." Often sustainable development plans express sustainability in terms of anticipating and managing consequences of development. Academic research typically views sustainability as a procedural term that refers to mechanisms by which to make the protection of well-being a reality. No matter the wording, sustainability is a values-laden concept that implies future-focused planning and an acknowledgement of impacts and how to either negate or ameliorate them. *The Army Strategy for the Environment* defines sustainability as a state that simultaneously meets current and future mission requirement world-wide, safeguards human health, improves quality of life, and enhances the natural environment (ASA–I&E 2004).

Additionally, sustainability is always contextual; in each location, the process determines the desired outcome. What may support the well-being of one community may not support the well-being of another community. Therefore, the definition of sustainability must be developed locally by a diverse group of stakeholders must recognize the relationships between economy, society, and environment. Knowledge of how these three elements interact with one another is needed to identify sustainable conduct for a particular region. If sustainable development is to be achieved, sustainable decisionmaking and planning must be integrated across these three areas in a regional context.

Researchers differ in their recommendations for specific implementation strategies to achieve sustainable development. However, all agree that the concept of sustainability is to conduct our business in such a manner that does not preclude options for the future. Communities that fail to plan for the future run grave risks of diminished importance or even oblivion in the fluctuating world of the 21st century (Davidson 2000). Incorporating and acting on thoughts about the future increases the likelihood of success in the long run. While the future is fundamentally uncertain, it is possible to develop scenarios based on given assumptions and estimate with some precision how these will trend in the future. This is most commonly referred to as forecasting—thinking about what might happen and shaping current and ongoing actions to fit the future scenarios. Forecasting is the recommended strategy for sustainable development.

Forecasting and Trending Concepts

Forecasting is a way of summarizing expectations about what will happen in the future. Broadly speaking, there are two distinct methods of forecasting: judgmental and statistical (Armstrong 1999). Judgmental forecasting methods involve methods by which experts process information. The well-known Delphi Method is an example of a judgmental method. Experts can be asked to make predictions about how others will act in given situations. Experts can also identify analogous situations and base forecasts on knowledge gained from those situations. The experts may have access to quantitative data, and their approach may be structured, but the final forecasts are the result of some process that goes on in their heads. The case for expert forecasting is strong among researchers because expert opinions work best when quantifiable data is lacking or of poor quality (Stewart 1987). However, there are very few studies that use expert systems for producing environmental forecasts because judgmental forecasts are susceptible to various biases (Brenner, Koehler et al. 1996). Despite the immense amount of research effort, environmental forecasting relies on statistical forecasting.

Statistical forecasting methods involve exploring trends within existing quantitative data. Extrapolation is the most common statistical method used in environmental forecasting. J. Scott Armstrong asserts that environmental forecasting typically uses extrapolation because the forecasting often involves decisions that have long term consequences, and are thus more likely to be subjective to severe bias due to the increased inaccuracy of long-term forecasting (Armstrong 1999). To address this issue, forecasters try to ensure that the information and procedures are objective. Additionally, forecasters favor a structured method in which costs and complexity can be more easily controlled. Extrapolation forecasts use only historical time series data. Although extrapolation is relatively simple and inexpensive, it has not produced gains in accuracy (Armstrong 1984). Extrapolation is an appropriate tool to use when indicators can be expected to operate as they have in the past, but it suffers when a time series is subjected to a shock, discontinuity, or a stochastic influence.

Similarly, a growing body of research shows that time series indicators are often interdependent. Extrapolating each indicator independently results in a picture of the future that makes little or no sense. For example, individual extrapolations may result in predicting housing production to soar and employment to fall dramatically. Together these forecasts do not add up to a realistic picture since housing production typically follows employment trends.

Statistical and urban planning research literature illustrates that underlying causal forces push trends in different directions over a forecast horizon. The research of Sanders and Ritzman (Sanders 2001) gives a general example. The authors interviewed numerous British forecasting experts concerning the extrapolation of the annual number of deaths on highways using time series data. Simply extrapolating the annual number of deaths observed historically was found to result in the most inaccurate picture of the future. More accurate pictures of the future were found from studies correlating the increases in the safety of highways and automobiles to a reduction in the number of deaths as well as studies illustrating that the probability of deaths increase as the number of miles driven increases. The number of highway deaths is an example of a complex time series where causal forces push the series' trend in different directions over the forecast horizon.

The integration of judgmental and statistical forecasting may be the most favored method of forecasting. However, to accomplish this integration, there must first be an understanding of how events and outcomes relate to the drivers and to one another. The amount of literature illustrating the relationship between the environment, economy, and society is immense. The concern of these studies is the degree environmental conditions facilitate or constrain an individual's choices. One of the first publishers of such observations was Kurt Lewin (1938). Lewin spoke specifically of the physical environment's impacts on human behavior. For example, as individuals perceive gasoline prices rapidly rising, their amount of driving often decreases. More research soon followed as psychologists, urban planners, and statisticians began to examine the link between the environment, economy, and society.

Today such research identifies links that affect virtually all activities from the most specific to the most general. Research concerning the key factors, links, and drivers addressed specifically for this project is discussed later on in this report. For now, it is sufficient to note that investigative research depicting the relationship between the environment, economy, and society was the key to drawing more accurate pictures of the current and future spatial environment. The most notable contribution to the concept of forecasting or trending is that it is imperative to avoid measuring one part of a community as if it were entirely independent of other parts. Establishing the links is crucial. Sustainability planning must reflect the reality that the environment, economy, and society are tightly interconnected. Judgmental forecasting is useful because domain experts often have knowledge of recent events whose effects have not yet been observed in a time series, of events that have occurred in the past, but are not expected to recur in the future, or of events that have not occurred in the past, but are expected for the future. For example, they may know about policy changes that are likely to cause substantial changes over the forecast horizon. While this type of information should be valuable for forecasting, there are also risks in using unaided judgment. Experts may see more in the data than is warranted as they are subject to a variety of biases such as anchoring, double counting, and optimism.

Statistical methods are less prone to biases and can make efficient use of existing data. Statistical methods are reliable; given the same data, they will produce the same forecast whether the series relates to costs or revenues, to good news or bad. However, statistical procedures are myopic, knowing only about the data that are presented to them. The most accurate forecasting/trending methodologies use both statistical and judgmental research to model relationships between the current and future social, economic, and physical environment.

Forecasting Models

Urban modeling in the early 1960s was characterized by its initial attempts to integrate judgmental and statistical forecasts. Such models were practice-led and rooted in empirically defined problems. The most prominent models are associated with Lowry (1964), Herbert and Stevens (1960), and Schlanger (1965). These models were mostly linear systems. There was a suggestive relationship to input-output analysis, however the models were static in structure, and only one solution was possible given initial conditions. They faced structural problems with a specific number of calculable variables, well-defined goals, and firmly established technical solutions (Oppenheim 1986). It was not until 1977 that Macgill (1977) created a truly dynamic model. Later Williams (1979) developed another version (Allen, Engelen et al. 1986). These dynamic models were the first to consider temporal changes and whether the solution would remain stable over time. They described the changing fabric of the urban environment. There was no longer one equation that individually extrapolated each factor linearly through time, but rather a host of hundreds of equations that integrated economic and spatial interactions as one factor was extrapolated through time (Simmonds 1986; Batty 1986).

Since the 1980s, advances in computer technology have allowed dynamic modeling to become more realistic. Computer systems are able to handle more equations at faster rates. Their availability to general consumers has also lead modeling efforts to be more localized within communities. Communities and organizations are more equipped to apply the general framework within their own systems and integrate new modeling theories as they see fit for their environments. One such example is the integration of geographical information system (GIS) software with other modeling techniques to both create maps and analyze plausible scenarios for the future. These attempts at dynamically modeling the environment have had varied responses of success. The team reviewed several modeling techniques and systems and chose three possible applications for the project: Land-use Evolution and impact Assessment Model (LEAM), General Land Use Change (GLUC), and Regional Simulator (RSim).

LEAM

The Land-use Evolution and impact Assessment Model (LEAM), produced at the University of Illinois at Champaign-Urbana and CERL is one example of a system that uses GIS to analyze future land-use patterns. This effort was funded by a Nation Science Foundation grant and the DOD's Strategic Environmental Research and Develop Program (SERDP). LEAM describes land-use changes across a landscape that result from the spatial and dynamic interaction among systems in the region—economic, ecological, and social (Figure 2-1).

In the LEAM approach, groups or individuals who have substantive knowledge relating to a particular system, for example vehicle sheds or species diversity, develop and test separate models of that system (Deal and Schunk 2003). These contextual sub-models are run simultaneously in each grid cell of raster-based GIS map(s) linked to form the main framework of the dynamic spatial model (LEAM). The spatial modeling environment collaborative approach enables the model to be created in an open and distributed manner that brings different expertise to bear on the problem. Inputs to the model use U.S. Geological Survey (USGS) national land cover data sets (30x30m resolution), census and economic data (readily available and transportable to multiple sites), along with variables relating to impact assessments sub-models (e.g., habitat, eco-regional inputs, water and energy inputs) to parameterize the model.

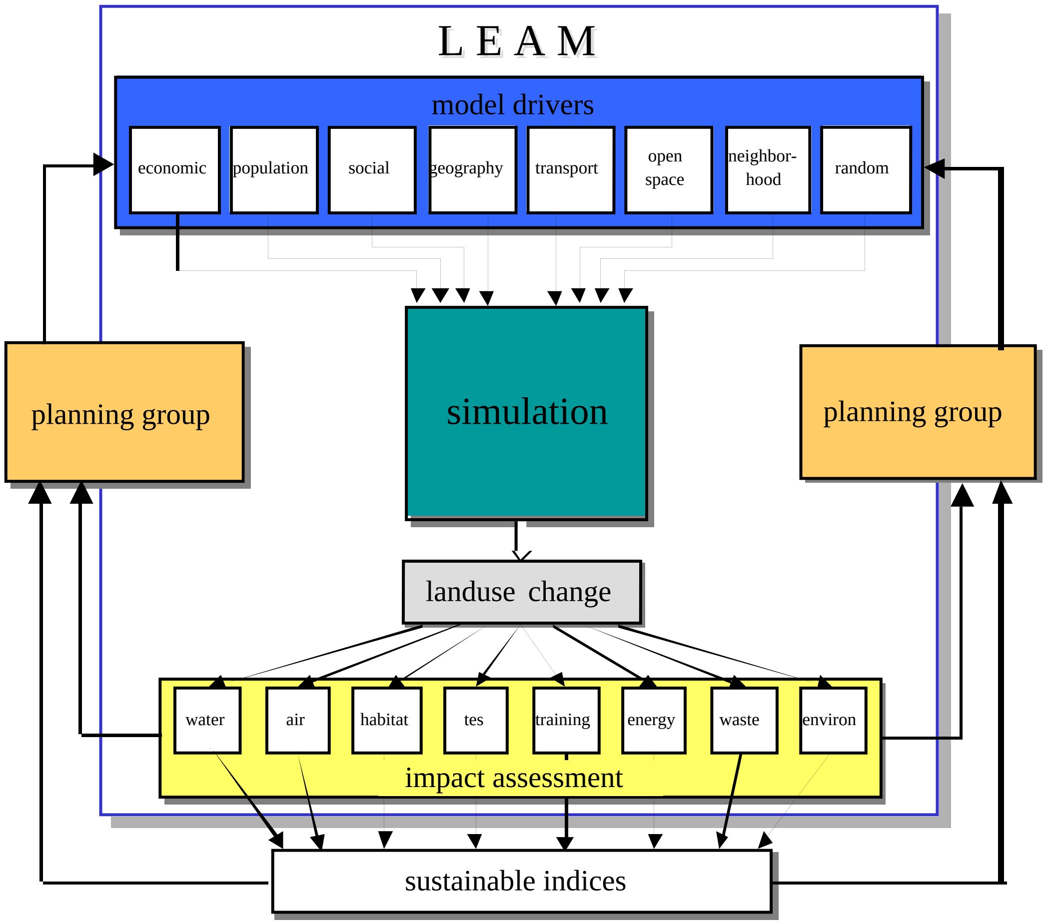

Figure 2-1. The LEAM spatial modeling environment.

The resulting products of LEAM model runs are analyses of a series of policy scenarios with feedback from the various drivers as they change over time. GIS maps or movies show the land-use transformations over time as a product of policy related inputs. These dynamic visual outputs are critical for testing policy scenarios and raising concerns regarding the impacts of development, environmental degradation, or conflicting land-use policies. The LEAM is part of a spatial decision support system that includes a simple user interface and transportable data sets for application to multiple sites.

The fundamental LEAM approach to capturing land use transformation dynamics begins with model drivers. Model drivers are considered those forces, typically human, that contribute to urban land use transformation decisions. They also describe land use transformation probabilities. The simulation visually displays the landscape transformation realized at each time step using scenario-based planning exercises. The resulting land-use changes are analyzed for environmental impacts in the impact assessment phase. Sustainability indices are calculated to derive impacts from land-use change, and may then be fed back into the model drivers.

GLUC

The General Land Use Change (GLUC) model was developed at the University of Illinois and CERL under funding from SERPD and the Common High Performance Software Support Initiative (CHSSI). It is a land use evolution model similar to LEAM and uses the same software engine. It is useful for predicting urban growth patterns 10 to 50 years into the future across a large area based on alternative local, county, state, and Federal land use investments and policies. Examples include: the location and size of proposed county roads, state and Federal highways, and size and access points for limited access highways; zoning; purchases of property (or property rights) to limit development; construction of lakes and reservoirs; establishment of permanent natural areas; and location of new employment centers. GLUC is specifically being developed as part of the LEAM suite of software and procedures, and is a part of the Army Corps of Engineers' Sustainability, Encroachment, and Room to Maneuver (SERM) program, which can be found at URL:

https://eko.usace.army.mil/fa/serm/

GLUC is a spatially explicit raster-GIS based dynamic simulation model. It works with a spatial resolution of 30 meters and uses a time step of 1 year. At each time step, a hedonic modeling approach is used to identify the relative attractiveness of each grid cell for conversion from undeveloped to either low-density urban, high-density urban, or permanent open uses. GLUC then uses a probability function to select cells that will change to meet the locally predefined population increases. The output of GLUC are time-series steps of land use patterns that are predicted to develop based on the initial land use pattern, the land use investments and policies, and the projected population change. GLUC only projects three land use changes: undeveloped to low-density urban, undeveloped to high-density urban, and undeveloped to permanent open. Thus, it does not address questions of urban decline in a city or region.

Additionally, GLUC does not distinguish between different socio-economic classifications of neighborhoods; nor will it establish new transportation routes (air, water, rail, or road). In other words, GLUC does not predict detailed growth, but rather general growth of a city within the context of its surrounding region. GLUC is designed to provide quick and reasonable urban growth projections in the 10- to 50-year time frame.

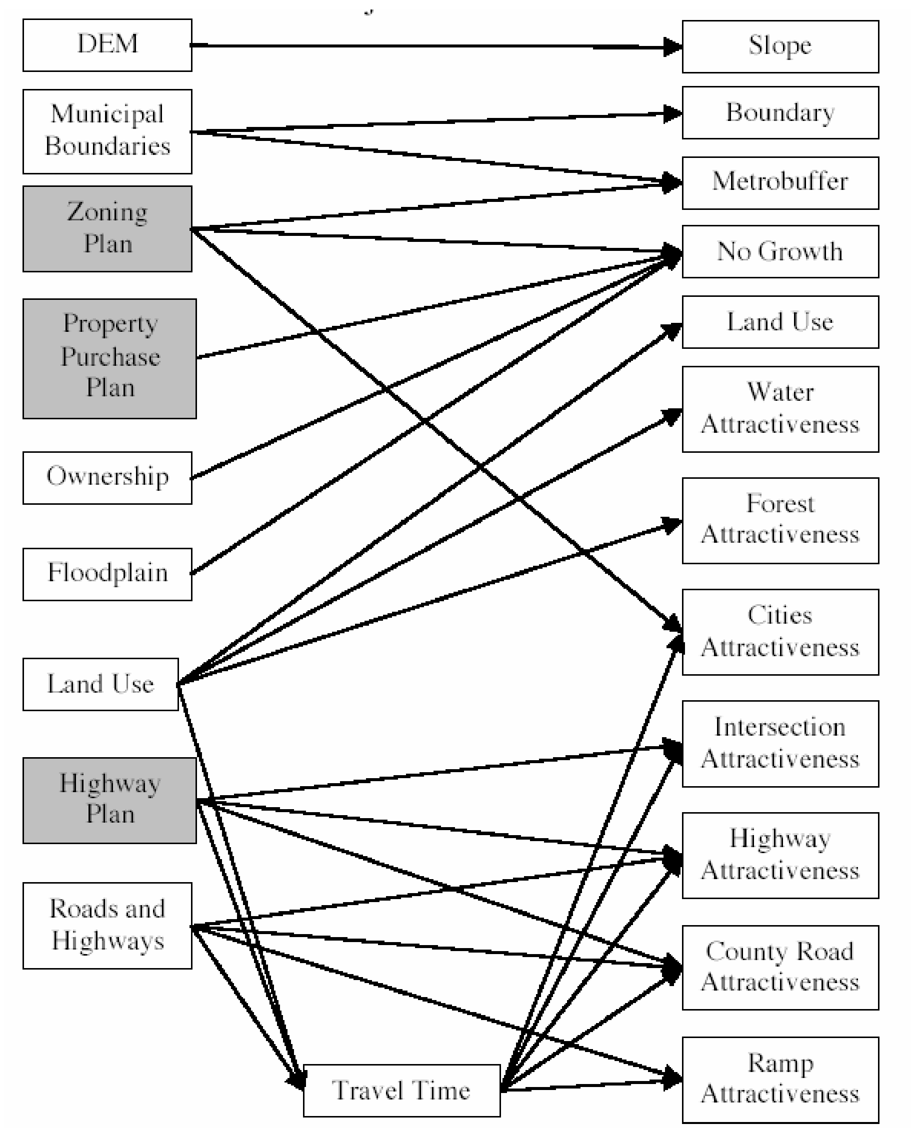

Figure 2-2. GLUC input maps.

Source: Terstriep, Jeffrey, and James Westervelt, *GLUC User Guide* (6 October 2004), accessible through URL: http://www.cecer.army.mil/KD/SERM

GLUC and LEAM researchers continue to make improvements to the model. The current version is available to be installed on any Unix-based computer. These files and information may be downloaded by starting at the SERM website. The general GLUC approach is to take raster GIS layers (listed on the left of Figure 2-2) along with travel time data to develop input maps (listed on the right of Figure 2-2) that are then manipulated through a series of equations to predict the probability of land use change for each raster cell.

Development of GLUC focuses on the problems of urban encroachment near military installations. The land-use projections can be evaluated with respect to both impacts on existing or planned use of military installation training and testing areas and loss of long-term installation training and testing opportunities. However, GLUC has applications to any community. All planners, local governments, and stakeholders are encouraged to use GLUC to test for potential long-term implications of proposed land management investments and policies.

RSim

The ***R**egional **Sim**ulation* model (RSim) was developed by a team from the Environmental Sciences Division, Oak Ridge National Laboratory (ORNL), the Department of Computer Science, University of Tennessee, Knoxville, the School of Atmospheric & Earth Sciences, Georgia Institute of Technology, the U.S. Army Center for Health Promotion and Preventive Medicine, Environmental Noise Program, Aberdeen Proving Ground, and the Intermountain Region Digital Image Archive Center, Department of Forest, Range, and Wildlife Sciences, Utah State University. The research is funded as a project sponsored by SERDP and being carried out by ORNL. ORNL is managed by the University of Tennessee-Battelle LLC for the U.S. Department of Energy under contract DE-AC05-00OR22725. The project web-site is accessible through URL:

http://www.esd.ornl.gov/programs/SERDP/RSim/

Development of RSim began in 2002. Overall, RSim is designed to integrate environmental effects of on-base training and testing and off-base development. Effects considered include air and water quality, noise, and habitats for endangered and game species (Dale, Aldridge et al. 2003). A risk assessment approach is being used to determine impacts of single and integrated risks. The plan is to make the simulation environment available via web interface. The model is being used in a gaming mode so that users can explore repercussions of military and land-use decisions. RSim is being developed for the region around Fort Benning, GA.

Specific to the process/technologies of the current model, the Fort Benning region is defined based on socio-economic factors, the prime drivers of environmental changes in the region. Most impacts focus on Fort Benning or decisions made in its immediate vicinity. A formal analysis is being conducted to allow users to determine the most appropriate strategy to match their goals. As users simulate conditions from various perspectives, they can determine how making decisions based on different goals affects the environment and mission viability. Potential users of the system include the Alabama and Georgia Departments of Transportation, which design and implement new road systems; home owners concerned about commuting, drinking safe water and breathing clean air; the installation commander who must actively train military personnel and test equipment and devices; and other decisionmakers (e.g., timber company mangers, developers, etc.). The simulation tool is of general applicability to land owners and managers, but is of special interest to military planners at DOD installations.

The computer simulation environment for this project builds on the Land-Use Change Analysis System (LUCAS) model. LUCAS was developed in 1994 to examine the impact of human activities on land use and the subsequent impacts on environmental and natural resource sustainability. LUCAS stores, displays, and analyzes map layers derived from remotely-sensed images, census and ownership maps, topographical maps, and outputs from econometric models using the Geographic Resources Analysis Support System (GRASS), a public-domain GIS. Simulations using LUCAS generate new maps of land cover representing the amount of land-cover change. Issues such as biodiversity conservation, conservation goals, long-term landscape integrity, changes in real estate values, species abundance, and land-ownership characteristics can be addressed by LUCAS. Within RSim, LUCAS is being re-engineered for modeling land-use change, resource use, and land management policies for the Fort Benning region in southwest Georgia.

The research effort is designed to contribute to workable management and monitoring plans. RSim is designed so that it can be incorporated into the Land Management Systems (LMS) and thus readily available throughout the DOD. In addition, the effort is developing new ideas on how to deal with issues of scale, feedbacks, optimization, scope of issues, and regional perspective. The team is developing an approach that integrates processes that operate on independent temporal and spatial scales, similar to the approach described for the air quality model. They are incorporating feedbacks between different aspects of the environment that operate at different scales. Historically, environmental concerns have focused on impacts within the installation due to onsite activities. Here the modeling team is examining impacts of the region on the installation, of the installation on the region, and potential feedbacks.

The plan is to develop a web-based integrated model that can become a part of the ongoing planning effort for the region. Therefore, in the research process the RSim team works closely with Fort Benning personnel who are involved in planning and management. The RSim effort is designed to contribute to workable management and monitoring plans.

Model Selection

The project team decided to use LEAM due to several factors. In addition to LEAM's development maturity, cost and timeliness were two other significant factors in its selection. LEAM is an example of an advanced dynamic model. The concepts of dynamic modeling can also be seen in the simple day-to-day planning within local communities. For instance when projecting local population growth, communities are often employing simplistic models to represent the interactions among population, employment, and wages (Mills and Lubuelle 1995). The three urban growth models of most interest were detailed above.

Appendix A provides a comprehensive list of modeling tools that were considered for use on this project. There are setbacks in costs of creating these models. Environmental forecasting often involves decisions that have long-term consequences, and it is costly to design and use a model that accounts for an extensive array of possible forecasts. In addition, these forecasts are only as accurate as the data supplied. There are countless case studies where time and money limited the scope of forecasting research. Every aspect simply cannot be realistically examined. Thus, researchers must select a limited set of indicators that are effective in measuring and can be supportive to decisionmaking.

Indicators

An effective indicator is something that points to an issue or condition. Its purpose is to illustrate how well a system is working. If there is a problem, an indicator can help determine what direction to take to address the issue. Indicators are as varied as the types of systems they monitor. However, effective indicators have certain characteristics in common: relevance, clarity, reliability, and timeliness (Hart 2004). "Relevance" refers to the fact that the indicator must fit the purpose for measuring. For example, if instead of measuring the amount of gas in a tank, the gas gauge showed the octane rating of the gasoline, it would not help in deciding when to refill the tank.

Next, an indicator must be understandable. If the meaning of the data is unknown, it is not an effective measure. For example, is the crime rate indicator measuring parking tickets, accident reports, arson, murder, or a combination? It is important to understand the true information that the indicator is imparting.

Indicators must also be reliable. Reliability refers to the ability to trust what the indicator shows. Someone is much more likely to trust water quality ratings reported from the U.S. Environmental Protection Agency (USEPA) as opposed to an unknown source published on the Internet.

Finally, indicators must provide timely information. They must give information while there is time to act on a problem. For instance employment rates updated every 10 years may not be helpful. Economies and businesses change quickly. Similarly, data is should be easy to obtain and readily available; it may not be effective to use data that researchers must obtain specific permissions to obtain. Additionally, if the data is available for one community and not another, it would be impossible to use the indicator to compare the communities, and for such a purpose, it would be an ineffective indicator.

Using Forecasts

When using forecasts, it is not enough to simply note the impact of current development. Forecasts must also ensure compatibility over the long term. Decisionmakers must understand what is likely to happen in the future and what the impacts will be. The primary reason for making forecasts is to determine whether to intervene, and if so, how. Forecasting helps decisionmakers assess alternative policy scenarios, mid-course corrections, and other interventions to mitigate future problems before they occur.

Forecasters need to use effective indicators and consider how the stakeholders of the social, economic, and physical environment will react. For example, to reduce pollution in Santiago, Chile, in the early 1990s, the government restricted the use of automobiles in the central business district. Their solution was to allow entry only to those cars whose license plates ended in even numbers on 1 day and those ending in odd numbers on the next day. However, such a plan did not have as great of an impact on pollution as it did on those who sell automobiles (so people could have cars with both even and odd numbered license plates) and commuters (who became less productive due to the extra time they spent on public transit). A forecast of the effects on only part of the system might be worse than no forecast at all because it might lead to unwise decisions.

The success or failure of forecasting and futures research depends on the methods used and the skills of the practitioners. It is imperative to understand that, even though methods may be highly quantitative or qualitative, the purpose is not to know the future, but to help make better decisions today by anticipating opportunities and threats and considering how to address them (Gordon and Glenn 1999). AEPI observed that the actual impacts of forecasting are difficult to measure and rely heavily on attaining high-level buy-in and public legitimization as signs of effectiveness. Alternative futures that add to the conventional wisdom aid in decisionmaking. The future cannot be known, but the possibilities and consequences of current paths can be explored. Decisions can be made that do influence the outcome of events and trends when informed and effective.

Scenario Planning

Scenario planning and key forces exploration are common strategic management tools for analyzing the full effects of forecasts. Although these strategies are similar, scenario planning resembles a set of stories developed through group discussion and dynamic modeling to illustrate plausible futures. It involves prioritizing a set of "key forces" to watch and then systematically exploring the interaction between trends or outcomes. Each method uses effective indicators as a means to forecasting plausible futures.

The first step of scenario planning is to understand the existing physical and sociological landscape. Examples of needed data include population and demographic information, historical and cultural resources, topography, traffic, land value, climate, and species richness. The next step is to evaluate how well the landscape characteristics are working as a guide to understand what changes might be desired. Such an assessment is sometimes a matter of law or regulation (for example, does water quality meet statutory requirements?) or sometimes a matter of common expectations (for example, is traffic congestion high?).

Once an understanding of the landscape and how it functions is developed, ideas as to how the landscape might be changed start to form. To simulate possible change, a number of alternative scenarios are created. In this case, a scenario is a specific spatial allocation of land uses at a specific time or a population change, such as a troop plus-up at an installation, with clearly articulated assumptions. The result of scenario-based planning is an illustration of multiple consequences that could occur in the future based on choices made in the present. CERL research concludes that scenario-based planning and its methodology are now maturing and will technically allow the development of a generalized protocol. Within the past 5 years, several examples of scenario-based regional planning have been applied to military installations at Camp Pendleton Marine Corps Base, CA; within the Fort Huachuca region, AZ; and at several installations in the Mojave Desert region (Rose, Lozar et al. 2000).

Whether one begins with stories (scenario-planning) or with a systematic list of forces (key-forces), the planning region must be clearly defined. Sociologists and environmental impact analysts advocate that local regions are the stage for the larger region (Branch 1988). In other words, what happens in the study region is impacted by actions at various levels such as land-use changes in an adjacent region, new laws and regulations created at the state level, and national weather patterns. Each concept or indicator has its uniquely defined region—contiguous or noncontiguous. Interactions between regions are key components to forecasting and trending.

Backcasting

As shown above, forecasting and prediction can be problematic when addressing environmental and resource policy issues. Technology is advancing and the tools are becoming more powerful. Still, there is a need for techniques of analysis that can determine the range of possible interactions between human and natural systems over time, to analyze how to avoid or respond to undesirable futures, and how to create desirable futures. This is especially true where great change is predicted and extreme intervention is anticipated (Hojer and Mattsson 2000). A scenario analysis method called backcasting may be used in conjunction with conventional predictive forecasting techniques (Robinson 1990).

Backcasting analyses are not concerned with what futures are likely to happen, but with how desirable futures can be attained. Backcasting is explicitly strategic in nature because it works backwards from a particular desired future end-point to the present to determine the physical feasibility of that future and what policy measures would be required to reach that point. In the backcasting process, future states need time to evolve while policy and other changes take effect. Therefore, end-points are usually chosen for a time quite far (25 to 50 years) into the future.

The Natural Step has adopted backcasting into a step-by-step approach. This is referred to as the A-B-C-D model for planning and is used for complex systems such as the interactions between humans and the environment (Nattrass and Altomare 2002). The four-step method consists of the following processes:

A – Developing an awareness of why the current socioeconomic / environmental system is unsustainable.

B – Understanding what the minimum success factors are for sustainability to be achieved and assessing the current reality of the players and systems in relation to those success factors.

C – Imagining future scenarios where both the success factors for sustainability and the success factors for the human systems are being met.

D – Using backcasting to enable the organization or community to identify the most effective strategies, interventions, and actions to meet both the environmental sustainability and organizational objectives.

This methodology has been described in the Natural Step format, but it is certainly not limited to that application. Robinson's original concept of backcasting can be expanded to a more generic six-step process as follows:

1. Determine objectives:
   a. Describe the purpose of analysis.
   b. Determine the temporal, spatial, and substantive scope of analysis.
   c. Decide the number and type of scenarios

2. Specify goals, constraints, and targets:
   a. Set goals, constraints, and targets for scenario analysis.
   b. Set goals, constraints, and targets for exogenous variables.

3. Describe the present system:
   a. Outline physical consumption and production processes (or define the strategic environmental context).

4. Specify exogenous variables:
   a. Develop description of the exogenous variables.
   b. Specify external inputs to the scenario analysis.

5. Undertake scenario analysis:
   a. Choose the scenario generation approach.
   b. Analyze future consumption and production processes at the end-point and mid-points.
   c. Develop the scenario(s).
   d. Iterate as required to achieve internal consistency.

6. Undertake impact analysis:
   a. Consolidate scenario results.
   b. Analyze social, economic, and environmental impacts.
   c. Compare results of step 6(a) and 6(b) with step 2.
   d. Iterate analysis (steps 2, 4 and 5) as required to ensure consistency between goals and results.

Steps 1 through 5 define the analytical flow of the analyses, while step 6 determines the policy flow as it feeds back to step 1 to ensure outcome are achieved.

Summary

A generally agreed upon definition of sustainability is to meet current needs without compromising the capability to meet future needs. For the military, sustainability refers to the capability to sustain the mission. From this concept, sustainability becomes the foundation for the Army's strategy for the future and the paradigm that focuses the Army's thinking in addressing both present and future needs.

Trends or forecasts allow for characterization of the future, but are limited in nature as they do not define the policy framework or interventions necessary to ensure a sustainable future. The most accurate forecasting/trending methodologies use both statistical and judgmental research to model relationships between the current and future social, economic, and physical environment. Understanding the relationships between the environment, economy, and society is the key to effective forecasting/trending.

There is a large continuum of possible relationships between the environment, economy, and society. Advances in computer modeling have aided in exploring many of these relationships, although it is still expensive and time consuming to model all of the possible relationships. These models produce scenarios based on their inputs and, therefore, it is critical for forecasters to select and use a well-defined list of effective indicators and well correlated drivers when modeling the future.

Backcasting is a technique in which a desired future state is defined and one works backwards from that state to the present. The process then determines the feasibility of that future and determines the policy measures that are required to reach that point. The difference between the desired end state and the forecasted end state define the fertile ground for policy change and course correction. Therefore, backcasting and forecasting are quite complementary, especially in situations where great change is needed to achieve the desired outcomes. Backcasting is especially appropriate where trends are leading towards an undesired state. Forecasting methods can inform the analyst when backcasting is required.

3 Key Forces and Issues

As noted earlier, the planning region must clearly be defined whether starting with scenario-planning or with a systematic list of key forces. Sociologists and environmental impact analysts advocate that local regions be the stage for the larger region. Events in adjacent regions, including laws and regulations created at the state level and national weather patterns, impact the study region. Each key force concept or indicator has its uniquely defined region—contiguous or non-contiguous. How these regions interact is a major component to forecasting and trending.

It is important to examine some of the forces that are likely to change over the next 20 to 30 years to define the future stressors that will impact the environment on a regional basis. Some of these critical factors or key forces are land-use change, population growth and development patterns, climate change, and the availability and price of energy resources which may alter the current development paradigm. Over time, the action of these forces will shape outcomes. Outcomes of interest are impacts on the availability and quality of water and the health of watersheds, changes in habitat and biodiversity including impacts on threatened and endangered species, and effects on air quality. The sections that follow discuss each of these key forces and outcomes generally. Later research will focus on a specific local region and use a set of scenarios to investigate how these forces will impact outcomes and sustainability related to that region.

Key Forces

Demographics and Land-use Change

According to the U.S. Department of Agriculture's National Resources Inventory (NRI), developed land in the contiguous United States increased by 34.5 million acres, or 47 percent, between 1982 and 2002 (NRCS 2004). This means that almost one-third of all of the land converted from rural to urban and suburban uses since European settlement occurred in only 20 years. This 34.5-million-acre expansion represents an area roughly the size of the State of North Carolina. During the same 15-year period, between 1982 and 2002, population grew by about 24 percent (Census Bureau 2003). Thus, land consumption occurred at about twice the underlying rate of population growth. In addition, the gap between the rate of land development and population growth is widening. Between 1982 and 1992, land was developed at 1.8 times the rate of population growth. During the period between 1992 and 2002, that multiple had grown to 2.03.

Between 2002 and 2025, the U.S. population is projected to grow by 22 percent. If the relationship between land use and population in the last decade continues, there will be 45 million more acres of developed land in the contiguous United States than exist today. This newly developed acreage—equivalent to the land area of North Dakota—will be more than half the amount of land developed from the founding of the country until 1983.

Many coastal metropolitan areas experience more rapid expansion than the nation as a whole. Between 1982 and 1997, for example, the metropolitan population of New Orleans declined by 1.4 percent, but its urban area expanded by 25 percent (Fulton et al., 2001). Similarly, the New York region's population grew 8 percent between 1970 and 1990, while urban land increased by 65 percent (Diamond and Noonan 1996). From 1973 to 1994, the urban area of Charleston, SC, expanded from 45,000 acres to 160,000 acres—a 250 percent increase. Yet population grew at a much more modest rate of 40 percent. New Orleans, New York, and Charleston exemplify a national trend. Nationwide, developed land is spreading at rates significantly higher than the underlying rate of population growth. One of the main drivers for this low-density growth was the advent of the automobile with its high market penetration. In low-density growth areas, there is about one car per adult (Glaeser and Kahn 2003).

The impact of land conversion is greatly magnified on the coasts because they host more than half of the U.S. population on less than one-fifth the nation's land area. In 1982, developed land covered 53 million acres, or 3 percent of the non-coastal watersheds in the contiguous United States. In contrast, 10 percent of the acreage of coastal watersheds was developed. By 1997, 71 million acres, or 4.2 percent, of the interior of the United States was developed. The coastal portion had risen to 27 million acres, or 13.7 percent of the land area. These percentages varied with each region of the country. The coastal watersheds of the mid-Atlantic region were 30 percent developed in 1997, up from 22 percent in 1982. New England's coastal watersheds were the second most heavily developed, at 17 percent in 1997, followed by California's at 15 percent, and the South Atlantic/Gulf region at 12.5 percent. In contrast, development covered no more than 10.5 percent of any region's non-coastal watersheds. The most obvious manifestation of growth is the physical expansion of metropolitan regions and coastal resort areas. This expansion of developed land and paved surfaces is unprecedented and its continuation will have disastrous effects on coastal ecosystems. Development in coastal watersheds degrades the creeks and marshes that run through them. Once pavement and roofs cover 10 percent of a watershed's acreage, the health of aquatic ecosystems begins to decline (Klein 1979).

If these trends continue, more than one quarter of the nation's coastal watersheds will be developed by 2025. The mid-Atlantic region would see development covering more than 60 percent of its coastal watersheds, while between 25 and 30 percent of the coastal watersheds of New England, California, and the South Atlantic/Gulf regions would be developed. As a point of comparison, only four states in the nation presently have more than one-quarter of their land area developed (Beach 2002).

While coastal impacts are expected to be significant, growth and development is also occurring in what were previous rural areas with fragile ecosystems such as the Southwest and mountain states. Figure 3-1 shows typical population growth patterns. The two-fold effect of population growth and continued reductions in development density indicate significant habitat and environmental impacts over the next 25 years unless development patterns change markedly. Sprawl has accelerated over the last decade. However, efforts to guide growth and development to a more sustainable path have not yet had significant effect. Scenarios must consider current trends and more benign paths to establish a set of bounds for future development.

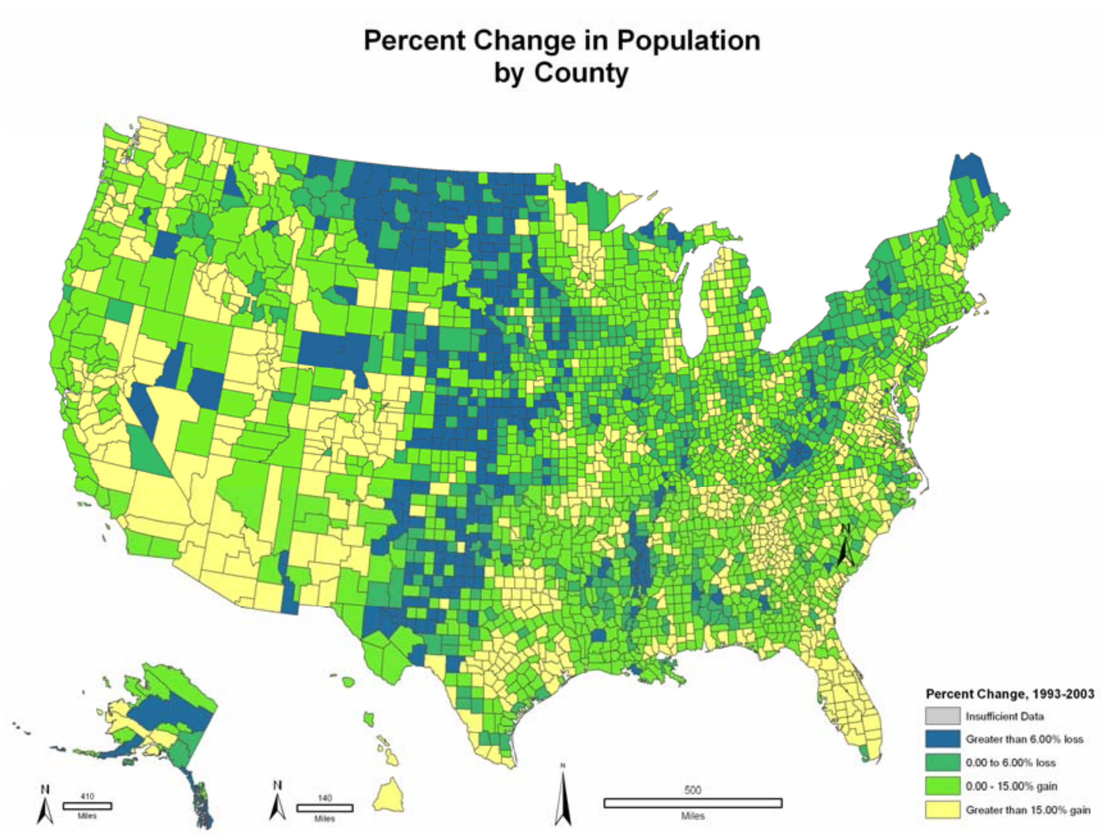

Figure 3-1. Typical U.S. population growth patterns.

Climate Change

The composition of the atmosphere—its gases and particles—plays a critical role in global and regional changes because the atmosphere links all of the principal components of the Earth system. The atmosphere interacts with the oceans, land, terrestrial and marine plants and animals, and the cryosphere (regions of ice and snow). Because of these linkages, the atmosphere is a conduit of change. Emissions from natural sources and human activities enter the atmosphere at the surface and are transported to other geographical locations and often higher altitudes. Some emissions undergo chemical transformation or removal while in the atmosphere or interact with cloud formation and precipitation. Some natural events and human activities that change atmospheric composition also change the Earth's radiative forcing response and, thus, the energy balance on the planet. Subsequent responses to changes in atmospheric composition by the stratospheric ozone layer, the climate system, and regional chemical composition (air quality) create multiple environmental effects that can influence both human health and natural systems (Mahoney, Asrar et al. 2004).

A principal feature of the atmosphere is that it acts as a long-term "reservoir" for certain trace gases that can cause global changes. The long removal times of some gases, such as CO_2—more than 100 years—and perfluorocarbons (PFCs)—more than 1,000 to 50,000 years—imply that any associated global changes could persist over decades, centuries, and millennia—affecting all nations, their people, and their ecosystems. This will occur even if the anthropogenic sources were to immediately stop and not continue to increase as current trends indicate for many of the greenhouse gases and PFCs. Worldwide consumption of energy, primarily fossil fuels—the main source of CO_2, is expected to increase 58 percent by 2025 (EIA 2004). This energy projection may not come to pass as to the types and proportions of energy sources in the future, but it is indicative of the expected energy demands in the future and the probability of increasing generation of greenhouse gases into the foreseeable future. This will bring about continued atmospheric changes and alteration of the planets climate.

In general, it is very likely that North America will get substantially warmer. Temperatures are projected to rise more rapidly in the next 100 years than in the last 10,000 years (National Assessment Synthesis Team 2000). North America has warmed by about 0.7 °C during the past century and precipitation has increased, but both trends are regionally varied and there have been seasonal reductions in precipitation in some areas. The recent Pew Center report provides compelling evidence that ecosystems are already responding to climate change (Parmesan and Galbraith 2004). Warmer temperatures have resulted in longer growing seasons at the national level, altered carbon cycling and storage in the Alaskan tundra, and increased the frequency of fires and other disturbances in U.S. forests. North America could warm by 1 °C to 3 °C over the next century for a low-emissions case. Warming could be as much as 3.5 °C 7.5 °C for the higher emission case (Cohen, Miller et al. 2001). In the Arctic, warming has actually been much greater than expected and the ice sheet has shrunk by nearly 40 percent over the last 35 years. The summer ice coverage has shrunk by 15 to 20 percent in the last 30 years (ACIA 2004). The recent ACIA study indicates that, by the end of the century, there might be no ice left in the Arctic Ocean in the summertime. Northern ocean water density and salinity is dropping, leading to possible impacts on the thermohaline circulation currents.

It is also very likely that there will be more precipitation overall, with more of it coming in heavy downpours. In spite of this, some areas are likely to get drier as increased evaporation due to higher temperatures outpaces increased precipitation. Droughts and flash floods are likely to become more frequent and intense.

Impact on Water Resources

Changes in precipitation are highly uncertain. There is little agreement across climate scenarios regarding changes in total annual runoff across North America. The modeled impact of increased temperatures on lake evaporation leads to consistent projections of reduced lake levels and outflows for the Great Lakes–St. Lawrence system under most climate change scenarios. The only exception is the transient scenario incorporating sulfate aerosol emissions, which projects slight increases in lake levels and outflows.

Where snowmelt currently is an important part of the hydrological regimes such as the Columbia basin, seasonal shifts in runoff are likely, with a larger proportion of runoff occurring in winter. This will also result in possible reductions in summer flows. Where lower summer flows and higher water temperatures occur, there may be reduced water quality and increased stress on aquatic ecosystems.

Possible changes in the frequency, intensity, and duration of heavy precipitation events may require changes in land-use planning and infrastructure design to avoid increased damages arising from flooding, landslides, sewerage overflows, and releases of contaminants to natural water bodies.

Impact on Natural Resources

In North America, climate change is expected to increase the extent and productivity of forested lands over the next 50–100 years. Climate change is likely to cause changes in the nature and extent of incidences such as fire outbreaks and insect plagues. Also expected are changes in fire regimes, including an earlier start to the fire season, and significant increases in the area experiencing high to extreme fire danger. Climate change will also lead to loss of specific ecosystem types, such as high alpine areas and specific coastal and inland wetland types.

Timber inventories are likely to increase over the 21st century. Hardwood productivity is likely to increase more than softwood productivity in some regions, including the Southeast. Lands that are managed for timber production are likely to be less susceptible to climate change than unmanaged forests because of the potential for adaptive management.

The impact on biodiversity will be significant. It is possible that some species will adapt to changes in climate by shifting their ranges, but human and geographic barriers, and the presence of invasive non-native species will limit the degree of adaptation that will occur. Losses in local biodiversity are likely to accelerate towards the end of the 21st century.

Impact on Food and Fiber

Food production is projected to benefit from a warmer climate, but there probably will be strong regional effects. Some areas in North America will suffer significant loss of comparative advantage to other regions. There is potential for increased drought in the Great Plains and the Canadian Prairies. Overall, crop yields in the United States and Canada will have a wide range of impacts, depending on ecoregion. Studies that include farm- and agricultural market-level adjustments indicate that the negative effects of climate change on agriculture probably have been overestimated. The ability of farmers to adapt their input and output choices will depend on market and institutional signals, which may be partially influenced by climate change.

Increased interest in agricultural sinks for carbon sequestration includes proposed use of reduced-tillage practices in North America. Negative consequences may include increased use of pesticides, reduced yields, and increased risk for farmers. Potential benefits include reduced input costs, increased soil moisture, and reduced soil erosion.

Climate-related variations in the marine environment—including changes in sea-surface temperatures, nutrient supply, and circulation dynamics—play an important role in determining the productivity of several North American fisheries. Projected climate changes have the potential to affect coastal and marine ecosystems, with impacts on the abundance and spatial distribution of species that are important to commercial and recreational fisheries. The degree of impact is likely to vary within a wide range, depending on species and community characteristics and region-specific conditions. Climate variability constitutes a significant source of uncertainty for fishery managers. Recent experiences with Pacific salmon and Atlantic cod suggests that sustainable fisheries management will require timely and accurate scientific information on environmental conditions that affect fish stocks, as well as institutional flexibility to respond quickly to such information.

Impact on Human Health

Increased frequency and severity of heat waves may lead to an increase in illness and death, particularly among young, elderly, and frail people, especially in large urban centers. The net effect of reduced severity of extreme cold is likely to have a beneficial effect. Acclimatization may be slower than the rate of ambient temperature change. Increased frequency of convective storms could lead to more cases of thunderstorm-associated asthma. More frequent flood events and other extreme events may result in an increase in deaths, injuries, infectious diseases, and stress-related disorders, as well as other adverse health effects associated with social disruption, environmentally forced migration, and settlement in urban slums.

Vector-borne diseases, including malaria and dengue fever, may expand their ranges in the United States and may develop in Canada. Tick-borne Lyme disease may also expand its range in Canada. However, socioeconomic factors such as public health measures will play a large role in determining the existence or extent of such infections. Diseases associated with water may increase with warming of air and water temperatures, combined with heavy runoff events from agricultural and urban surfaces.

Respiratory disorders may be exacerbated by warming-induced increases in the frequency of smog events, acidic deposition, and particulate air pollution.

Impact on Human Settlements and Infrastructure

Potential impacts of climate change on cities include fewer periods of extreme winter cold; increased frequency of extreme heat; rising sea levels and risk of storm surge; and changes in timing, frequency, and severity of flooding associated with storms and precipitation extremes. These changes in the frequency, severity, and duration of extreme events may be among the most important risks associated with climate change. The rising cost of natural disasters in North America illustrates the vulnerability of current settlement practices (CBO 2002). Human alterations of natural systems—such as drainage basins, barrier islands, and coastal margins—influence the impact of extreme weather hazards. Adaptations such as levees and dams often are successful in managing most variations in the weather, but they can increase vulnerability to the most extreme events.

Abrupt Climate Change

The impacts noted above are based on gradual climate change where there is time for adaptation and adjustments to the economy and ecological systems. Another potential response is abrupt climate change. Until recently, the dominant view of climate change was that the climate system changed gradually in response to the processes noted above. Evidence now shows that climate has changed much more rapidly in the past and this rather abrupt change is likely to occur again in the future with large impacts on ecosystems and societies (National Research Council 2004). The expected future warming may come smoothly or it may come in jumps with short-lived or local coolings, floods or droughts, and other unexpected changes. Societies and ecosystems are not well suited to deal with the abruptness and unpredictability of the possible changes. There is a possibility that the gradual global warming could lead to a relatively abrupt slowing of the ocean's thermohaline conveyor, leading to harsher winter weather, sharply reduced soil moisture, and more intense winds (Schwartz and Randall 2003). Thus, there would be some regional cooling, but overall, the Earth would still be warmer on average.

The major impacts of abrupt climate change are most likely to occur when economic or ecological systems cross important thresholds and move to a different climate regime. Historically, a notable aspect of large, abrupt global and regional climate changes is precipitation. Precipitation is inherently more variable than temperature. Paleoclimatic records show that extreme and persistent droughts have occurred throughout the past few millennia in widespread regions. The recognition of abrupt changes in the past reinforces concerns about anthropogenic climate change. Current and expected trends have the potential to push the climate system through a threshold to a new climate state. Abrupt climate change occurs when the climate system transitions to a new state at a rate determined by the climate system itself and faster than the cause, and with a rate of change or variability that is significantly greater than the recent variability of the climate for that region.

Energy Resource Issues

Petroleum

Petroleum is a global commodity and the United States is inextricably tied to the world market for petroleum. Some analysts project that world oil production will peak later this decade, then plateau for several years, and subsequently decline (Campbell and Laherrere 1998; Deffeyes 2001; Laherrere 2003; Campbell 2004). In fact, non-OPEC conventional oil production may already be at its peak. In crude oil markets, uncertainties surround continued unrest in many of the key producing regions. Oil flow from Venezuela was disrupted in 2003 due to internal political turmoil. Iraq also has significant excess capacity (EIA 2002), but bringing this on-line in the post war climate is proving to be problematic.

We may be now entering an era where the availability of excess capacity in producing nations is no longer available to meet increases in world-wide demand. This new oil crisis has already started and within the decade will become a permanent condition. Demand may permanently outstrip supply and it will create economic and political discontinuity as the world adjusts to a new energy environment (Roberts 2004). A study from the Oil Depletion Analysis Center in London concludes that all of the major new oil-recovery projects scheduled to come on line over the next 6 years are unlikely to increase supplies enough to meet the world's expected demand increases (ODAC 2004).

The Energy Information Administration (EIA 2004) projects an increase in the demand for oil and production of 56 percent in the next 20 years. Meeting such a demand would require significantly higher rates of discovery than have been experienced in the last several decades. To meet the current increase in demand, for every four barrels of oil used in the world today, producers must replace the four barrels oil consumed and find a fifth barrel to meet new demand—and that depletion rate is increasing. When reserves are back dated to discovery, it can be seen that actual discoveries peaked in the 1960s.

The United States now imports over 59 percent of its crude oil supply. That rate is expected to increase throughout the foreseeable future up to about 70 percent by 2025 (EIA 2004). The nation is becoming more vulnerable and is ill equipped to deal with the potential economic and geopolitical implications of oil market volatilities (Romm and Curtis 1996). Due to the ready substitutability between oil and natural gas in industry and power generation, the price of natural gas will quickly reflect changes in the price of oil. However, current prices for natural gas exceed those for oil. Coal prices are also somewhat susceptible to price increases in natural gas and oil and we are seeing Eastern coal prices rise (Roberts and Hunt 2004).

Natural Gas

The United States is headed for a crisis in natural gas supply. Analysts estimate that the nation's natural gas supply fell 3 percent in 2004, and it will fall another 1 percent in 2005. Natural gas production in the lower 48 states and Canada is dropping and, currently, there is no way to get stranded Alaskan and other North Slope natural gas to market. U.S. basins have matured and premium reservoirs have been depleted. The United States must now replace about 29 percent of its natural gas production each year due to depletion of existing wells. The decline rate is increasing over time and projected to exceed 32 percent in a few years. As a result, natural gas prices have been very volatile over the past several years and this trend will continue. We have seen a significant upward shift in prices starting in January 2003 which will last for the foreseeable future. This upward price trend stems in part from a huge shortfall in supplies available to the U.S. market, which may be in the range of 1 trillion cubic feet in 2004 and 2005. This would be true even if there is no increase in domestic demand. Unfortunately, at the same time supplies are diminishing, demand is certain to be growing due to the impact of 200,000 MW of natural gas-fired generating capacity that has been added to the grid since 1999 and tightened NOx restrictions that have gone into effect in 2003 and 2004. The weather each year will play a major role in determining natural gas prices and reserve margins. High prices are already leading to market shifts with major closures of fertilizer manufacturing plants which compete for natural gas at a far lower price than currently available. Also, some industrial users are able to switch to oil.

There are plentiful supplies of natural gas in the world, but unfortunately, up to half of the natural gas supplies in the world are considered stranded—too far from markets to be economically harvested. One solution is the increased use of liquefied natural gas (LNG) and the expansion of LNG terminals on the U.S. coast. The four existing U.S. LNG terminals (Everett, MA; Cove Point, MD; Elba Island, GA; and Lake Charles, LA) are all expected to expand by 2007, and additional facilities are expected to be built in the lower 48 States, to serve the West Coast, Gulf, Mid-Atlantic, and South Atlantic States, with a new small facility in New England and a new facility in the Bahamas serving Florida via pipeline. Another facility has been built in Baja California, Mexico, to serve the California market. Total net LNG imports are expected to increase significantly in the future, as they must to meet current and expected domestic demand growth. Unfortunately, virtually all the proposed new LNG terminals are experiencing heavy local opposition. If built, there may not be commodity available due to the lack of LNG production capacity and the specialized ships to transport it. There is also a homeland security issue associated with LNG. These terminals and ships are potential targets for terrorists.

Energy Implications

Petroleum products and natural gas represent about two-thirds of the nation's energy supply. Based on the above, the domestic outlook for both of these energy sources is problematical with price and availability issues certain to have major impacts on the economy and bring about significant energy policy changes and technology shifts in the next 25 years. In the near future potential price spikes, disruptions, and shocks may strike the general economy as the world energy situation plays out over the next decades. A recent bipartisan commission on energy policy released its report on the national energy situation (NCEP 2004). It recommends a slate of energy research, efficiency, and production initiatives to address the coming energy challenges. The recently released World Energy Outlook indicates that an investment of $16 trillion dollars is required to meet expected energy demands world-wide through 2030 (IEA 2004).

Another important consideration is how our current development and land-use paradigms are related to the availability and price of petroleum products. Much of the energy requirements in the United States are related to our development patterns and higher prices will alter these patterns to a more sustainable paradigm.

Outcomes

Air Quality

The air in the United States is polluted from multiple sources such as the operation of cars and trucks; burning coal, oil, and other fossil fuels; and manufacturing chemicals. Air pollution also comes from smaller sources such as dry cleaning, gasoline filling stations, and degreasing and painting operations. These activities add gases and particles to the air. When these gases and particles accumulate in the air in high enough concentrations, they can cause harm to people and the environment. Higher pollution levels are found where there are higher densities of sources, especially in cities and surrounding counties where there are more cars, trucks, industrial and commercial operations.

The Clean Air Act, which was last amended in 1990, requires USEPA to set National Ambient Air Quality Standards (NAAQS) for wide-spread pollutants from numerous and diverse sources considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards. The first are primary standards which set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. The second type of standards set limits to protect public welfare. This includes protection against visibility impairment, damage to animals, crops, vegetation, and buildings. The USEPA has set NAAQS for six principal pollutants, which are called "criteria" pollutants. The six pollutants are ozone (O_3), particulate matter (PM), carbon monoxide (C), sulfur dioxide (SO_2), nitrogen oxides (NOx), and Lead (Pb). The USEPA tracks information on areas of the country where air pollution levels persistently exceed the national ambient air quality standards for each of the six criteria pollutants. These are considered nonattainment areas and are subject to special regulations to reduce emissions. Criteria pollutants are described below.

Ozone

Ozone (O_3) is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground level is created by a chemical reaction between oxides of nitrogen and volatile organic compounds (VOC) in the presence of heat and sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground level and, depending on its location in the atmosphere, may be considered a pollutant. Ozone that occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface forms a layer that protects life on earth from the sun's harmful rays. In the Earth's lower atmosphere, ground-level ozone is considered a pollutant.

Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents are some of the major sources of NO_x and VOCs that help to form ozone. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. As a result, it is known as a summertime air pollutant. Many urban areas tend to have high levels of ground level ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and pollutants that form it hundreds of miles away from their original sources. Thus, large metropolitan areas can contribute significantly to background levels in areas where ozone would not normally be a problem.

Particulate Matter

The term "particulate matter" (PM) includes both solid particles and liquid droplets found in air. Many manmade and natural sources emit PM directly or emit other pollutants that react in the atmosphere to form PM. These solid and liquid particles come in a wide range of sizes.

Particles less than 10 micrometers in diameter (PM_{10}) pose a health concern because they can be inhaled into and accumulate in the respiratory system. Particles less than 2.5 micrometers in diameter ($PM_{2.5}$) are referred to as fine particles and are believed to post the largest health risks. Because of their small size, fine particles can lodge deeply into the lungs. Sources of fine particles include all types of combustion (motor vehicles, power plants, wood burning, etc.) and some industrial processes. Particles with diameters between 2.5 and 10 micrometers are referred to as coarse. Sources of coarse particles include crushing or grinding operations, and dust from paved or unpaved roads.

In 1997, USEPA established NAAQS for $PM_{2.5}$ for the first time as well as revised NAAQS for PM_{10}. The monitoring and implementation plans for these two pollutants are different.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, and (at higher levels) poisonous gas. It is formed when carbon in fuels is not burned completely. It is a product of motor vehicle exhaust, which contributes about 60 percent of all CO emissions nationwide. High concentrations of CO generally occur in areas with heavy traffic congestion. In cities, as much as 95 percent of all CO emissions may emanate from automobile exhaust. Other sources of CO emissions include industrial processes such as carbon black manufacturing, non-transportation fuel combustion, and natural sources such as wildfires. Woodstoves, cooking, cigarette smoke, and space heating are sources of CO in indoor environments. Peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are greater and nighttime inversion conditions are more frequent.

Sulfur Dioxide

Sulfur dioxide (SO_2) is a colorless, reactive gas and is produced during the burning of sulfur-containing fuels such as coal and oil, during metal smelting, and by other industrial processes. It belongs to a family of gases called sulfur oxides (SOx). Major sources include power plants, industrial boilers, petroleum refineries, smelters, and iron and steel mills. Generally, the highest concentrations of sulfur dioxide are found near large fuel combustion sources.

Acid deposition or "acid rain" occurs when SO_2 and oxides of nitrogen (NOx) react with water, oxygen, and oxidants to form acidic compounds. It is deposited in dry form (gas, particles) or wet form (rain, snow, fog), and can be carried by wind hundreds of miles across state and national borders. Acid rain harms lakes and streams, and damages trees, crops, historic buildings, and monuments. The estimated nationwide emissions of SO_2 in 1999 were 18.9 million short tons.

Nitrogen Oxides

Nitrogen oxides (NO_x) is the generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colorless and odorless. However, one common pollutant, nitrogen dioxide (NO_2) along with particles in the air can often be seen as a reddish-brown layer over many urban areas.

Since air is mostly nitrogen, nitrogen oxides form when fuel is burned at high temperatures, as in a combustion process. The primary sources of NO_x are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.

Lead

Lead is a metal found naturally in the environment as well as in manufactured products. The major sources of lead emissions have historically been from fuels in motor vehicles (such as cars and trucks) and industrial sources. Emissions from on-road vehicles decreased 99 percent between 1970 and 1995 due primarily to the use of unleaded gasoline. Use of leaded gasoline in highway vehicles was prohibited on 31 December 1995. Due to the phase out of leaded gasoline, ore and metals processing is the major source of lead emissions to the air today.

Air Quality Issues

Air quality tends to degrade when development brings an increase in automobile and industrial emissions. Some pollutants, such as ozone tend to be associated with high automobile density while others such as SO_2 and particulates tend to be associated with industry, especially coal-fired power plants. Periodic burns also cause some air quality problems and can exacerbate situations where other non-point sources are already having an impact. High levels of any one of the criteria air pollutants can cause restrictions on sources and special rules to bring a region into compliance.

Water

Water scarcity may be the most underestimated resource issue facing the world today. World water use has tripled in the past 50 years. Current global water usage is 70 percent for irrigation, 20 percent for industry, and 10 percent for residential purposes. Forty percent of our food supply now comes from irrigated land, showing increased reliance on irrigation in the world food economy. While the demand continues to rise, the basic amount of fresh water supply provided by the hydrological cycle remains static. There are two principal signs of stress as the demand for water outruns the supply: rivers run dry and water tables fall (Brown 2001).

Many of the world's major rivers now fail to make it to the sea, or there is very little water left in them when they do reach the sea. The Colorado River, the major river in the southwestern United States, rarely reaches the Gulf of California. It is drained dry to satisfy the agricultural needs in Colorado, Arizona, and, California. The Nile River has little water left in it when it reaches the Mediterranean. The Ganges, shared by India and Bangladesh, is almost dry when it reaches the Bay of Bengal. China's Yellow River, the cradle of Chinese civilization, first ran dry in 1972, but beginning in 1985, it has run dry for part of each year.

Water tables are falling on every continent. Aquifer depletion is a new global problem that has emerged in the last half century. This is because it is only during this period that the pumping capacity has existed to deplete aquifers. The size of the world water deficit—the amount of over pumping in the world—using data for India, China, the Middle East, North Africa, and the United States, is estimated to be 160 billion tons of water, which equals 160 billion cubic meters (Postel 1999). The United State's portion of the water shortfall is about 2,700 billion gal per year or about 7 percent of the total.

One of the wild cards in the water situation and one of the factors that makes assessing the future water situation difficult is climate change. A second level effect of climate change is its impacts on the cryosphere. The melting of ice on land along with temperature expansion of sea water leads to rising sea levels, an event that is now occurring. The temperature rise in mountainous regions will affect water supply, particularly for agriculture.

A rise in average temperature in mountainous regions of 1 or 2 degrees Celsius can substantially alter the precipitation mix between rainfall and snowfall, with substantial increases in the amount of precipitation coming down as rain and a reduction in the amount coming down as snow. This change translates into more runoff and more flooding during the rainy season and less water being stored as snow and ice in the mountains for use in the dry season. The snow pack acts as a reservoir, which is slowly draining. Ice is melting in all the major mountainous regions of the world. In the United States, Glacier National Park located in the State of Montana, had 150 glaciers in it a century or so ago. Now there are only 50 and the USGS projects that, in another 30 years, none may be left at all.

In the United States, the per capita water consumption has been lowered over the past 20 years; yet, 16 million people face water rationing (Glenn and Gordon 2004). Over the next decade, the United States is expected to move from a high water availability nation to an average water availability nation (CIA 2000). In addition to climate change issues and over pumping of aquifers for irrigation and domestic water supply, a major contributor in the United States to water problems is the way land is developed. Sprawling growth is paving over more and more wetlands and forests contributing to the depletion of our water supplies (Otto, Ransel et al. 2002). The arid West is not the only area facing critical water shortages. The rapidly suburbanizing Southeast is now in serious trouble, as are many other formerly water-rich regions of the country. Over the last decade, studies have linked suburban sprawl to increased traffic and air pollution as well as the rapid loss of farmland and open space. Sprawl not only pollutes water supplies, it also reduces those supplies. Impervious surfaces–roads, parking lots, driveways, and roofs–replace meadows and forests so that rain no longer can seep into the ground to replenish aquifers. Rainwater is swept away by gutters and storm sewer systems. The sprawling of America has translated into a significant loss of valuable natural resources. Undeveloped land is valuable not just for recreation and wildlife, but also because of its natural filtering function. Wetlands act like sponges, absorbing precipitation and runoff and slowly releasing it into the ground.

More than one-third of Americans get their drinking water directly from groundwater, and the remaining two-thirds depend on surface water. The groundwater issues also impact surface water because, typically, about half of a stream's volume comes from groundwater. These streams and the lakes are then the source of drinking water for the other two-thirds of the population. Figure 3-2 shows the potential impacts of climate change and land settlement patterns on the future U.S. ground water supplies (Hurd, Leary et al. 1999). Vulnerability ranges were defined as the ratio of average groundwater withdrawals (Q_{GW}) in 1990 to annual average baseflow (Q_{Base}), reflecting the extent that groundwater use rates may be exceeding recharge. High depletion rates are vulnerable to long-run changes in hydrology and future lack of supply. Much of the U.S. West, Southwest, central plains, and Florida are highly vulnerable.

Level of development is an indicator that measures the ratio of current water withdrawal to mean annual unregulated streamflow. Watersheds with low water availability and high demand are vulnerable, i.e., in areas of development, intensive use of off-stream water generally results in decreased water availability. Reduction in streamflow, either via seasonal or dramatic climatic change, increases both instream and off-stream uses, especially in areas of high development and high irrigation. Water availability could be compromised resulting in a negative impact on biological carrying capacity and biodiversity. Vulnerability levels are defined as the ratio of total annual surface and groundwater withdrawals in 1990 (Q_W) to unregulated mean annual streamflow (Q_S). This ratio reflects the extent to which a watershed's water resources are developed for consumptive uses. The withdrawals in many areas have been increasing with time as development occurs. Figure 3-3 shows how much of the U.S. West, Southwest, and central plains are highly vulnerable.

Water availability is an increasing domestic and international problem. Indeed, it may even be more important than energy since there are only two Earth resources that are absolutely essential to human existence—water and soil (Youngquist 1997). From this reality comes the imperative to use water resources effectively and efficiently and to consider water issues in long term sustainability considerations.

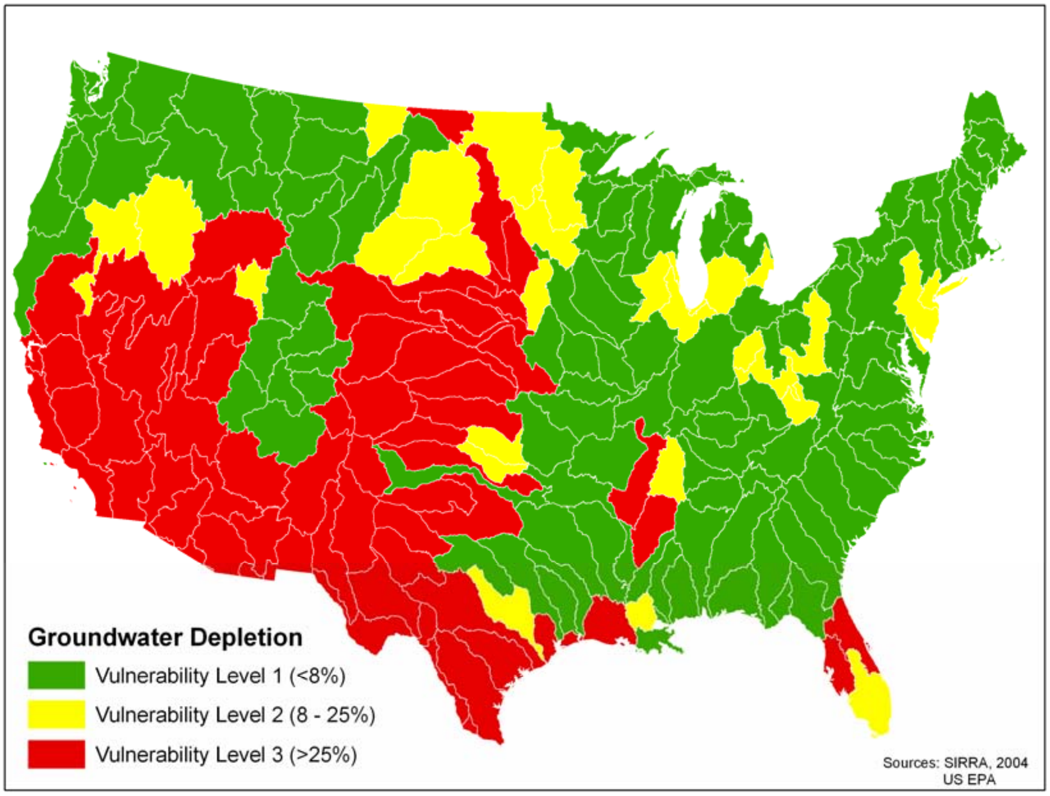

Figure 3-2. Vulnerability to groundwater depletion.

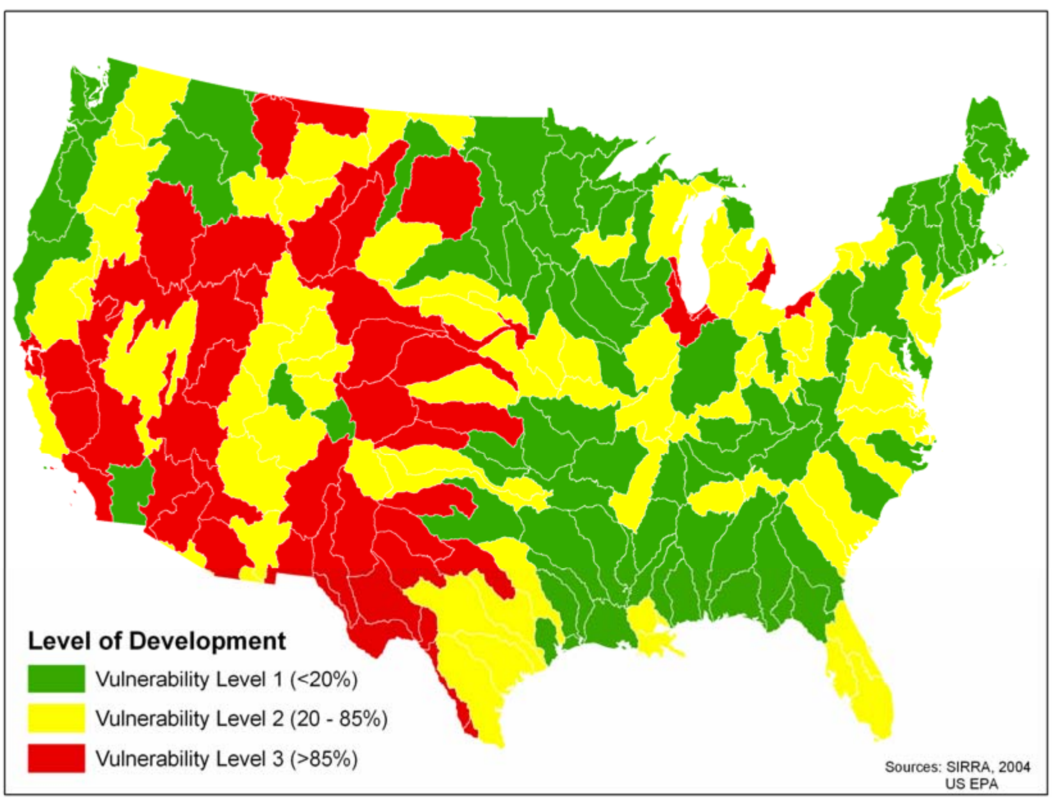

Figure 3-3. Level of development.

Biodiversity

Biodiversity is the pattern and variety of life and its processes. It is a manifestation of the genetic diversity and is the result of evolutionary adaptation of plants and animals to environmental conditions. Relationships between type and quality of habitat and species diversity are tightly coupled. This tight linkage is leading to significant losses in biodiversity as habitat is altered or destroyed through either land-use or climate change, thus biodiversity represents the nexus of the other key issues. Threatened and endangered species are a subset of the biodiversity issue. These bell-weather species get public attention; their loss is symptomatic of habitat degradation and ecosystem damage on a grander scale. Natural habitats are under severe and widespread stress due to the loss, alteration, and degradation of natural ecosystems resulting from direct and indirect human activities. Species imperilment directly results from the development paradigm we call sprawl—low-density, automobile-dependent development into natural areas outside of cities and towns (Doyle, Kostyack et al. 2001). Sprawl leads to direct habitat loss, habitat degradation, and loss of species diversity. Land that is high quality habitat unfortunately also attracts people. The most endangered ecosystems are typically at low elevations and have people attracting characteristics such as fertile soils, amiable climates, easy terrains, abundant natural resources, and other factors that encourage human settlement and exploitation (Noss, III et al. 1995).

To positively affect the course of biodiversity loss, some deliberate action must alter the way development occurs to protect habitat from fragmentation and from the direct and indirect impacts of development (Steinitz, Adams et al. 1997). This involves complex and difficult choices that must be implemented on the regional level. While private conservation schemes work best for protecting a region's biodiversity, they may be very difficult to implement at the scale needed to preserve biodiversity in areas threatened by development. It is also important to alter the efficiencies of land use during urban development. Concepts such as new cities and multi-center alternatives are likely to be superior ways to accommodate growth even though they are less effective than land conservation in maintaining biodiversity. Peter Calthorpe has proposed pedestrian pockets or new, small cities as a way of accommodating growth while minimizing impacts on the land (Calthorpe 1993). Current development patterns represent the highest risk for biodiversity. Stakeholders in a region must move toward some combination of biodiversity preservation or the future will continue the trend towards the simpler, less life supporting ecosystems of suburbia and modern agriculture.

Climate change will also have significant impact on biodiversity as weather patterns change and current habitat becomes non-viable for numbers of species. This is a longer range issue, but still very much a problem that is not being effectively addressed in the world today. Ecosystems at high altitudes, high latitudes, and shorelines are currently the most affected by climate change. More generalized impacts will follow. Future scenarios do not bode well for biodiversity in general, and threatened and endangered species in particular, unless current efforts at directing development and addressing climate change gain more traction. Specific issues will be addressed on a regional basis for various study sites.

4 Sustainability Assessment Tools and Implementation Programs

The DOD recognizes that military installations are often the catalyst for actions and developments occurring “outside the fence.” Today’s military installations are struggling with ever-increasing readiness requirements involving training more soldiers on less land. In addition to time and spatial constraints, Installation Commanders are facing challenges of environmental factors and growing encroachment issues that can seriously restrict, and in some cases shut down the training capability of an installation. The following two sections describe methods, systems, strategies, and programs that are part of the developing toolkit to help meet these challenges. Note that the military are not the only ones working on issues concerning development scenarios and forecasting. Early stages of this work included literature and technical reviews of many tools and systems preliminary to the development of the project’s methodologies. Appendix A contains information on additional resources and models that were reviewed, and that are generally and commercially available, but were found to be not specifically germane to the project.

Methods and Systems

Proactive Options with Neighbors for Defense installation Sustainability

The Proactive Options with Neighbors for Defense-installation Sustainability (PONDS) is a web-based tool (Figure 4-1) developed by ERDC/CERL as part of the SERM program. PONDS provides resources and case studies to help nurture relationships between military installations and their neighbors by promoting opportunities for planning and partnering. For example, communities can work with military installations to create regional transportation plans or mass transit systems to mitigate air pollution caused by traffic and congestion.

The purpose of PONDS is to provide the military and neighboring communities with a central information source to help encourage partnering opportunities and resolve land use conflicts. The web-based tool and database contains information on a wide variety of land use issues such as encroachment, water conservation, threatened and endangered species, and noise. The PONDS website is an information-sharing hub for DOD installations and neighboring communities who are seeking proven solutions for resolving land use conflicts. A searchable database allows users to find relevant case studies and articles on land conflict resolutions and land mitigation strategies within and outside of DOD installations. The database contains case studies and examples from military installations, Federal agencies, the private sector, and non-profit organizations. PONDS is searchable by military or non-military examples, by region, or by location, type of study, stakeholder, mitigation strategy employed, or topic.

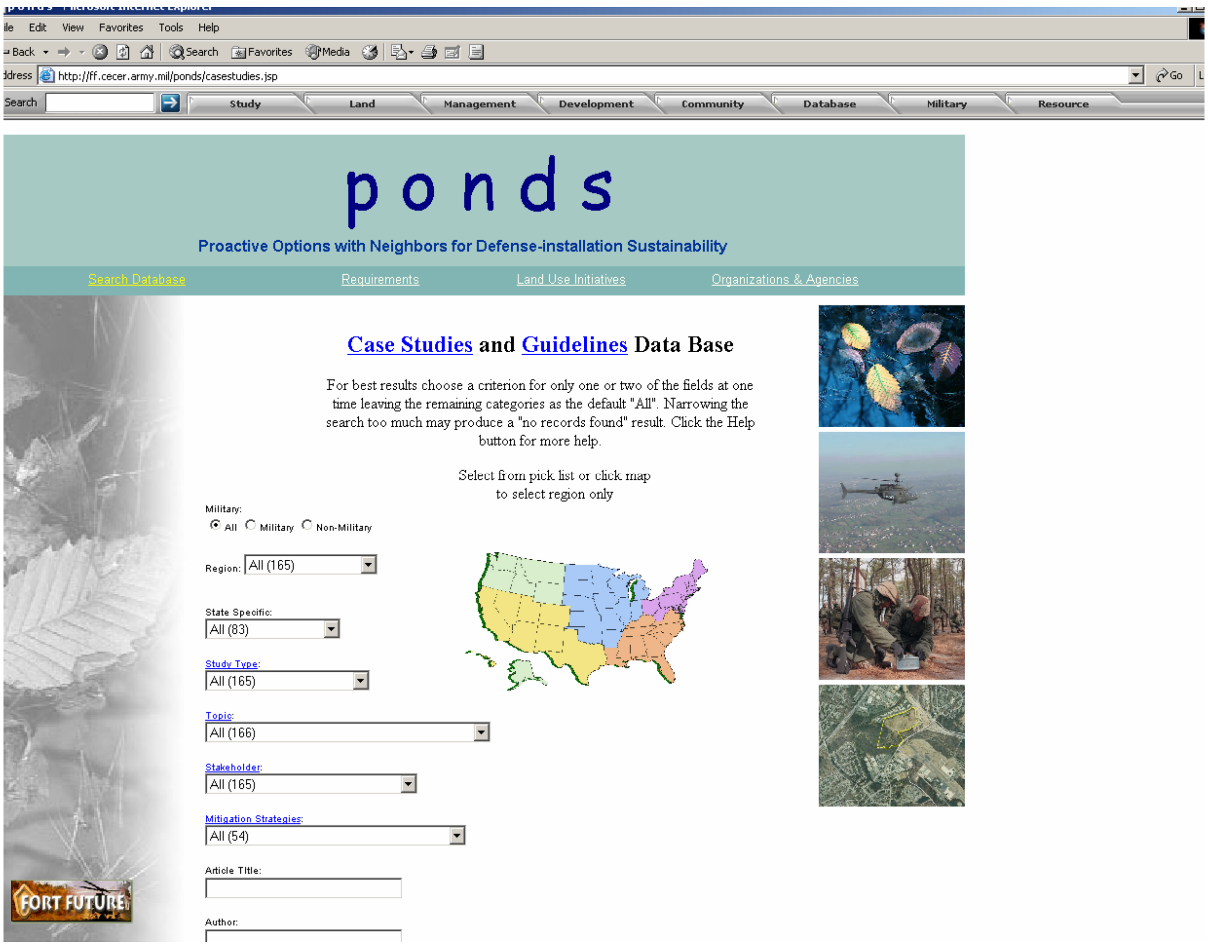

Figure 4-1. The Proactive Options with Neighbors for Defense-installation Sustainability (PONDS) home page.

Fleet Environmental Information Management System

As part of its environmental strategy, the Navy has developed the Fleet Environmental Information Management System (EIMS), a single comprehensive geospatial environmental information system. The first operational use was completed in the fall of 2003. It is owned and operated by the U.S. Navy. The web-based user interface is available through the U.S. Navy portal (Figure 4-2). It is designed to enhance mission accomplishment while achieving environmental protection. EIMS identifies early the effects of operations on the environment and of environmental laws and regulations on operations—allowing for the avoidance or mitigation of adverse effects. In other words, it avoids unnecessary costs for site cleanup and restoration after an operation, minimizes potential for peacetime operation delays to meet regulatory requirements, and reduces the possibility of adverse publicity and future exercise area restrictions.

Designed to support major exercise planning, it facilitates effective exercise planning by providing users with a full suite of analysis tools and instant access to shared authoritative data.

EIMS uses commercial, off-the-shelf technology (COTS) to browse Federal, state, and local data sources. EIMS has several objectives. The first is to enhance mission accomplishment while achieving environmental protection at the lowest possible cost by providing environmental planners with analysis tools and access to data. It is also intended to provide common ground for staffing, maintain readiness through training area and range access, and balance readiness and stewardship.

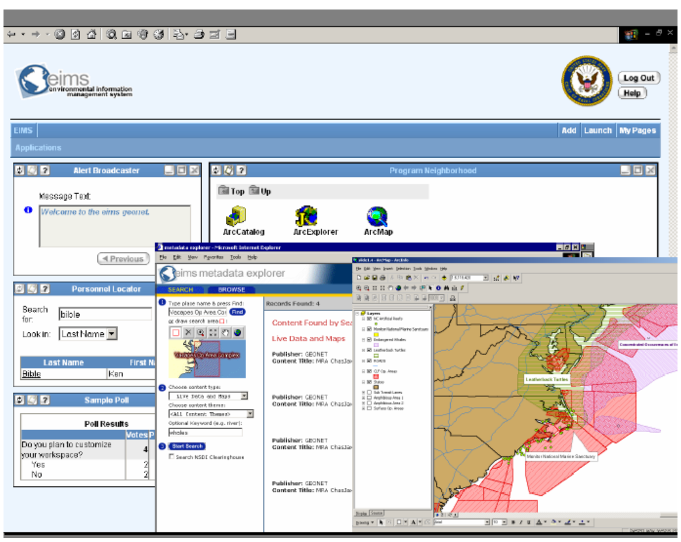

Figure 4-2. The Navy's Fleet Environmental Information Management System (EIMS) web page.

Sustainable Installations Regional Resource Assessment

The Sustainable Installations Regional Resource Assessment (SIRRA) methodology is a process of characterizing the regions surrounding 308 DOD installations based on a set of sustainability issues (Jenicek, Fournier et al. 2004). The process uses uniform vulnerability assessments with a broad set of indicators covering the range of issues that affect DOD installations. The assessment is used to express the relative ranking of regions surrounding installations using single measures that define a stress. This standardized approach allows the use of national-level data to evaluate regional aspects of the installation setting. This evaluation provides for a heightened awareness of long-term issues that could threaten mission sustainment. The sustainability issue areas are: Air, Energy, Urban Development, TES, Locational, Water, Economic, Quality of Life, and Infrastructure.

Potential indicators for measuring these regional resources within the nine issue areas were selected based on a set of requirements. The data needed to be available at a uniform scale nation-wide to ensure consistency in comparisons and recorded for multiple time periods to enable the evaluation of change. The information was prepared by a reputable source, such as a government agency or professional data vendor, and accompanied by metadata for quality assurance. The data needed to be provided in a digital format, to accelerate data gathering and preparation for analysis and have the ability to be converted to GIS format.

The nine issue areas with their corresponding indicators represent a broad spectrum of issues related to resource availability and development. The 48 indicators provide a wide variety of information about the region's population demographics and trends, economics, land development and usage, watershed quantity and health, natural disasters, infrastructure, air pollution, energy situation, and quality of life. Indicators come from a variety of sources such as the USGS for water resource information, the USEPA for air pollution data and water supply characterization, the U.S. Fish and Wildlife Service (USFWS) for endangered species data, the U.S. Census Bureau for population statistics, and the U.S. Department of Energy (USDOE) for energy related data. The SIRRA framework provides for multiple views of the data collected. The national data sets are provided at the lowest practicable level. This enables a more focused view of the implications associated with specific objective questions.

Sustainability ratings are developed in several different ways. National regulatory targets exist for some indicators. Examples include USEPA's six criteria air pollutants that comprise the air quality indicator, USGS designated seismic zones, and listing of species as threatened or endangered by state or Federal authorities. Other data sources require statistical analysis and evaluation based on the research literature. Quality of Life indicators are examples of these.

SIRRA has adopted a red/amber/green depiction of high/medium/low vulnerability for summary presentations. However, numeric indicators, reasoning, and raw data are also available for each of the ratings. Table 4-1 lists the SIRRA indicators.

Table 4-1. List of SIRRA indicators.

Issue	Indicator	Data Source	Data Level
	Air Sustainability		
AS1	Criteria Pollutant Non-Attainment	EPA/EIA	County
AS2	Noise Sensitivity	U.S. Census Bureau	Installation
AS3	Air Space Demand	FAA	Installation
	Energy Sustainability		
EA1	Electrical Grid Congestion	NERC	NERCSub
EA2	Electrical Reserve Margin	NERC	NERCReg
EA3	Renewable Energy - Wind	NREL	Solargridunit
EA4	Renewable Energy - Solar	NREL	Windgridunit
EA5	Renewable Energy - Biomass	NREL	State
EA6	Electrical Price Structure (Dereg)	EIA	State
EA7	Net metering	Green Power network	State
	Urban Development		
UD1	Regional population density	U.S. Census Bureau	County
UD2	Incr. Regional Growth Rate	U.S. Census Bureau	County
UD3	Regional population growth	U.S. Census Bureau	County
UD4	Regional Land Urbanization	NLCD	Installation
UD5	State smart growth plans	APA web site	State
UD6	Joint Land Use Study (JLU.S.)	JLUS Office	Installation
UD7	Proximity to MSA	U.S. Census Bureau	Installation
	TES Sustainability		
TE1	# TES in state	FWS	State
TE2	Species at Risk	JAWRA	watershed
TE3	Federally Listed TES by Ecoregion	NatureServe	Ecoregion
TE4	TES of Concern	NatureServe	Ecoregion
	Locational Sustainability		
LI1	Federally declared floods	FEMA database	County
LI2	Seismic Zones	USGS maps	Zone
LI3	Weather-related damage	NWS/NOAA	State
LI4	Federally declared disasters	FEMA database	County
LI5	Tornadoes	NOAA	County
	Water Sustainability		
WA1	Level of Development	JAWRA	Watershed
WA2	Ground Water Depletion	JAWRA	Watershed
WA3	Flood Risk	JAWRA	Watershed
WA4	Low Flow Sensitivity	JAWRA	Watershed
WA5	Water Quality	JAWRA	Watershed
	Economic Sustainability		
EP1	DoD Local Employment	www.bea.gov (REIS)	County
EP2	Job Availability/unemployment	Bureau Labor Statistics	County
EP3	Housing Affordability	U.S. Census Bureau	County
EP4	Poverty	U.S. Census Bureau	County

Issue	Indicator	Data Source	Data Level
	QOL Sustainability		
QL1	Crime Rate	NACJD	County
QL2	Housing Availability	U.S. Census Bureau	County
QL3	Rental Availability	U.S. Census Bureau	County
QL4	Healthcare Availability	HHS	County
QL5	Educational Attainment	U.S. Census Bureau	County
QL6	Commute Times	U.S. Census Bureau	County
	Infrastructure Sustainability		
TA1	Capacity of Comml Airports	TAF System	Installation
TA2	Airport Suitability-C5	FAA	Installation
TA3	Airport Suitability-C141	FAA	Installation
TR1	Railroad Capacity	FRA	County
TR2	Proximity to Interstate	IRRIS	Installation
TR3	Roadway Congestion	2002 Urban Mobility & FHWA	State
TR4	Traffic Volume	TTI & FHWA	State

Resource Capability Model

The Air Force developed the Resource Capability Model (RCM) to assess the adequacy or "readiness" of air, land, water, and spectrum resources to meet mission requirements at installations and ranges. The RCM has three purposes. These are to measure the adequacy of air, land, water, and spectrum to meet operational needs; quantify encroachment where present; and identify and measure resources potentially available to support additional mission (Rowe, Berger et al. 2004). The Army is also in the process of developing a version of RCM for its own application under a project through the AEPI (Dubrow 2004). This discussion specifically addresses the Air Force version, but the concepts and indicators are similar for the Army version with the addition of land-based training requirements. The RCM methodology is depicted in Figure 4-3.

Determining and articulating operational requirements is the first step in the methodology. For the Air Force, these needs or requirements are defined in the Ready Aircrew Program and in Command or base-level Air Force Instructions. These definitions drive the requirements for air, water, land, and spectrum resources to support testing and training.

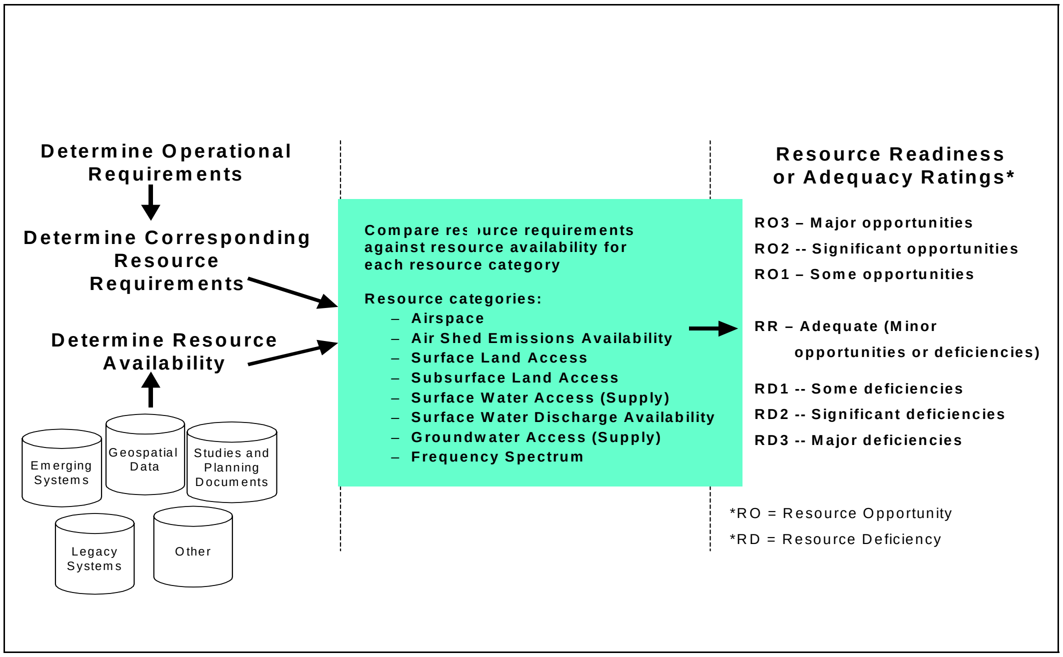

Figure 4-3. Summary of RCM methodology.

The second step in the methodology is to determine corresponding air, land, water, and spectrum resource requirements at a particular installation or range. Defining this link is critical. Without it, it is difficult for the Air Force to articulate a basis for the air, land, water, and spectrum resources it really needs.

The third step in the RCM methodology is to determine resource availability. The answer to this third step of the process requires information on resource conditions. The fourth step in the RCM methodology involves a comparison between required resources and available resources at an installation or range for a set of air, land, water, and spectrum resource categories. These resource categories (cf. the center of Figure 4-3) are: airspace, air shed emissions availability, surface land access, subsurface land access, water discharge availability, water access or supply, and frequency spectrum. The results of this comparison provide a resource readiness rating using a set of defined breakpoints. Resource readiness ratings (cf. the right side of Figure 4-3) include Resource Opportunity (RO) ratings 1, 2, and 3; Resource Deficiency (RD) ratings 1, 2, and 3; and a Resource Ready (RR) rating where available resources and operationally required resources are similar in quantity.

The resource ratings are indices based on a set of metrics or indicators. Table 4-2 summarizes the various metrics that have been developed for measuring the adequacy of air, land, water, and spectrum resources to meet operational requirements. In the case of airspace, there are five metrics (indicators). The first airspace metric is *Compatible Volume* and compares the total volume of a defined airspace unit to the volume remaining after the removal of avoidance/incompatible areas. The second airspace metric is *Time Volume Denied* and provides an indication of the amount of time that an airspace volume is not available to support flight missions. The third airspace metric is *Hours* and compares required hours to available hours. The fourth metric is *Distance* and compares the maximum desired distance to the airspace unit in question with actual distance. The fifth airspace metric is *Minimum Size Dimensions* and compares the total volume of calculated airspace for a specific type of training with the volume of airspace remaining after the removal of avoidance/incompatible areas in a specific airspace unit.

Table 4-2 lists three metrics for air quality, five metrics for land access, six metrics for water supply, four metrics for water discharge, and two categories of metrics for assessing the adequacy of frequency spectrum. One category of spectrum metrics focuses on required frequency assignments versus available assignments in the VHF and UHF bands as possible indicator bands for regional congestion. A second category of frequency metrics focuses on specific tactical and non-tactical bands that are subject to encroachment within and around Air Force facilities.

The RCM was pilot tested at ACC and AETC locations in November of 2002. Metrics used in each pilot test were applied to air, land, water, and spectrum resources at the installation, associated ranges, and multiple airspace units. Metrics used were understood and generally accepted as useful measures by participating organizations. Airspace data collection and resource adequacy measurement for the Minimum Size Dimensions airspace metric is not straightforward. Required airspace dimensions were developed by Fighter Wing staff for specific maneuvers such as Basic Surface Attack and Close Air Support. Airspace and surface land encroachments were identified and quantified at the installation and ranges. Water supply, water discharge, and spectrum resource opportunities were also identified and quantified.

Detailed instructions, metrics, and questions for applying the RCM have been developed. Most data used to assess the adequacy of air, land, water, and spectrum resources exist in base-level documents such as General Plans, Environmental Assessments, land use studies, and natural and cultural resource management plans. RCM is still a work in progress; much of its data is collected locally through surveys and interviews. RCM is a good resource for the indicators where it has been applied and will supplement other indicators and data from other resources. It includes some important operational metrics that are vital for sustainability assessment.

Table 4-2. Summary of metrics in the RCM.

Metric Type and Name	Brief Description
Airspace: Compatible Volume metric	Compares total volume of an airspace unit to the volume remaining after the removal of avoidance/incompatible areas (available volume).
Airspace: Time Volume Denied metric	Provides an indication of the amount of time that airspace is not available to support flight missions.
Airspace: Hours metric	Compares required hours for training (i.e., scheduled hours) to available hours for training in a specific airspace unit.
Airspace: Distance metric	Compares maximum desired distance to the airspace unit to actual distance to the airspace unit.
Airspace: Minimum Size Dimensions metric	Compares calculated airspace volume for a specific type of training (e.g., Air-Ground Basic Surface Attack) and Mission Design Series (i.e., F-16), and compares this calculated volume with available airspace resources as in the Compatible Volume metric.
Air Quality: Total Emissions Inventory metric	Quantifies the total air emissions availability based on Clean Air Act restrictions and compares this number with air emissions requirements that are based on Air Emissions Inventory.
Air Quality: Most Restrictive Emissions Unit metric	Evaluates emissions availability against the existing Title V operating permit and quantifies the emissions from those sources (i.e., Capital Emission Units) most highly “restricted” by the operating permit.
Air Quality: Attainment Classification metric	Identifies the degree of air quality degradation based on the attainment status for the district in which the installation is located.
Land: Current Off-Site Compatible Acres metric	Quantifies compatible and incompatible areas within off-installation or range noise and safety buffers. Evaluates current compatibilities and incompatibilities within operationally required areas.
Land: Projected Off-Site Compatible Acres metric	Quantifies future compatible and incompatible acres within off-installation or range noise and safety buffers. This metric evaluates projected future compatibilities and incompatibilities within operationally required areas for the time period of 5 years out.
Land: Developable Acres metric	Quantifies the degree to which land within the boundaries of the infrastructure asset are available for development, taking composite constraints from encroachment and other factors into account.
Land: Operational Acreage Adequacy metric	Quantifies the percentage of the undeveloped acres that are available for development taking into account various composite constraints from encroachment and other factors that would prevent or constrain development of the undeveloped acres.
Undeveloped Acres: Entire Installation metric	Quantifies the percentage of undeveloped acres within the installation.
Water Supply: System Capacity vs. Usage metric	Quantifies the current capacity of the water supply system and compares this to the current annual water requirements.
Water Supply: Constrained Month System Capacity vs. Usage metric	Quantifies the degree to which current water supplies are able to meet the current demand in the month with the most significant difference between water supply and demand.
Water Supply: Unconstrained Months metric	Quantifies the number of months where there is not a constraint on water supply.
Water Supply: Months Restricted metric	Quantifies the number of months where there is a restriction on water supply.
Water Supply: Quality metric	Quantifies the quality of the water available at the tap for consumption.

Metric Type and Name	Brief Description
Water Supply: Physical Supply vs. Usage metric	Addresses that status of the water supply in the geographic area to help ascertain whether additional activities at the infrastructure asset are likely to tax water resources.
Water Discharge: Wastewater Volume Capacity vs. Discharge metric	Quantifies discharge volumes and compares them to discharge system capacity based on an average in gallons per day.
Water Discharge: Overflow Frequency metric	Evaluates the frequency of overflows of the wastewater and storm water systems.
Water Discharge: Water Quality Discharge metric	Evaluates the quality of the discharge relative to regulatory or permit limits.
Water Discharge: Receiving Body Water Quality metric	Evaluates the quality of the watershed where the installation is located relative to the local or state water quality standards.
Frequency metrics	Measures spectral congestion specifically within the VHF (162–174 MHz) and UHF (406.1–420 MHz) bands and specific military target bands that are subject to congestion within and around Air Force facilities.

Environmental Climate Model

The U.S. Army Environmental Center (USAEC) developed the Encroachment Condition Model (ECM) to assess demographic and environmental conditions in support of the Office of the Deputy Chief of Staff for Operations and Plans (DAMO-TR) task to analyze the relative training value of Army installations. That effort is known as the Installation Training Capacity (ITC) model. The ITC determines the relative capability of the installations studied to support live training by Active and Reserve Component units stationed at, or regularly training on, those installations while incorporating the live training requirements of Service Schools on those installations. The ITC assessments focus on land, ranges, training facilities, and demographic/environmental factors affecting training. The studies do not consider other installation capabilities such as cantonment area facilities, infrastructure, and housing.

The ECM is a methodology used by G3 to assess land and resources for training mission sustainability in the Army. Initiated in 1997, EMC has since supported HQDA in several ways. It was used as “database of record” to support initial and follow-on Interim Brigade Combat Team Stationing Decisions. It proved capability to handle multiple *what-if* scenarios. EMC supported the U.S. Army Forces Command (FORSCOM) War-fighting Center (Mobilization) Studies and provided input and analysis to Quadrennial Defense Review (QDR). Finally, EMC provided input to Objective Force (OF) Stationing Analysis.

Stated goals of the ECM are to identify and evaluate: (1) environmental issues that impact training; (2) encroachment issues that impact training; (3) impact of costs to maintain land for training; (4) environmental ability of the land to support and sustain training; and (5) capability of the installation to expand or reconfigure to support training.

In 2004, the ECM's methodologies were reshaped to highlight the training focus. In the original methodology, there were 15 key environmental and demographic factors (e.g., air quality, water, noise, land withdrawal, population densities, etc.) considered important and applicable to the ability of the installation to sustain readiness that were given a point value specific to an installation based on collected data. The point values were then totaled to give an overall sustainment score—the higher the score the better.

However, shortcomings of the original methodology were identified as: (1) not training focused; (2) it captures environmental conditions on installations, but not the extent to which they impinge on training; (3) statistical analysis of the ISR data which feeds current ECM reveals that observer bias in likely; and (4) scoring breakdown is subjective in its score weighting. Therefore, a modified methodology focused on training analysis was articulated—making ECM a GIS-based tool with quantifiable output, which will measure a given training restriction/land area/number of days for a given environmental factor driving the restriction.

The interface first displays the potential impacts on training present at a give installation. These identified impacts are often identified using the 15 key environmental and demographic factors set-up by the original methodology. The potential impacts are then overlaid in a graphical format and through a set of formulas used to assess impacts on current training (Figure 4-4). The result is an effective way to support the installation training capacity model. Because its focus on training is highlighted, it captures both the environmental conditions on installations and the extent to which they impinge on training.

The new methodology incorporates much of the previous method. There is still a centralized data collection where government-reported data and installation observations are gathered and incorporated into existing data layers. The data collection process is not automated. Therefore, information gathering and updating requires significant time and financial costs. As a result, the data is not always current—there is a lag in collecting and uploading new data. Additionally, there are difficulties in working with different GIS program maturity levels at the various installations. Despite these limitations, one of the greatest benefits of the ECM project is the continual advance that the project team strives for. With each study installation, the team issues reports on the key environmental and demographic factors that detail the ECM applied methodologies. It is from these methodology reports that other studies can benefit. The most recently issued report (2004) addresses population projections.

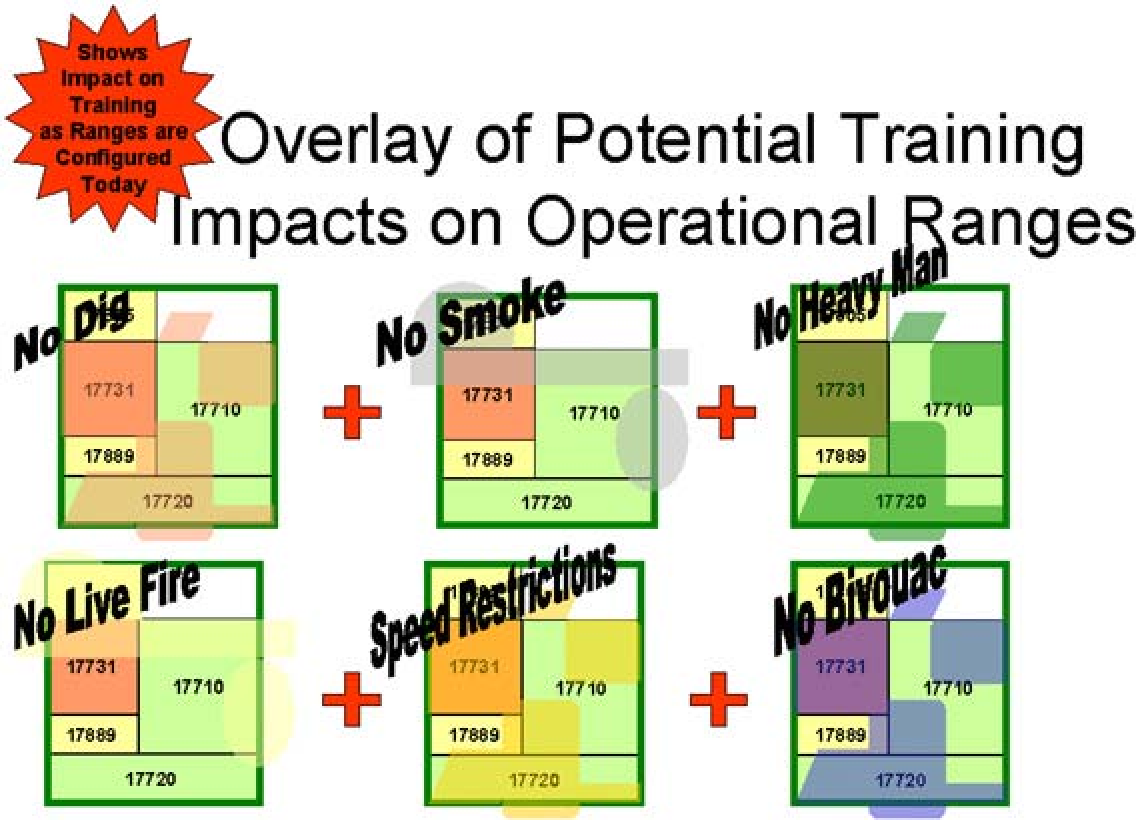

Figure 4-4. Overlay of potential impacts.

The installations studied are assigned to the following commands:

- U.S. Military Academy
- Army Training and Evaluation Command
- U.S. Army Forces Command
- U.S. Army Training and Doctrine Command
- U.S. Army Pacific
- Military District of Washington
- Army Materiel Command
- U.S. Army Medical Command
- National Guard Bureau
- U.S. Army Reserve Command (USARC).

The consideration of Army National Guard (ARNG) installations is to identify only the largest installations with potential for accommodating some of the Active Component (AC) live training requirements. However, the ARNG and USAR training loads habitually executed on AC installations are considered in the ITC.

In FY05, the ECM was renamed as the "Encroachment Condition Module." Beta tests at Fort Pickett and Fort Riley were scheduled for the 4th quarter of FY05. Other applications of ECM are scheduled through FY08.

Training Center Sustainment Initiative

The 2002 Defense Authorization Act, required a comprehensive assessment of unexploded ordnance, discarded military munitions, and munitions constituents located at current and former defense sites. To support this requirement, the ARNG is conducting an assessment of the environmental vulnerabilities at its Training Centers entitled Training Center Sustainment Initiative (TCSI). The goals of TCSI include providing Installation Commanders an environmental sustainment profile of their installations as well as the ability for ARNG to prioritize Training Centers based on environmental vulnerabilities (Church and Ahn 2003).

The areas of focus were based on the sustainment considerations listed in the October through December 2000 Quarterly Readiness Report to the Congress and on the unique challenges of ARNG Training Centers. The considerations include water resources, urban growth/encroachment, threatened and endangered species (TES), air quality, noise, and other areas important to the sustainability of an ARNG Training Center.

Data to support the assessments were collected from Army and NGB databases as well as Range Development Plans, ICRMPs, INRMPs, and GIS sources. The information used from these sources includes the type and volume of munitions fired at each Training Center, the constituents contained in those munitions, hydrogeology; soil, rainfall, vegetation, TES, noise, encroachment, and regulatory compliance status. The system will consolidate the data and store it in a data warehouse that will provide query and report capabilities. The system will also provide ranking models that overlay operational activities on the environmental profile. The ranking models will allow ARNG's decisionmakers to prioritize resources to ensure the sustainability of the Training Centers. The applicable data to support the queries and sustainability evaluations will be displayed on GIS maps.

To assist with the development of the TCSI, ARNG contracted Weston Solutions, Inc. through the U.S. Army Corps of Engineers (USACE), Tulsa District. TCSI evaluates range sustainability data for 123 ARNG Training Centers. The main task of TCSI's development was to compile Training Center data into a central data management system to facilitate evaluation of Training Center information with respect to environmental, safety, installation, and training issues.

TCSI will provide a central point of access for information relevant to Training Center sustainability. More than 180 data fields have been identified to support the needs of TCSI.

Once all available data is assimilated from the reports and databases into the data warehouse, the information is stored in WebCAS—a query-supporting interface. Without the centralized data management warehouse provided by TCSI, it would be very difficult for ARNG to identify the challenges for the Training Centers since most of the data currently resides in various sources, including both electronic and hardcopy formats. The query interface will provide the user a means of retrieving a dataset from WebCAS using multiple criteria. The user will see the results of the query, the source references associated with each data point, and a calculation of percent complete for each data field, i.e., for what percentage of Training Centers does TCSI have data for that query. The interface will also allow the user to view GIS data for a particular Training Center via a link to ARNG's Arc-IMS server. The ASIP information regarding Unit location will be available on GIS. For example, a user may run a query for the number of ranges with wetlands on them. The result may show 400 ranges and the associated Training Centers. The result would also show whether or not TCSI has wetland data for all Training Centers. The query result could say the data set is 98 percent complete with wetland data missing from three Training Centers (and list the three Training Centers).

TCSI will also support ranking models. The models will be developed to evaluate the following sustainability categories: urban growth and encroachment, water resources (hydrogeology), threatened and endangered species, air quality, noise, unexploded ordnance (UXO) and munitions constituents, maritime restrictions, airspace restrictions, regulatory violations, outreach, and cultural resources. Determining the environmental setting for a particular category uses a decision tree based on a series of questions. These questions are expanded versions of the query system already developed for TCSI. The setting and dataset queried includes features of the Training Center that to a certain extent cannot realistically be changed. Using the Water Resource category for an example, some of the data from the query system that would be included in the decision tree would be type of aquifer, aquifer depth, soil type/permeability, proximity of a range to surface water, and rainfall. Each series of questions in the decision tree will lead to an endpoint that provides an overall assessment of the Training Center's environmental setting. The endpoints will be ranked numerically from highest level of vulnerability to lowest. The number associated with a Training Center's endpoint will denote the environmental setting vulnerability of the Training Center for factoring into the ranking methodology. The endpoints will also be assigned a risk level of high, medium, or low based on the defined risk levels.

Mitigation measures already in place at a Training Center are expected to be considered in the overall evaluation. If a Training Center ranks very high in a category, yet the Training Center has already taken steps to mitigate the potential impacts, then the ranking methodology must give the Training Center credit. Accounting for mitigation in the ranking system will help ARNG decisionmakers determine where to provide funding resources to assist highly vulnerable Training Centers. If a Training Center already has effective mitigation in place, then it should not rank as high as another Training Center with an equally vulnerable situation that has no mitigation measures in place. Therefore the Training Center that has no mitigation in place will have a higher likelihood of receiving the resource allocation it needs. Mitigation measures will be specific to the sustainability category. Some types of mitigation might include groundwater treatment systems, subsurface barriers, surface water runoff diversions, endangered species management programs, etc. Mitigation options will be counted as either "Yes the Training Center has them for the sustainability issue," or "No they do not." If a Training Center has Mitigation marked as "Yes," then that Training Center ranking would drop from the risk category initially assigned to a lower risk category. By factoring in the mitigation score, a more realistic score for a Training Center will be produced that accounts for the vulnerability and gives credit for Best Management Practices (BMPs).

To score a Training Center for a Sustainability Consideration, the TCSI will multiply the endpoint score from the Decision Tree (environmental setting) by the total combined score for the operational activity. This value will determine the overall high/medium/low vulnerability score. The use of mitigation measures by a Training Center will then be considered and the vulnerability score will be adjusted to a lower category on the high/medium/low scale, if applicable. If there is no mitigation for a particular Training Center, then the vulnerability score and high/medium/low ranking will be the final score. The final numeric score for each Training Center will be used to rank the Training Centers. Each Training Center will be ranked for each Sustainability Consideration.

TCSI is a work in progress. Its multi-phased approach to managing environmental data allows the combining of all available resources to ARNG into one data storage warehouse and provides the information in a format suitable for running dataset queries and producing reports. It also supports a ranking methodology for specific sustainability challenges that will allow ARNG decisionmakers to determine how to manage their resources to best maintain the readiness of its Training Centers.

Strategies and Programs

Joint Land Use Study Program

In the mid-1970s, the DOD established several programs in response to existing and potential threats of incompatible land development compromising the defense missions at military installations. These programs are designed to promote compatible development on and off military bases. The initial programs include noise propagation studies of military activities to delineate on- and off-base areas most likely to be affected by unacceptable noise levels and the identification of aircraft landing and take-off accident potential zones that often extend off a base and into the neighboring community.

In 1985, Congress authorized the DOD to make community planning assistance grants *(Title 10 U.S.C. Section 2391)* to state and local government one of the programs to help better understand and incorporate the Air Installations Compatible Use Zones and Environmental Noise Management Program technical data into local planning programs. The Office of Economic Adjustment manages the program called Joint Land Use Study (JLUS).

The JLUS process is a cooperative land use planning effort between the affected local government and the military installation. The study is developed by the local municipal authority(s) with installation participation in the effort. The recommendations contained in the study present a rationale and justification for providing a policy framework to support adoption and implementation of compatible development measures designed to prevent urban encroachment; safeguard the military mission; and protect the public health, safety, and welfare. JLUS implementation measures may involve revisions to community comprehensive plans and traditional land use and development controls, such as zoning, subdivision regulations, structural height restrictions, and promotion of planned unit development concepts. Additional actions may include amending local building codes to require increased sound attenuation in existing and new buildings, land exchanges, and transfer of development rights, and real estate disclosure.

Smart Growth Programs

Incompatible residential and commercial development of land close to military installations can affect the ability of an installation to carry out its mission. Such development also threatens public safety because accidents sometimes occur in the areas surrounding an installation. The economic health of a community is affected if military operations and missions must relocate because of urban encroachment. States and local governments have begun to take actions to prevent encroachment and more measures are likely with heightened concerns about national security and economic health.

Some states are encouraging compatible land use around their military installations by having local governments: (1) anticipate future urban growth patterns and create a strategic land-use plan that prevents encroachment near military installations, and (2) establish high noise and accident potential zones near military installations and develop zoning codes that support compatible development of land located within these areas.

Part of the American Planning Association's (APA's) Growing Smart Program launched in 1994, State Smart Growth Plans encompass the planning, design, development, and revitalization of cities, towns, suburbs, and rural areas to create and promote social equity, a sense of place and community, as well as to preserve natural and cultural resources. The Smart Growth initiative helps states modernize statutes affecting planning and the management of land-use change. The first phase of the program focused on state and regional planning and the relationship and responsibilities that exist among state, regional, and local planning efforts. The second phase resulted in model legislation dealing with local planning including planning agency and planning commission structure, plan preparation, and the integration of state environmental policy acts with local planning. The third phase provides communities and states with model legislation for the implementing tools communities need to manage change (Johnson, Salkin et al. 2002). The presence of a state smart growth plan is important because smart growth legislation can reduce sprawl and decrease the growth of urbanized land surrounding a military installation. The potential encroachment caused by sprawl and urban development can affect the type and intensity of training that can take place on the installation.

The Growing Smart Directorate provides assistance to APA with this program and is composed of individuals appointed by the country's major organizations that represent elected officials. Included are representatives of the Council of State Community Development Agencies, National Conference of State Legislatures, National League of Cities, National Association of Counties, National Association of Regional Councils, National Association of Towns and Townships, and U.S. Conference of Mayors. In addition, the Directorate includes several members-at-large who represent the built and natural environments and local government law.

A handful of states have risen to meet the challenge of urban encroachment. For instance, some states have passed legislation that established high noise and accident potential zones near military installations and developed zoning codes that support compatible development of land located within these zones. Other states want local governments to anticipate future urban growth patterns and create strategic land-use plans that prevent encroachment near military installations.

Alternative Futures Studies

Alternative Futures Studies were a set of studies undertaken by the Harvard University Graduate School of Design and funded by the DOD Legacy Resource Management Program. Study areas included the Camp Pendleton region in California (Steinitz, Adams et al. 1997) and the Upper San Pedro River Basin in Arizona and Sonora (the region around Fort Huachuca) (Steinitz et al. 2003). The projects developed a set of future management and policy options for specific regions based on different assumptions providing an effective mechanism to examine possible outcomes and their benefits and consequences. The alternative futures for the Camp Pendleton area explored urban growth and change in the rapidly developing region located between San Diego and Los Angeles, California, at four scales: the region as a whole, the Temecula Valley, a new urban center, and five typical sites. The pressures created by the trend of urbanization were described and proposals for alternative conservation and design strategy developed. The report also outlined some important costs and benefits and offered suggestions for implementation. Alternative futures for the San Pedro River Basin defined future scenarios in the form of land-use/land-cover grids that were examined relative to their impact on surface-water conditions such as surface runoff and sediment yield. These hydrological outputs were estimated for the baseline year of 2000 and predicted 20 years in the future. This work provided a demonstration of how new geographic information system-based hydrologic modeling tools can be used to evaluate the spatial impacts of urban growth patterns on surface-water hydrology.

Cooperative Agreements and Conservation

Land use planners have long understood the need for consolidated planning across political boundaries. Collaborative interaction between adjacent land managers predates the U.S. Constitution; however, tools necessary to support Federal missions and natural resource conservation requirements across public-private land mosaics are increasingly ineffective. The nation's modern regulatory and resource constrained climate increasingly confounds this cooperation. A new tool that has been proven effective in joint land management is a cooperative agreement that was signed in 1995 by Fort Bragg, NC, The Nature Conservancy (TNC), and the U.S. Army Environmental Center (USAEC). The agreement enables cost-sharing the acquisition of conservation encumbrances in the vicinity of Fort Bragg. Conservation encumbrances are defined as fee simple land purchases by TNC or the purchase of perpetuity deed restrictions by TNC (Farley and Belfit 2001). All acquisitions are made with willing sellers and based on fair market value of the acquired assets. All acquisitions have provisions for low impact soldier access to the conserved lands. While most bioregional planning is by nature highly crafted to meet specific local requirements, lessons learned from this project are instructive. In this case, both encroachment by incompatible development in the vicinity of a military installation and training restrictions due to environmental compliance are being reduced. Under limited circumstances, this tool can provide long-term security for military missions and declining natural resources.

Military and Agricultural Economic Security in Eastern North Carolina: A Partnership Initiative

In April, 2004 the Golden LEAF Foundation awarded a grant of $250,000 to The Conservation Fund and a number of partner organizations to undertake a comprehensive project using conservation tools and techniques to help low- and moderate-income farmers and landowners increase income-producing potential from their lands, while also reducing the threat of encroachment around military bases and in "flyover zones." This 18-month project has been designed to leverage conservation dollars and programs to meet integrated economic and environmental needs in 42 counties that affect and/or depend heavily on military jobs; to help farmers strengthen their operations and "mine" the resources available through state and Federal conservation programs; and to identify state policies that will leverage agricultural and military jobs and economic benefits through protection of working farms and forests (Sager 2004).

Low-and moderate-income and minority farmers and landowners are at greatest risk of losing lands to development. In some cases, lands are lost due to inability to pay property taxes. In others, increasing farm operation costs and decreasing commodity prices have drastically reduced agricultural revenues. Many African American-owned lands, in particular, are in fractionated ownership or "heirs property" status and at dramatically increased risk of being lost through partition sales. The USDA documented in 1997 that, nationally, over 9,000 acres of African American-owned farms are being lost every week. A high number of landholdings around North Carolina's military bases and in flyover zones are owned by low- and moderate-income and minority landowners, thus increasing the chances of encroachment and reduction of efficiency in military operations.

While many of those lands are eligible for funding and other support through state and Federal conservation programs, the landowner populations are not typically targeted by conservation interests because of the smaller size of their landholdings. This project was designed to help landowners connect with funding, technical assistance, and other resources, so the lands can be protected from development, and meet both the landowners' needs for income and the military's needs for open space.

Project partners include The Conservation Fund, Land Loss Prevention Project, Sandhills Family Heritage Association, Black Family Land Trust, Georgetown Renaissance Community Association, NC Department of Environment & Natural Resources, NC Department of Transportation, and the NC Department of Agriculture. The three primary components of the project are: (1) mapping and identification of low- and moderate-income and minority farmers and landowners; (2) outreach, education, and technical assistance to targeted farmers and landowners; and (3) policy research and analysis.

5 Regional SSA Demonstration Site

The Sandhills fall line ecoregion stretches from Alabama across Georgia into the Carolinas, just below the Piedmont. These lands share ecosystem management issues, including management of Federally endangered species such as the red cockaded woodpecker and the perceived need for restoration of forest and wetland ecosystems. The Sandhills ecoregion (shown in Figure 5-1 in yellow) was defined using Ecological Units of the Eastern United States—First Approximation, published by the U.S. Department of Agriculture (USDA) Forest Service.

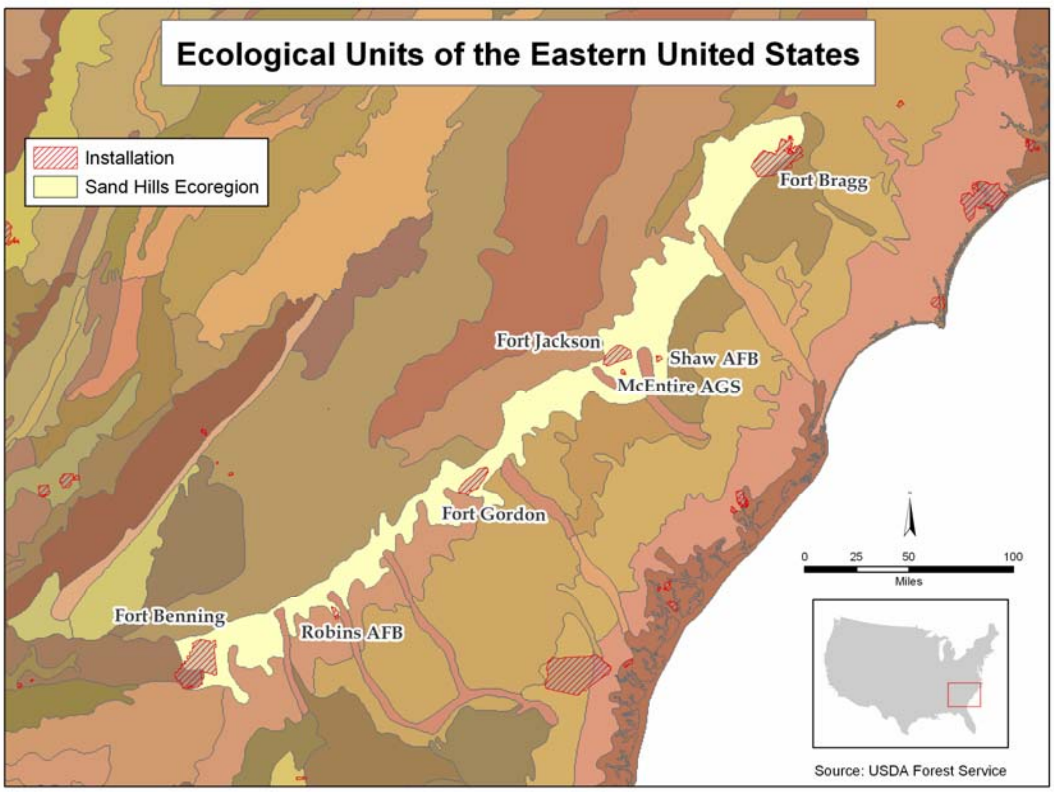

Figure 5-1. The Sandhills fall line ecoregion.

Federal installations in the region include Fort Benning, Robbins AFB, and Fort Gordon in Georgia; the DOE Savannah River Site (SRS), Fort Jackson, and Shaw AFB in South Carolina; and Fort Bragg in North Carolina. Surrounding metropolitan areas include Atlanta and Savannah, GA, and Charlotte, NC (Figure 5-2).

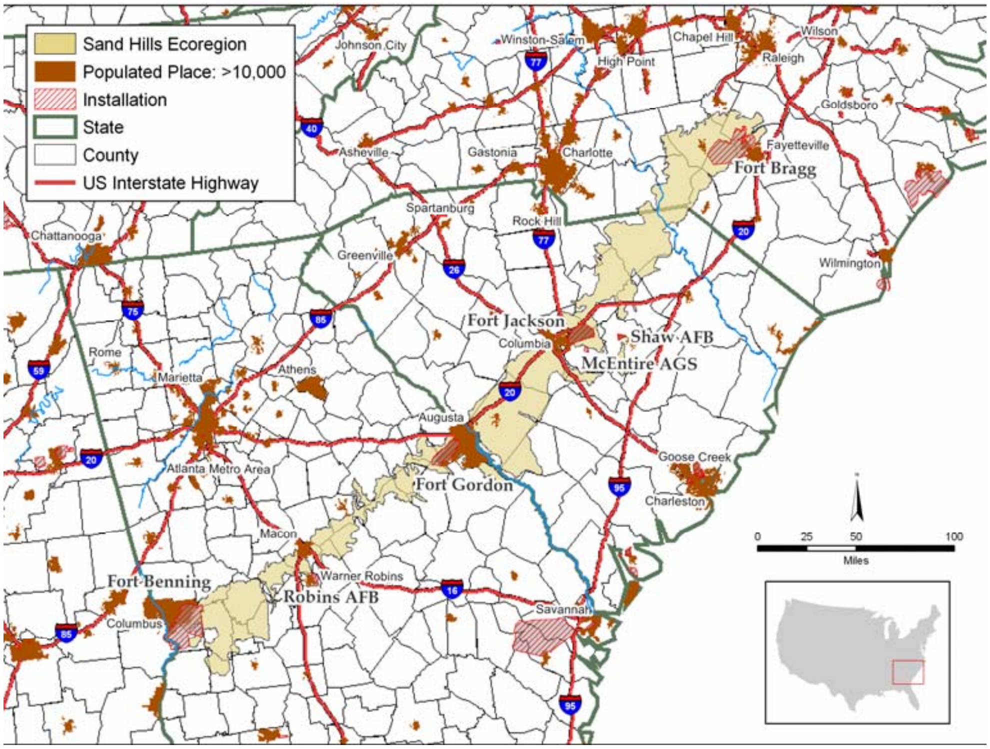

Figure 5-2. The Sandhills ecoregion extends from Alabama into North Carolina; nearby metropolitan areas include Atlanta, Charlotte, and Savannah.

Southeast Regional Issues

The Southeast has grown rapidly over the last several decades; its population increased by more than 30 percent between 1970 and 1990. Much of this growth occurred in coastal counties, which are projected to grow by another 40 percent between 2000 and 2025. The number of farms in the region decreased 80 percent between 1930 and 1997, but the Southeast still produces roughly one quarter of U.S. agricultural crops. The Southeast also produces about half of America's timber supplies. The region also produces a large portion of the nation's fish, poultry, tobacco, oil, coal, and natural gas. Roughly half of the remaining wetlands in the lower 48 states are located in the Southeast, and more than three quarters of the Nation's annual wetland losses over the past 50 years occurred in this region. Despite having much of the landscape altered over the last century, a wide range of ecosystem types still exists and overall species diversity is high (National Assessment Synthesis Team 2000).

The Southeast is prone to frequent natural disasters. Over half of the nation's costliest weather-related disasters in the past 20 years have occurred in the Southeast. The impact climate change will make on the region in the next 25 years is difficult to assess. Some key issues are evident and will have nearer term impacts. These range from intensified sensitivity to El Niño (increased rainfall) and La Niña (increased droughts) effects to coastal impacts of rising sea level and salt water contamination of forest soils. Increased flooding is expected in the low-lying coastal areas from the Carolinas to Texas. Projected increases in maximum temperatures and heat index will lead to human health concerns and greater energy demands for air-conditioning. The major crop growing areas of the lower Mississippi Valley and Gulf Coast are likely to be more negatively affected, while the northern Atlantic Coastal Plain is likely to be more positively affected. Drought cycles may also play a role in area-wide impacts.

Surface water resources in the Southeast are intensively managed with dams and channels, and almost all are affected by human activities. Currently some streams and lakes have water quality that is either below recommended levels or nearly so. These stresses on water quality are associated with intensive agricultural practices, urban development, coastal processes, and mining activities. The impacts of these stresses are likely to be exacerbated by projected climate change. For example, higher temperatures reduce dissolved oxygen levels in water. Extreme precipitation events—the frequency of which are likely to continue to increase, lead to flood waters fouled with sewage, rotting farm animal carcasses, fuel, and chemicals swamping water treatment plants and contaminating public water supplies.

Current Regional Research Efforts

This region already has considerable efforts underway to understand, characterize, and catalog the ecological data available. The Strategic Environmental Research and Development Program (SERDP) funds an effort focused on addressing science and technology requirements for ecosystem management at DOD military installations. This project, entitled the SERDP Ecosystem Management Project (SEMP), is currently hosted at Fort Benning, GA. Websites that contain data and information about the project are available through URLs:

https://www.denix.osd.mil/denix/Public/Library/SEMP/semp.html
http://www.cecer.army.mil/KD/SEMP/index.cfm?chn_id=1063

A related ERDC initiative is the Ecological Characterization and Monitoring Initiative (ECMI) which works with the host installation to gather, assess, and document historic and current ecological data sources and monitoring efforts. A second initiative, the Data Repository, stores information on all the characterization and monitoring efforts in a common data repository. All teams and the installation managers share this data.

The SEMP Data Repository is an important part of the SEMP project plan, and is designed specifically to provide data access and exchange among the SEMP study partners and serve as a stable, long-term data archive mechanism to protect the SERDP investment. It has been operational since the end of FY 2000. The conceptual design for the SEMP repository is simple and functional. Contents are planned to include:

1. Baseline GIS data of Fort Benning and the surrounding area
2. Digital imagery of Fort Benning and surrounding area (digital orthoquads, satellite imagery, etc.)
3. ECMI monitoring data (e.g., ECMI meteorological weather station data and hydrologic surface water data, etc.)
4. SEMP research project data. As the individual SEMP research projects continue, contributions to the repository will include their field data, analysis results, and model output from the research teams.

A related study, funded by SERPD, is studying urban dynamics in the immediate vicinity of Fort Benning. Research teams from ORNL, University of Florida, University of Illinois, University of Georgia's Savannah River Ecology Laboratory, and ERDC are working at Fort Benning, collaborating on strategies for selection of research sites, sharing common review forums, and contributing data into a common data repository. These research projects are designed to provide knowledge, tools, and techniques to enhance sustainable mission use and stewardship of military installation and to contribute to understanding and enhancing the ecological role of military installations within their ecoregions.

Historical population growth rates are expected to continue in the area and environmental stresses and impacts will continue. This region, with its common ecological issues, high number of military and Federal lands, and readily accessible data is an ideal test bed for the proposed strategic sustainability assessment methodologies to be developed and tested.

Scenario Development

Meeting the project goals and methodology requires the development of three major scenarios and several unique and localized scenarios. The overall project needs to be bounded by two scenarios labeled "status quo" and "desired future."

Modeling the Sandhills region in its entirety presents a challenge. Developing scenarios that project future impacts of the key stressors over a 20- to 30-year period requires restricting the modeling to sub-regions of the study area. Scenarios require specific input drivers and defined assumptions and must meet the following criteria to be considered for the project:

- Required data is available and readily accessed.
- Scenario is plausible and a forecast can be made.
- The scenario is relevant to the region.
- Outcomes have potential mission impact.
- Linkage to operations plans can be made.

The status quo scenario is a temporal and spatial projection of land use changes and impacts in the region over the next 25 to 30 years based on business as usual assumptions. The entire Sandhills ecoregion will not be modeled. It is planned to model the areas around Fort Benning and Fort Bragg using the LEAM model. The scenario assumes the completion of the fall line highway (which is already complete from Columbus to Macon). If time and resources permit, the status quo modeling will also be done for the areas around Macon, GA, Augusta, GA, and Columbia, SC. Population projections will be based on local projections and development patterns of the present will be assumed to continue. This methodology will provide land-use change patterns. Based on the changes in land-use, impacts will be developed. These include demands for water and energy, automobile density and use, water quality changes, and habitat disruption.

Three additional scenarios will also be undertaken. The first will model the Columbus, GA, area to determine impacts of the planned plus up at Fort Benning of 6,000–10,000 soldiers. Current plans call for an increase of 5,490 troops along with 3,686 spouses and 6,634 children starting in 2006. Most will live off-post and impact the local communities. Additional troops may be added later as installations in Europe are closed. The scenario assumes additions in 2006, 2007, and 2008. The economic impact is expected to be an additional $600 million by 2006. This economic modeling will be linked into the LEAM model to provide land-use impacts based on change dynamics.

The second additional scenario will consider the greater regional growth and development north of the Sandhills region of Georgia including the counties south of Atlanta. This scenario will incorporate the expected development expansion to the south from Atlanta and provide a scenario basis for evaluating air quality in the region over the next 25 years. The land-use change and economic growth scenario will provide input to the USEPA's Economic Growth Analysis System (EGAS), version 4.0, for an estimate of air quality impacts in the region (E.H. Pechan & Associates 2001). Information and modeling from the Fall line Air Quality Study (FAQS) will also inform the scenario (Russell, Odman et al. 2001).

The third additional scenario will consider abrupt climate change in the region associated with a breakdown of the thermohaline ocean conveyer system. The scenario will assume an average annual temperature drop of 5 °F from 2015–2025. Associated with this will be persistent drought throughout the southeastern United States. The impacts on the watersheds will be evaluated.

The desired future scenario will be developed based on research and the results from future workshops and meetings. The scenario will be the basis for determining the gaps between the desired state and the projected state. Backcasting techniques will then be used to determine policy and implementation requirements to achieve the objectives desired in the future state.

The desired future for the Sandhills Ecoregion is based on increasing sustainability with respect to the objectives or key outcomes defined in the key forces and issues schema. The key objectives are air, water, and biodiversity. The set of drivers or exogenous variables that impact these outcomes are population and land-use change, energy resource issues, and climate change. The end state objectives defined below are in terms of the environmental outcomes desired. These are intended to comply with the Army Environmental Strategy and take into account local stakeholder desires. Strategies to achieve them are determined using backcasting technique to consider the range of actions within and between human and natural systems over time that avoid or respond to the undesirable aspects of the given scenarios.

Environmental Sustainability Objectives for the Sandhills Ecoregion

A set of sustainability objectives was developed by reviewing Fort Bragg's sustainability program with its surrounding communities. Objectives are:

- *Air* – Air quality throughout the region meets ambient standards year-round with no exceptions, and there is no degradation from present ambient quality where standards are exceeded. The air is colorless, odorless, and pesticide free. Industry and power plants meet or exceed source performance standards.
- *Water* – Water is plentiful, meets standards, and natural systems are healthy. Watersheds meet standards, wetlands are protected and increased, and stormwater is treated and handled throughout the region by natural means that enhance ground water replenishment and watershed health.
- *Biodiversity* – Biodiversity is increasing, habitat is maintained and growing, TES are recovering, no new species added to TES list, ecological patches are connected through a system of greenways, and public lands are maintained without pesticides.

6 Conclusions

Today's military installations are often the catalyst for actions and developments occurring "outside the fence." The Army recognizes that military installations do not exist or operate in isolation; they must comply with environmental laws and regulations, and coexist with nearby urbanized (or urbanizing) areas. The combination of factors—new environmental laws and nearby urban development—creates significant pressure to alter land-use practices on military installations. These "encroachment" issues, which consist of the many pressures that limit the military use of land, air-, and sea-space, can affect an installation's sustainability by seriously restricting, and in some cases shutting down the training ability of an installation.

The Strategic Sustainability Assessment (SSA) project will use a variety of models and research tools for strategic analyses to provide the Army with a fact-based visualization of future trends and issues critical to maintaining installation sustainability. The envisioned product is a series of ongoing, regular studies and reports that focus on specific regions or issues that enable the development of implementation plans and concepts for the Army Strategy for the Environment. This project defined and analyzed key issues, outcomes, and trends related to SSA as it applies to Army installations over a 20- to 30-year time horizon. The key issues identified in this work were: demographics and land-use change, climate change, and energy resource issues. While these key issues are interrelated and complex, the primary drivers for most encroachment and environmental issues in and around our military installations are population growth and land-use change. Specific outcomes addressed here include: air quality, water quality, and biodiversity.

Trends of increased resource consumption and destructive land-use make regions less habitable, deplete natural capital, destroy nature's ability to create renewable resources, and deplete the available stock of nonrenewable resources. Environmental problems that stem from resource consumption are now becoming critical worldwide issues. Development patterns and population dynamics increasingly pressure habitat and aquatic ecosystems, and contribute to high energy consumption. Urban development often results in trends of land-use change (e.g., deforestation) and high energy consumption, which can both have major effects on the carbon cycle, resulting in global climate change, loss of biodiversity, and consequent regional impacts.

Serious consideration must be given to defining a more sustainable path for military installations, and for the nation as a whole. In general, most societies tend to deal with environmental issues on a local basis and improve their immediate surroundings. Military installations are part of the regional landscape; their sustainability and operational flexibility are subject to the regional development and ecoregional impacts.

Significant progress has already been made in developing the tools and concepts to approach these complex regional scale problems (Chapters 2 and 3). A fact-based visualization of issues and trends will allow the Army to see the future in terms of those issues that are critical to sustainability. Determining the desired end state and backcasting to the present will provide guidance for policy change and adaptation to future trends. The variety of models and research tools available will provide ongoing analyses (via a series of ongoing, regular studies and reports focusing on specific regions or issues) that will enable the Army to achieve and maintain sustainable installations. This process will also result in several beneficial byproducts, e.g., partnerships with organizations also working on sustainability, as well as creating opportunities for further dialogue with internal and external stakeholders.

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Appendix A: Existing Land-use Change Resources and Tools

The DOD is not the only entity addressing environment and land management issues. Encroachment, in nature, is two sided. Both public and private sectors are struggling with the negative aspects of urban sprawl, increasing spatial constraints, and decreasing resources. A number of private consulting corporations, research institutes, and foundations have focused their efforts on land use sustainability. Some organizations merely provide guidance and collect or conduct research and host workshops. Others have developed their own processes and methodologies to address the issues. Information sources are available to both public or private entities. The following sections describe major information sources.

Information Resources

Growing Smart

Information Resource: APA Growing Smart Working Papers
Developers: American Planning Association
Web Site: http://www.planning.org

APA's Growing Smart project has resulted in a collection of useful information on growth and the management of change in U.S. communities. Included is some of the finest and most advanced thinking on legislative reform in the U.S. Topics include: (1) regional tax-base sharing, (2) the role of the governor in state land-use reform, (3) state and regional roles in transportation and land use judicial review of land-use decisions, (4) interstate compacts and affordable housing, (5) state and regional fair-share housing planning, (6) developments of regional impact, (7) areas of critical state concern, and (8) accommodating home rule in state land-use reform.

EconDate.Net

Information Resource: EconData.Net
Developers: Andrew Reamer
Web Site: www.econdata.net

EconData.Net is designed to help practitioners, researchers, students, and other data users quickly gain access to relevant state and sub-state socioeconomic data. The site aims to be a convenient, comprehensive first stop for anyone searching among the vast, disparate array of public and private data sources on the Web. EconData.Net is sponsored by the Economic Development Administration as a service to regional data users, and is jointly operated by Impresa, Inc. and Andrew Reamer & Associates, independent economic development consulting firms.

EconData.Net is divided into eight parts: (1) links by subject, (2) links by provider, (3) what's new, (4) 10 best sites, (5) data collections, (6) quick links, (7) registration, and (8) user's guide.

LUCAS Library

Information Resource: Land Use and Community Alliance Service (LUCAS Library)
Developers: Pace University School of Law
Web Site: http://www.pace.edu/lawschool/index.html

The LUCAS library provides more than 4,000 pages of material produced by the Land Use Law Center to help community leaders and experienced land-use practitioners balance the needs for economic development with environmental protection.

SD Tool Kit

Information Resource: Sustainable Development Tool Kit
Developers: The Florida House Institute—John Lambie
Web Site: www.i4sd.org/toolkit.htm

The Sustainable Development Tool Kit is a set of collaborative processes to support vision-based planning and community development that have resulted from work in communities. The processes work in conjunction with GIS and place-based planning and decision support tools to aid communities in developing and implementing consensus-driven sustainable development. The tool kit is based on the philosophy that the opportunity to get the future we want depends on understanding of whole systems, and the capacity to act on that knowledge. The tools were developed to facilitate the processes of teaching, learning, taking the action, and measuring progress. It is a process of continuous improvement where each new project in a community contributes to the desired future, turns resistance to change into market, and creates local economic opportunity. The toolkit is designed to help provide a means for bottom-up civic participation in the planning and development process to create a blueprint for sustainable economic development.

Smart Growth Network

Information Resource: Smart Growth Network website
Developers: Sustainable Communities Network and CONCERN, Inc.,
Web Site: http://www.smartgrowth.org

CONCERN is an information network coordinated by USEPA to assist private sector, public sector, and NGO partners in creating smart growth in neighborhoods, communities, and regions throughout the country. The network facilitates information sharing on financing for infill and brownfields redevelopment, tools for evaluating development options, and pilot money-saving investments that reap economic and environmental benefits.

Software Tools and Dynamic Models

Other organizations have developed software tools/dynamic models for evaluating urban growth and dynamics. Because private consulting firms or foundations develop them, users must pay for the services, and detailed descriptions of their methodologies and the software systems or code are not available. However, the basic framework is advertised. The following sections list a selection of available tools.

Community Visualization and Simulation Software

Computer Tool: CommunityViz
Developers: The Orton Family Foundation
Web Site: www.CommunityViz.com

CommunityViz assists small cities and towns grappling with the rapid changes brought about by growth and development pressures. CommunityViz provides GIS-based analysis and real-world 3D modeling to help people envision land use alternatives and understand their potential impacts, explore options and share possibilities, and examine scenarios from all angles — environmental, economic, and social.

An example of one application is an alternate futures studies to inform development of a community comprehensive plan. CommunityViz software quantifies the impacts of continued growth from an environmental, social and economic perspective. Taking into consideration such factors as water usage, population growth trends, and growth impacts on schools and employment, a community can use the components of CommunityViz to create several scenarios representing different growth patterns. Scenario Constructor helps to create the scenarios which represent the possible and desired conditions for land use and growth patterns. SiteBuilder 3D illustrates the visual impacts that new buildings, new access roads and additional vegetation would have on the landscape. SiteBuilder 3D also displays virtual walk- and fly-through views of the proposed roads and buildings. Policy Simulator models alternative future growth patterns and calculates their impacts on existing schools, businesses, available land and taxes at 25, 50, and 100 percent of build-out. Other applications include developing a resource management plan, developing a growth management plan, floodplain naturalization, drinking water protection, park site selection, and deciding between corridor vs. downtown development.

Blueline Group

Consultant Services: Blueline Group (formerly UGrow)
Developers: Prescott College, NASA (Wilson W. Orr)
Web Site: www.prescott.edu

Blueline Group is a system dynamics suite of models for urban policy design and testing. Numeric (system dynamics), spatial (GIS-maps) and 3-Dimensional (fly through visualization) tools are integrated to serve a community's needs. Blueline Group is part of an overall process of working with community leaders to identify drivers of change in the region, adapting the core Blueline Group model to address those drivers, and then testing a variety of future scenarios based on changes in local development policy, input conditions, or external variables.

Blueline Group is PC-based running over 300 equations, which define the basic interdisciplinary relationships among the economic, social, and environmental sectors of a community. The model runs from 1950 to 2100 with pauses at years 1990 and 2030 for policy adjustments. It is designed to test proposed policies and can be stopped at any year to produce the community status as a scenario responding to the proposed policy(s). There are presently 10 policy option categories which encourage or discourage efficiencies in such areas as housing density, energy consumption, transportation, land use, land cover, and business activity. Each of these may be adjusted for "intensity," representing the strength with which the policy is implemented. From the inputs and various policy options, the model produces a variety of future scenarios and projects groups of variables into sectors such as: quality of life, economics and business, housing, population, land use, transportation, climate change impacts, and energy. The numerical output is then used to generate GIS-format maps of the "future communities."

California Urban and Biodiversity Analysis Model

Computer Tool: CURBA
Developers: John Landis, Michael Reilly, Pablo Monzon, and Chris Cogan.
Web Site: www.dcrp.ced.berkeley.edu

The CURBA model was developed as a tool to help urban planners to evaluate the possible effects of alternative urban growth patterns and policies on biodiversity and natural habitat quality. CURBA can help direct urban growth while promoting environmental and ecological quality.

The CURBA model consists of two major components, an Urban Growth Model and a Policy Simulation and Evaluation Model. The Urban Growth Model assists the user in calibrating equations that describe past urbanization patterns and applying the equations to project future development patterns. The Policy Simulation and Evaluation Model projects how alternative development policies will affect future urbanization patterns and the associated impacts on habitat integrity. For example, CURBA can help users investigate the effects of urban growth on vegetation land cover by type, habitat for various species (e.g., different mammals, reptiles, and birds), changes in the level of fragmentation, etc. The CURBA model is used in conjunction with ArcView and various Avenue scripts.

California Urban Futures (CUF-1)

The California Urban Futures Model is known as the CUF Model or CUF-1 (earlier versions of the model were known as the Bay Area Simulation System—BASS II). The purpose of the CUF-1 model is to provide a framework for simulating how growth and development policies might alter the location, pattern, and intensity of urban development. The model is designed to consider growth and development policies at various levels of government (e.g., state government, local government, and special districts). The model was originally developed to simulate the impacts of alternative regulatory and investment policy initiatives on urban development in the Northern California Bay Region.

Note: CUF-1 has been superceded by CUF-2 and CURBA.

The CUF-1 model allows the user to: (1) project population growth at a sub-area level (e.g., a city) and then aggregate projected growth to larger units (e.g., a county), (2) allocate growth to individual sites based on development profitability, (3) incorporate several variables, including spatial accessibility, to determine the location and density of new development, (4) assemble, organize, manage, and display data describing land development options with geographic information systems (GIS), (5) incorporate development policies into the growth forecasting process, and,

(6) simulate new policy scenarios quickly and display results in easy to understand map forms with various levels of detail.

The CUF-1 model uses two primary units of analysis, political jurisdictions (incorporated cities or counties) and developable land units (i.e., undeveloped or underdeveloped areas that may be developed or redeveloped—DLUs). First, the model projects population growth based on city population growth trends and development potential by DLU. The CUF-1 model then simulates growth of an area by determining how much new development to allocate to each DLU per model period based on population growth of each city or county, the profitability potential of each DLU if developed, and user-specified development regulations and/or incentives. This is accomplished using four related sub models: the bottom-up population growth submodel, a spatial database, the spatial allocation submodel, and the annexation-incorporation submodel

California Urban Futures Model 2nd Generation (CUF-2)

Computer Tool: California Urban Futures Model 2nd Generation (CUF-2)
Developers: John Landis
Web Site: www.dcrp.ced.berkeley.edu

The purpose of the California Urban Futures Model Second Generation (CUF-2) model, like the CUF-1 model, is to provide a framework for simulating how growth and development policies might alter the location, pattern, and intensity of urban development. (See the evaluation of the CUF-1 model for a more detailed description of the model's intended use.) The second-generation was developed to address some of the theoretical holes of the first model.

The CUF-2 model performs many of the functions as the CUF-1 model (see the evaluation of the CUF-1 model). Several changes were made to the first generation, however. The following paragraph briefly describe each of the four main components of the CUF-2 model.

The activity projection component uses a series of econometric models to project future population, households, and employment by jurisdiction at 10-year intervals. Although the future population and households are projected as they are in the CUF-1 model, the employment projection is a new component of CUF-2.

The GIS based spatial database generates and updates the location and attributes of each developable land unit (DLU) and allows the user to visually display the spatial pattern of growth. In CUF-2, DLUs are one-hectare grid-cells, not (as in CUF-1) irregularly-shaped polygons.

The land use change submodel is calibrated against historical urban land use changes. Independent variables include: local population and employment growth; proximity to regional job centers; site slope; whether the site is within or beyond city boundaries or spheres of influence; the uses of surrounding sites; the availability of vacant land; and site proximity to freeway interchanges, transit stations, and major commercial, industrial, and public land uses. The model allows for spatial bidding for sites between four types of new development land uses and three types of redevelopment. The use change submodel is calibrated against historical urban land use changes.

DELTA Land-use Modeling Package

Computer Tool: DELTA
Developers: David Simmonds Consultancy
Web Site: http://www.davidsimmonds.com/main/models/models1a.htm

The DELTA model projects changes in urban areas, including changes in the location of households, population, employment and the amount of real estate development. Typically DELTA is set up to interact with a transport model. With a transport model, DELTA projects changes in land use that affect the demand for transportation and the impact of changes in accessibility on a variety of factors, including the location of different activities (e.g., households, employment) and the value of buildings. An optional regional level can be added within DELTA to model the regional economy and migration between urban areas.

Disaggregated Residential Allocation Model and the Employment Allocation Model

Computer Tool: DRAM/EMPAL
Developers: S.H. Putman and Associates, Inc.
Web Site: http://dolphin.upenn.edu/~yongmin/intro.html

DRAM/EMPAL projects the interactions and distribution of employment and housing in a specified geographic area. DRAM/EMPAL combines two spatial interaction models: the Disaggregated Residential Allocation Model (DRAM) and the Employment Allocation Model (EMPAL) to quantify the interactions between the metropolitan patterns of employment and population location and the networks of transportation facilities that connect them. DRAM/EMPAL provides a tool that relates future estimates of the location and type of employment in an area to their prior distributions, regional growth or decline, and the region's transportation system.

DRAM/EMPAL formed the two major components of an integrated set of computer models known as the Integrated Transportation and Land Use Package (ITLUP). Output from DRAM/EMPAL (i.e., employment and household location and land use, trips generated for home-to-work, home-to-shop, and work-to-shop) were used with the third component of ITLUP to perform standard travel demand modeling (including sub models to estimate trip distribution, modal choice, and traffic assignment).

DRAM/EMPAL has been incorporated into a new system called METROPILUS, which combines employment and residence location and land consumption into a single, comprehensive package operating within an ArcView GIS environment.

Growth Simulation Model

Computer Tool: Growth Simulation Model (GSM)
Developers: Joe Tassone
Web Site: http://www.mdp.state.md.us

The GSM was developed by the Maryland Office of Planning beginning in 1992 to project population growth and new development effects on land use/land cover nutrient pollution loads, and small streams under alternative land management strategies. To develop these estimates, the GSM uses population, household, and employment projections to estimate demand for residential and commercial development. Demand is then distributed to developable land, based on capacity under existing or alternative zoning, development regulations, and resource conservation mechanisms; and on information about development patterns and trends. Land use change to accommodate projected growth is then estimated as a function of management tools.

INDEX Planning Support System

Computer Tool: INDEX
Developers: Criterion Planners/Engineers, Inc.
Web Site: http://www.crit.com

INDEX is an interactive GIS-based planning support system that measures existing conditions, evaluates alternative plans, and supports implementation of adopted plans. Introduced in 1994, it is now one of the most widely distributed planning tools in the U.S., with over 90 organizations in 30 states equipped with the software. INDEX is an integrated suite of tools designed to support the entire process of community planning and development. Applications often begin with benchmark measurements of existing conditions to identify problems and opportunities that merit attention in plans. INDEX is then used to design and visualize alternative planning scenarios, analyze and score their performance, and compare and rank alternatives. Once plans are adopted, INDEX supports implementation by evaluating the consistency of development proposals against plan goals. Over time, achievements are periodically measured with progress reports. The tool is distinguished by its land-use/transportation analysis using a multi-modal travel network integrated with land-use parcels. INDEX is available in either ArcView 3.2, ArcGIS 8x, or MapObjects versions and can be purchased in standard or custom versions by organizations that desire their own copy; or modeling services can be provided by Criterion when analysis, but not software, is desired.

Institut für Raumplanung, Universität Dortmund

Computer Tool: IRPUD
Developers: Michael Wegener
Web Site: http://irpud.raumplanung.uni-dortmund.de/irpud/index_e.htm

The IRPUD model projects the location decisions of industry, residential developers and households, the travel patterns that result from location decisions, construction activity and land-use development, and the impacts of public policies in the fields of industrial development, housing, public facilities, and transportation within an urban area over a specified amount of time.

The IRPUD model consists of six integrated sub models that address the following factors: transportation; changes to population, employment, residential buildings, and non-residential buildings due to biological, technological, or long-term socioeconomic trends; public programs; private construction; regional labor market; and regional housing market. Together, the six sub models form one comprehensive standalone model system.

Land Transformation Model

Computer Tool: Land Transformation Model (LTM)
Developers: Dr. Bryan C. Pijanowski
Web Site: http://www.ltm.msu.edu

Development of the Land Transformation Model (LTM) began in 1995 and is ongoing. The model uses landscape ecology principles and patterns of interactions to simulate land use change process and to forecast land use change. Though the model can be used in any definable region, precedence is given to watersheds as the spatial extent in LTM applications. Conceptually, the LTM contains six interacting modules: (1) policy framework; (2) driving variables; (3) land transformation; (4) intensity of use; (5) processes and distributions; and (6) assessment endpoints. The pilot model was developed for Michigan's Saginaw Bay Watershed and contains two of the six LTM modules—driving variables and land transformation. The pilot model integrates a variety of land use change driving variables, such as population growth, agricultural sustainability, transportation, and farmland preservation policies for the watershed.

Land-Use Change Analysis System

Computer Tool: LUCAS

Developers: Michael W. Berry, Richard O. Flamm, Brett C. Hazen, Rhonda M. MacIntyre, and Karen S. Minser.

Web Site: http://www.cs.utk.edu/~lucas

LUCAS was developed in 1994 to examine the impact of human activities on land use and the subsequent impacts on environmental and natural resource sustainability. LUCAS stores, displays, and analyzes map layers derived from remotely-sensed images, census and ownership maps, topographical maps, and outputs from econometric models using the Geographic Resources Analysis Support System (GRASS), a public-domain GIS. Simulations using LUCAS generate new maps of land cover representing the amount of land-cover change. LUCAS can address such issues as biodiversity conservation, conservation goals, long-term landscape integrity, real estate value change, species abundance, and land-ownership characteristics.

Metropolitan Simulation

Computer Tool: METROSIM

Developers: Alex Anas & Associates

Web Site: http://tmip.fhwa.dot.gov

METROSIM is an operational large scale computer simulation model that uses an economic approach to forecast the interdependent effects of transportation and land use systems and of land use and transport policies at the metropolitan level. METROSIM is used to evaluate transportation projects and travel related changes, land use controls, employment growth scenarios, income growth and other policies or forecast changes.

METROSIM can be used to obtain quantitative forecasts of travel flows, employment changes, congestion levels, new construction of residential and commercial buildings, land use changes, etc. The user can specify land use constraints and zoning regulations in the model. The user can also obtain benefit-cost ratios for projects or policy interventions simulated by METROSIM.

METROSIM can produce a one-shot long run equilibrium forecast for transportation and land use in a metropolitan area, or METROSIM can operate in annual increments and produce yearly changes to transportation and land use from the existing situation until convergence to a steady state is achieved.

PLAnning for Community Energy, Economic and Environmental Sustainability

Computer Tool:PLACE3S

Developers: California Energy Commission, State Energy Office in Oregon, the Washington Dept. of Energy, and Parsons Brinckerhoff-McKeever/Morris, Inc.

Web Site: http://www.energy.ca.gov/places/

PLACE3S (PLAnning for Community Energy, Economic and Environmental Sustainability) is an urban design and land-use planning process created to help communities understand how growth and development decisions can contribute to improved sustainability. It uses energy consumption as a yardstick to measure various types of development paradigms.

MetroQUEST

Computer Tool: MetroQUEST

Developers: Envision Sustainability Tools Inc.

Web Site: www.envisiontools.com

QUEST is a state-of-the-art computer model for regional scenarios that has the look and appeal of a computer game. QUEST allows audiences to interactively create and compare future scenarios for their region and to evaluate the consequences of their choices through a wide range of sustainability indicators from air quality to unemployment. QUEST has been developed over the past 10 years at the University of British Columbia and Envision to bring scientists, decisionmakers and the public closer by combining the sophistication of an integrated modeling framework with a game-like interface.

QUEST has been designed to address the three critical challenges surrounding urban and regional sustainability. These are: (1) the need to consider both the long and short-term consequences of choices facing the region; (2) the need to consider a wide range of complex environmental, economic, and social issues when making decisions; and (3) the need to both educate and consult with a wide range of stakeholders and the public.

The purpose of QUEST is to encourage thinking about sustainability by actually placing the user in the position of making decisions that impinge on issues such as regional development and displaying the consequences of these decisions. Sustainability, after all, may be what we choose when we understand the consequences of our choices.

QUEST has been described as a state of the art computer model that has the look, user-friendliness, and appeal of a computer game, allowing it to cater to experts and non-expert audiences. It is an interactive modeling approach that allows users to actively explore different possible future scenarios, which can be custom-built for any region of the world to capture the region's priority sustainability issues. It facilitates dialogue and understanding among a variety of stakeholders about sustainability and strategic options by allowing users to evaluate the social, economic, and environmental consequences of their scenario choices. Regions as diverse as Whistler (Canada), Bali (Indonesia), Manchester (England), and Vancouver (Canada) have successfully used QUEST to engage decisionmakers and the public in the planning process.

Slope, Land-use, Elevation, Exclusion, Urban Growth, Transportation, and Hill Shading

Computer Tool: SLEUTH
Developers: Keith C. Clarke, Jeannette T. Candau
Web Site: http://www.ncgia.ucsb.edu/projects/gig

The SLEUTH model, also known as the Clarke Cellular Automata Urban Growth Model or as the Clarke Urban Growth Model, is intended to simulate urban growth to aid in understanding of how expanding urban areas consume their surrounding land, and the environmental impact this has on the local environment. SLEUTH derives its name from the six types of data inputs: slope, land use, urban, exclusion, transportation, and hill shading. SLEUTH is calibrated using these types of historical data. It produces forecasts of land use change from a local to regional scale.

This model simulates the transition from non-urban to urban land-use using cellular automata. This body of methods generates dynamic spatial patterns by applying growth rules to a grid of cells, each of whose land-use state is dependent on local factors (e.g., roads, existing urban areas, and topography), temporal factors, and random factors. Additionally, other non-urban land use transitions (such as range land to agricultural land) can be simulated assuming urbanization as the driver. Annual maps of forecasted change are generated allowing for animated display of forecasts over time as well as integration in GIS data bases for further spatial analysis.

Smart Growth Index

Computer Tool: Smart Growth Index (SGI)
Developers: Christopher Forinash
Web Site: http://epa.gov/smartgrowth/topics/sg_index.htm

Smart Growth Index is a GIS sketch model for simulating alternative land-use and transportation scenarios, and evaluating their outcomes using indicators of environmental and community performance. The result is land use and transportation decisions that encourage economic development, reduce fiscal expenditure, protect the environment, and improve community quality of life.

Urban Plan Growth Model

Computer Tool: PLAN
Developers: Developed by Robert Johnston at University of California, Davis; built by David Shabazian
Web Site: http://ice.ucdavis.edu

The UPLAN Urban Growth Model ("UPLAN") provides a land use evaluation and change analysis based on general land-use plans, population and employment projections, characteristics of housing, and other user-defined conditions. It is an integrated package of user-specified attractions that enable users to: (1) conduct a land suitability analysis, and (2) project future land use demand. UPLAN helps communities create alternative visions of the future by mapping alternative development patterns determined by local land development policies. Some of the policies and decisions UPLAN addresses include establishing various criteria to "weight" the suitability of different locations for a particular land use, incorporating various land use planning and zoning considerations and other allocation scenarios, and defining various growth scenarios. The model can also be used to determine various environmental and social constraints to growth by modifying the criteria and the associated weights.

The UPLAN model allows the user to develop specific parameters in the form of grids in which to model future land uses. The model allows the user to generate attraction grids, exclusion grids, general plan grids, and existing urban grids. Attractive grids are locations for future development (i.e., near to freeway ramps); exclusion grids, list areas where development should not occur (i.e., parks, waterways etc.); general plan grid is a composite grid of the general plan land use maps from the users region; and existing urban grid provides the current land use conditions. Each grid applies user-defined decision criteria (e.g., identifying and weighting grid factors), to derive study-area conditions. These decision criteria are applied to land use information stored in geographic information system (GIS) data files to create maps and reports showing where future development may occur.

What If?

Computer Tool: What If?™
Developers: Community Analysis and Planning Systems, Inc.
Web Site: www.what-if-pss.com

What If? is a GIS-based system that can be used to explore alternative community development scenarios and project future land use patterns and associated population, housing, and employment trends. It allows public officials and private citizens to examine the likely impacts of alternative policies for controlling urban growth, preserving agricultural land, or expanding public infrastructure in easy-to-understand maps and tables. It is designed to be used by non-technical people in public forums, allowing communities to use currently available GIS information to support community-based dialogue and collaborative decisionmaking. What If? ™ can be used to conduct a land suitability analysis, project future land use demand, prepare a land use plan, and allocate this demand to suitable locations.

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14. ABSTRACT

The Army Strategy for the Environment policy document establishes a long-range vision for enabling the Army to meet its mission today and into the future. The Strategy is based on the concept of "Sustainability," which focuses the Army's thinking on addressing both present and future needs while strengthening community partnerships that improve the Army's ability to organize, equip, train, and deploy as part of a joint force. The Strategic Sustainability Assessment (SSA) is a long-term project sponsored by the Army Environmental Policy Institute (AEPI). The Institute will use a variety of models and research tools to provide strategic analyses that will provide the Army with a fact-based visualization of future trends and issues critical to sustainability. The envisioned product is a series of ongoing, regular studies and reports that focus on specific regions or issues, and that enable the development of implementation plans and concepts for the Army Strategy for the Environment. This project defined and analyzed key forces, outcomes, and trends related to SSA as it applies to Army installations over a 20- to 30-year time horizon.

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