RECOMMENDATIONS FROM THE WORKSHOP ON OPTIMIZING AND IMPROVING GEOSPATIAL SERVICES TO SUPPORT LANDSCAPE-SCALE MITIGATION

A Report to the Secretary of the Interior

Convened jointly by the USGS Core Science Systems Mission Area and the DOI Office of the Chief Information Officer on October 22, 2014 in Washington, DC

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EXECUTIVE SUMMARY

The Department of the Interior (DOI) oversees roughly 20 percent of US lands and 20 percent of the development of US energy supplies, mediates the use of water in the Nation's 17 western states, and serves more than 500 federally recognized tribes and native communities in Alaska. Recently Secretary of the Interior Sally Jewell issued Secretarial Order 3330 "Improving Mitigation Policies and Practices of the Department of the Interior" that directed development of a coordinated Department-wide Strategy aimed at strengthening mitigation practices. SO 3330 states : *"Central to this strategy will be (1) the use of a landscape-scale approach to identify and facilitate investment in key conservation priorities in a region; (2) early integration of mitigation considerations in project planning and design; (3) ensuring the durability of mitigation measures over time; (4) ensuring transparency and consistency in mitigation decisions; and (5) a focus on mitigation efforts that improve the resilience of our Nation's resources in the face of climate change."*

In response to SO 3330, the DOI Office of Policy Analysis released "A Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior" (Clement et al., 2014) that outlines the actions necessary to successfully shift towards consistent, landscape-scale, science-based mitigation and includes this action: "*the Department, with leadership from the Geospatial Information Officer and the USGS, will convene a workshop of partners and experts to identify and evaluate existing landscape analysis data and tools and issue guidance for their use in mitigation decision-support".* In response to this charge, the USGS Core Science Systems Mission Area collaborated with the DOI Office of the Chief Information Officer to plan and convene a workshop entitled "*Optimizing and Improving Geospatial Services to Support Landscape-Scale Mitigation*". This Workshop explored the status and unmet needs for geospatial capabilities to support and advance landscape-scale mitigation efforts across the network of DOI agencies and partners, and was held on October 22, 2014 in association with the National Workshop on Large Landscape Conservation (NWLLC). The forum brought together a diverse group of approximately 70 participants representing the USGS, BLM, FWS, other DOI bureaus and federal agencies (~45 attendees), state agencies (~5 attendees), and a wide range of Non-governmental Organizations (~20 attendees). The Workshop provided a statement of needs for new capabilities to fulfill high priority requirements that are not addressed by the currently available suite of geospatial resources and services in use across the Department and its network of partners.

This Report uses the information gathered at the Workshop and in subsequent discussions with the attendees to provide seven focused and pragmatic recommendations for actions intended to address the most pressing requirements identified by the participants. Principally, the recommendations provided by this Report seek to answer the question: "*How can the Department of the Interior better utilize geospatial resources and services to develop landscape-scale strategies and better manage resources, values, and functions through the mitigation hierarchy at multiple scales?*"; these recommendations are listed below:

Recommendation 1: Improve National GAP Land Cover and Vertebrate Species Distribution models and national data products by the incorporation of habitat fragmentation indices and vegetation canopy metrics derived from above-ground LIDAR point clouds that are being collected through the USGS-led 3D Elevation Program (3DEP).

Recommendation 2: Use the Geospatial Platform to create a Mitigation Geospatial Data Infrastructure (GDI) Community of Practice and online presence for geospatial practitioners working to advance landscape-scale mitigation. Moreover, use this Mitigation GDI Community of Practice to organize, and support the efforts of a working group of expert geospatial knowledge curators for the mitigation-relevant GDI.

Recommendation 3: Inventory and where appropriate, collect, locally managed, project-specific geodata collected and maintained by federal and state agency field offices and NGOs, and make those datasets readily available through the most appropriate centralized geoportal(s). Register the relevant contents of these geoportals as a part of the Mitigation GDI Community of Practice, thereby reducing the barriers for DOI field offices and NGOs to share their data with the broad mitigation community and stimulate a shift towards operating at a national scale across federal and state agencies and NGOs.

Recommendation 4: Support the construction of merged and comprehensive high quality national data layers of land cover and land use (LANDFIRE, GAP, NLCD) along with the depiction of federal land parcels and roads to enable consistent and broad analysis of habitat “intactness” within regional assessments and decision-support modeling beyond jurisdictional boundaries.

Recommendation 5: Add mapping capabilities to databases used to track compensatory mitigation habitat plans (for example, the USFWS Tracking and Integrated Logging System (TAILS)) to increase the sophistication of geographic information that DOI staff can associate with each project-review record stored in a centralized and accessible archive. Additionally, explore possibilities for improving the linkages, interoperability, and geospatial data-sharing between the USFWS TAILS and the USACE Regulatory In-lieu Fee and Bank Information Tracking System (RIBITS) online databases to better provide a widely accessible inventory of the location, nature, history, and performance of all U.S. conservation banks.

Recommendation 6: Establish best practices and standards for broadly applicable and coordinated monitoring to support interoperability. This includes the establishment of robust and broadly applicable data management procedures relevant to collection and management of monitoring data.

CHAPTER 1: INTRODUCTION

The Department of the Interior (DOI) manages broad reaches of the Nation's federal lands, waters, and diverse natural resources, overseeing roughly 20 percent of US lands and 20 percent of the development of US energy supplies. The Department mediates the use of water supplies in the Nation's 17 western states, and services more than 500 federally recognized tribes and native communities in Alaska. The DOI portfolio includes stewardship for over 800 native migratory bird species and nearly 2,000 federally listed threatened and endangered species. Moreover, Interior's National Park Service preserves and manages over 400 holdings, and the Department insures the preservation of cultural resources on both federal and non-federal lands by leading the National Historic Preservation Program. The Department's responsibilities to both (1) manage infrastructure and energy development, and (2) conserve the Nation's natural and cultural resources require that DOI effectively mitigate development impacts in order to fulfill its statutory mandates. Mitigation is a fundamental method used by the DOI to manage lands and resources within its jurisdictional responsibilities.

In October 2013 Secretary of the Interior Sally Jewell issued Secretarial Order 3330 "Improving Mitigation Policies and Practices of the Department of the Interior". Secretarial Order 3330 charged the DOI's Energy and Climate Change Task Force with developing a coordinated Department-wide Strategy aimed at strengthening mitigation practices, stating that:
"Central to this strategy will be (1) the use of a landscape-scale approach to identify and facilitate investment in key conservation priorities in a region; (2) early integration of mitigation considerations in project planning and design; (3) ensuring the durability of mitigation measures over time; (4) ensuring transparency and consistency in mitigation decisions; and (5) a focus on mitigation efforts that improve the resilience of our Nation's resources in the face of climate change."

Subsequently, on April 10, 2014, the DOI Office of Policy Analysis released "A Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior" (Clement et al., 2014) that describes the challenges and opportunities implicit in modernizing DOI mitigation policy from its focus on project-by-project practices to enabling landscape-scale, consistent, science-based management, robustly supported by a full complement of geospatial resources and services. This new DOI Strategy aims to implement mitigation policies that will more effectively encourage infrastructure development while also better protecting natural and cultural resources. An overarching goal of the Strategy is to identify high-value mitigation opportunities and priorities at scales appropriate to manage and conserve the impacted resources in order to: a) enable project proponents to plan projects with less inherent conflict potential from the outset that avoid and minimize damage to conservation values, and, in the case of unavoidable impacts; b) aid project proponents and land managers in the accurate and efficient identification of high-value compensatory mitigation opportunities, and thereby; c) streamline the environmental review and permitting process, especially for large, complex projects such as roads, railways, transmission lines, pipelines, and mining operations.

Moreover, the Strategy states that the Department must work to inculcate these principles within four key steps of the landscape-scale approach to mitigation. Geospatial resources and services are essential to all four steps, specified as: I) identifying key landscape-scale attributes, and the conditions, trends and baselines that characterize these attributes, by conducting regional assessments; II) developing landscape-scale strategies and plans; III) conducting efficient and effective compensatory mitigation programs for residual impacts, and; IV) crafting monitoring programs that adaptively manage mitigation investments to ensure effectiveness despite changing conditions. Similarly, this Report is structured to align with these key steps.

Geospatial Data Infrastructure Needs of the DOI Landscape-Scale Mitigation Strategy

An extensive set of geospatial resources and services, herein collectively termed the mitigation-relevant "Geospatial Data Infrastructure", are presently available and being utilized to enable, inform, and enhance decision-making at all steps in the process of mitigation planning, execution, evaluation, and adaptation. The Geospatial Data Infrastructure already in place for mitigation has a key role in all the steps of the process, and is currently being used for a range of purposes including:

1) Extrapolating best available scientific understanding of natural processes using foundational data layers that describe and quantify the structure of the landscape.
2) Understanding the regional geographic distribution of resources, values and functions, and the prior impacts to them.
3) Identification of critical habitats in relation to the coverage of protected areas and proposed development sites.
4) Evaluating land cover, land use and habitat types for selecting development sites to avoid or minimize negative development consequences.
5) Predicting the long-term and regionally cumulative implications of multiple individual short-term actions.
6) Forecasting the coming landscape overprint of climate change and the likely spatial pattern of future infrastructure and energy sector development.
7) Scenario development and cost-benefit analyses for compensatory mitigation.
8) Tracking the success of environmental mitigation through time series change detection based on standardized and targeted monitoring observations.

The **Geospatial Data Infrastructure** (GDI) relevant to the mitigation hierarchy is a framework of geographic data, maps, metadata, discovery portals, and analysis tools that are connected to enable the use of spatial data in an efficient and flexible way to support enhanced decision-making. Stated most broadly, the mitigation GDI enables the exploitation and analysis of geospatial data, information, and services to describe, assess, predict, and visually depict physical features (both natural and constructed) and geographically referenced activities on the Earth (Kuhn, 2005).

Mitigation-relevant GDI ***geospatial resources*** include imagery and mapping data collected by commercial satellite, government satellite, aircraft, or provided by other sources, such as digital maps and commercial databases, solid earth, hydrologic, ecological observations, cadastral data, or any other discrete data that have locations on earth. Mitigation-relevant and GDI-resident geospatial resources have been produced by multiple sources utilizing interoperable data, metadata and data exchange standards, and may be presented multiple forms. In this report, the term geospatial resources is used to refer to foundational and baseline national, regional, or local data layers, time series or one-time point observations, standardized derived map products (for example, LANDFIRE / GAP land cover and National GAP Analysis habitat map products) and the associated geoportals that provide access to these geodatasets, derived maps and information products.

The concept of ***geospatial services*** within the mitigation-relevant GDI includes tools that enable users to analyze and manipulate data in collaboration or within stand-alone efforts, and also include instruction, training, laboratory support, and guidance for the use of geospatial data. More specifically, geospatial services are distinguished from geospatial resources, and include:

- Internet-accessible geospatial tools for spatial and process ***knowledge integration*** that enable early and broad collaboration;
- ***Decision-support models*** that allow tailored analyses using customized user-selected geospatial data inputs, or provide libraries of previously generated model outputs;
- Services that provide functional access to predictive climate models and to land use development ***forecast models***;
- Informatics tools that enable access to evolving time-series databases that capture and disseminate the observational output of ***monitoring frameworks***.

Impetus for this Report

The Strategy outlines the actions necessary to successfully shift towards consistent, landscape-scale, science-based mitigation, including the following Near-Term Policy Deliverable:
Develop Geospatial Data Tools for Landscape-Scale Mitigation - Q4 2014. The Department, with leadership from the Geospatial Information Officer and the USGS, will convene a workshop of partners and experts to identify and evaluate existing landscape analysis data and tools and issue guidance for their use in mitigation decision-support.

Accordingly, the USGS Core Science Systems Mission Area collaborated with the DOI Office of the Chief Information Officer to plan and convene a workshop entitled "*Optimizing and Improving Geospatial Services to Support Landscape-Scale Mitigation*" that explored the current state of, and the unmet needs for, geospatial capabilities in support of landscape-scale mitigation efforts in use by DOI agencies and partners. This Workshop was held on October 22, 2014 in association with the National Workshop on Large Landscape Conservation (NWLLC) and brought together approximately 70 participants representing the USGS, BLM, FWS, other DOI bureaus and federal agencies (~45 attendees), state agencies (~5 attendees), and a wide range of Non-governmental Organizations (~20 attendees). This Workshop sought to provide a statement of needs for new capabilities to fulfill high priority requirements that are not addressed by the currently available suite of geospatial resources and services in use across the Department and its network of partners. This Report uses the information gathered at the Workshop and through subsequent discussions with the attendees to provide 6 focused recommendations for actions that are intended to fulfill the most pressing requirements identified.

Goal and Objectives

Principally, this Report is concerned with answering the question: "*How can the Department of the Interior better utilize geospatial resources and services to develop landscape-scale strategies and to better manage resources, values, and functions through the mitigation hierarchy at multiple scales?*" This Report describes the unmet need for, and current use of, geospatial services in establishing regional assessments, developing landscape-scale strategies, conducting compensatory mitigation programs, and ensuring effectiveness through administering monitoring frameworks. Accordingly, this Report is focused primarily on:

- Determining geospatial needs when developing the identified steps of landscape-scale mitigation,
- Highlighting existing case studies or programs that comprise best practices in these steps for consideration,
- Identifying gaps between needs and existing investments in geospatial resources and services, and
- Presenting recommendations to the Department and its components for investments and management changes to address gaps, increase interagency cooperation to develop and use tools, find efficiencies and reduce costs.

The recommendations in this Report respond directly to the framing questions listed below:

1) How can the Department best leverage and share geospatial datasets, tools and geographical analysis expertise?
2) What is the most effective means for the Department to foster the use of valuable existing, but under-utilized, geospatial resources and services?
3) How can the Department most effectively build and promulgate the application of a comprehensive "best practices framework" across the entire landscape-scale mitigation - adaptive management cycle?
4) Given the daunting and expanding plethora of geospatial datasets, products, portals, and analysis software, what is the most viable approach for the Department to distill from the Geospatial Data Infrastructure a condensed and streamlined set of geospatial capabilities for validated application to mitigation in accord with SO 3330?

CHAPTER 2 - REGIONAL ASSESSMENTS

The US energy sector is experiencing an unprecedented expansion across diverse landscapes that involve the construction of numerous large utility-scale solar and wind renewable energy projects, and the annual drilling of thousands of hydrofracking oil and gas wells on both private and public lands. This massive growth in "all-of-the-above" energy production is driving the construction of new pipelines and electricity transmission lines that increasingly traverse the Nation. Moreover, this major industrial growth is happening while much of the existing key infrastructure, such as roads, railway lines, airports, tunnels and bridges is undergoing restoration, upgrade, or replacement. Consequently, there is a commensurate increase in the requirement to mitigate the environmental impacts of major development projects. Even after best efforts to avoid and minimize unwanted impacts, undoubtedly some large projects will still in-fill wetlands, disrupt wildlife corridors, fragment significant wildlife habitats, or damage resource values adjacent to protected areas such as National Parks, Refuges, Recreation Areas, and revered cultural resource sites. Federal agencies are mandated to respond with an analysis of potential negative environmental impacts whenever a large energy, transportation, or resource-extraction infrastructure project requires permitting or review. In the DOI Strategy, that analysis begins with a regional assessment of resource values, threats, and potential impacts that in contemporary practice always relies heavily on geospatial capabilities (Hayes, 2014).

The first step of the four-step process within the DOI Strategy's landscape-scale approach to mitigation involves *(I) identifying key landscape-scale attributes, and the conditions, trends and baselines that characterize these attributes, by conducting regional assessments*. Implicit in the Strategy is the notion that the maintenance of biological diversity, or "biodiversity" across regions is essential for the viability of ecosystem services. Conservation Biology regards the protection of biodiversity as inclusive of more than just protecting species diversity or taking actions to preserve known endangered species. Focus on regional biodiversity in place of the traditional project-by-project, stress-by-stress, species-by-species approach allows a more holistic perspective on environmental problems. Composition, structure, and function are primary elements of biodiversity that prevail across four levels of organization progressing from the most inclusive to finest scale, defined as (1) regional-landscape, (2) community-ecosystem, (3) population-species and (4) genetic (Noss, 1990, 1991).

By citing landscape-wide regional assessment as the first step in mitigation planning, the DOI Strategy adopts the approach of conservation biology, beginning at the highest level in this biodiversity hierarchy, starting with regional-scale mapping of landscape pattern and land cover, habitat structure and modeled species distributions. This coarse-filter mapping of regional structure is followed by the overlay of both areas of high stress and protected areas to reveal biologically significant sites at risk of degradation by energy or infrastructure development. The emphasis on regional assessment in the DOI Strategy recognizes that, at the landscape-scale, consideration and protection of biodiversity requires knowledge of the patterns and connectivity of habitats, and the resulting options for species to adjust their distributions in response to predicted change (Clement et al., 2014; Noss, 1990, 1991). The

Bureau of Land Management's (BLM) Rapid Eco-Regional Assessments (REAs) were presented at the Workshop as excellent case examples of regional assessments, and are described below.

BLM Rapid Eco-Regional Assessments

Rapid Eco-Regional Assessments are rapid assessments of an ecoregion's conservation elements (Figure 1), the change agents that impact them, and their current and future status. The need for REAs arose from BLM's recognition that public lands face increasingly complex and widespread environmental challenges that transcend traditional land management boundaries. Rapid energy sector growth, other infrastructure development, and climate change are affecting western US landscapes managed at least in part by the BLM. In response, the BLM has launched 15 REAs since 2010 to improve understanding of the current condition of these landscapes, and to predict the coming alteration of these landscapes by ongoing environmental changes and growing land use demands. The REAs assess biodiversity, conservation values, ecological conditions and trends within ecoregions, defined as expansive connected areas that have environmental coherence and connectivity, for example, the Sonoran Desert and the Colorado Plateau. Ecoregions cross administrative boundaries and encompass multiple BLM Field Office domains, ranging in size from 11 to 91 million acres. In close accord with the DOI Strategy, regional assessments of these very large areas provide land managers with a holistic view and expanded mitigation options to use in subsequently developing conservation strategies and plans, and in seeking opportunities for compensatory mitigation.

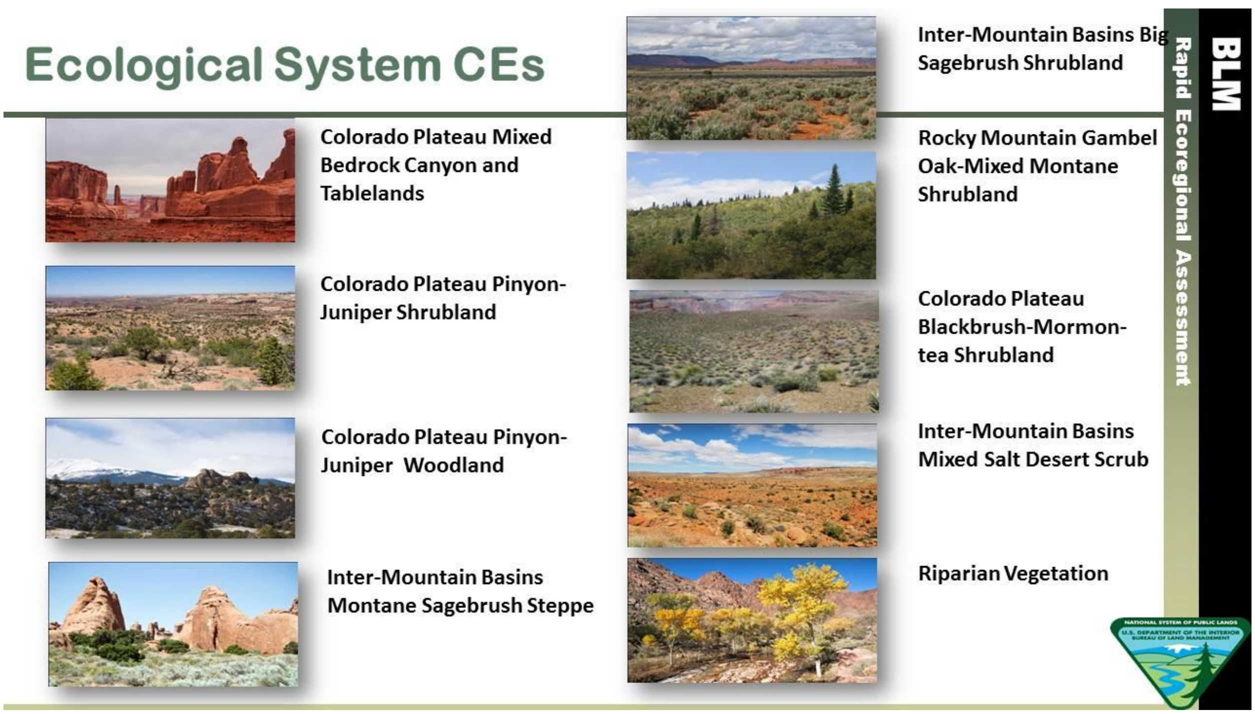

Figure 1. Conservation elements defined as ecological systems with BLM's Rapid Eco-regional Assessments (Courtesy of Karen Prentice, BLM).

By instituting REAs, the BLM is addressing complex land management challenges through: 1) examining landscape-scale resource conditions and trends, 2) identifying focal areas for conservation and development, 3) focusing resources where they are most needed, 4) integrating BLM management activities, 5) enabling adaptive management, and 6) providing a foundation for management partnerships. REAs are considered to be "rapid" assessments, because no new research or data collection is involved, instead, REAs synthesize existing geospatial information in a GIS, and are intended for completion in less than 18 months. REAs are ecoregional assessments that improve knowledge of ecological conditions and trends, natural processes and human influences, and additionally yield opportunities for resource conservation, restoration, development, and impact mitigation. Significantly, REAs capture resource values and patterns of change in biodiversity that are only apparent at the ecoregional scale, and are not perceived on local scales. Geospatial analyses within REAs describe and map areas of ecological importance, and delineate regionally significant or critical habitats for fish, wildlife, and threatened or endangered species. Next, GIS operations are used to evaluate the likelihood of future affects to habitats due to overarching drivers of ecological modification, specifically, climate change, wildfires, invasive species, and human-induced development (including energy sector and urban growth), plus additional change agents, if warranted, on an ecoregion-specific basis. Additionally, REAs add to the mitigation-relevant GDI by creating baseline ecological and geomorphological geospatial datasets that can be used to evaluate the success of future land management actions. Accordingly, REAs provide a basis for adaptive management that adjusts strategies in response to monitoring inputs and shifting conditions.

Examples of Significant Geospatial Datasets and Geoportals for Regional Assessments

The mitigation-relevant GDI *geospatial resources* that most fundamentally support regional assessments are foundational baseline national, regional, or local data layers, time series or one-time point observations, standardized derived map products depicting habitat and species distributions (for example, the National GAP Data Products) and the associated geoportals that provide access to these well vetted geodatasets and derived maps. Regional assessments typically utilize well-established geospatial analysis tools in Geographic Information Systems (GIS) that capture, store, manipulate, analyze, manage, and present all types of geographical data. Predominantly, the GIS analyses conducted within regional assessments make use of standardized functions that rely on spatio-temporal location as the key index variable, and enable the compatible representation and analysis of diverse data in common formats, projections and coordinate systems. Standard GIS analyses including data overlay, spatial feature buffering, and data-extraction operations are central to baseline regional assessments. More complex multi-criteria decision-support analysis within a GIS is often associated with the formulation of regional strategies and plans, and is discussed in detail in Chapter 3. This chapter presents below brief descriptions of the origins, functional utility, prime applications, and prospective enhancements for National Map and National GAP products and services, and the Geospatial Platform, that herein serve as examples of notable geospatial capabilities for regional assessments.

The National Map Geospatial Products and Services:

The National Map organizes, maintains, publishes, and disseminates the geospatial baseline of the Nation's topography, natural landscape, and built-up environment as a set of basic geospatial information provided through a variety of products and services. The National Map (http://nationalmap.gov/) supports GIS data download, digital versions of US Topo and historic topographic maps, geospatial data web map services and online viewing. A variety of pre-staged, small and large scale vector and raster data products are available for quick download (http://viewer.nationalmap.gov/viewer/) to support cartography, GIS analysis or modeling. National Map data products include the following:

- Vector Datasets – The National Hydrography Dataset (NHD), Governmental Boundary Units, Transportation, Structures, Elevation Contours, and Geographic Names are available as stand-alone products, or in an integrated vector package.
- Raster Datasets – Digital Elevation Models (DEMs), Orthoimagery, and Land Cover are available. DEMs include national coverage of 1 arc-second, 2 arc-second, and 1/3 arc-second resolutions; partial coverage at 1/9 arc-second and 5-meter resolution DEMs for Alaska. Other new derived LiDAR products are also available such as 1-meter DEMs, classified point clouds, and LiDAR Intensity Images. Regarding orthoimagery, 1-meter National Agricultural Imagery Program (NAIP) data and 1 foot and smaller resolution urban area data are available. Land Cover datasets include national U.S. coverages for 1995, 2001, 2006, and 2011.
- Cartographic Data Services – National Map geodata are also available as thematic overlay map services that can be directly incorporated into Web applications or a GIS without the need to download or process the data. New offerings from The National Map include cartographically designed Web based maps that provide a rapid backdrop for Web, mobile, or GIS applications.

The National Map Viewer provides access to topographic maps and its associated GIS Base Data products, as well as data visualization through web map services. The viewer includes several advanced tools that allow querying the data through web services and creating new overlays that can be saved for inclusion in a GIS. These products and services are used by GIS analysts and a wide variety of other users, enabling them to visualize, investigate, inspect, and download data and products for specific applications of topography, water resources, and the natural landscapes of the U.S. The National Map Viewer also supports visual integration or "mashing-up" of other Web-enabled data and allows users to save and share those "mash-ups" with other users.

Significant National Map enhancements are planned in the near-term for water (hydrography) and elevation data products, with enhanced elevation products and services to include: Hydro-flattened DEMs; Digital Surface Models (DSM); Digital Terrain Models(DTM); Topobathymetric data and DEMs; Height Above Ground (HAG); LiDAR and Ifsar Intensity Images; Contours; Cross Sections or Profiles; LiDAR Return Density (LRD); plus derived products for Hillshade, Aspect, Curvature, Slope, Flow Direction and Flow Accumulation. The National Map file distribution and map service hosting will be transitioned to public cloud-based delivery platforms over the next two years. New easy-to-use mobile or tablet-ready interfaces for accessing the data and web services are also in development with planned releases starting in 2015.

National GAP Analysis Program Geospatial Products:
The USGS National Gap Analysis Program (NGAP) and partners aim to describe, map and assess the status of biodiversity within the US. The program originated as a research initiative under the Fish and Wildlife Cooperative Research Units Program. Data methods were established in the late 1980's /early 1990's and have constantly been refined as technology changes and software improvements are made. The program relies heavily on compiling secondary data, literature research and expert opinion, and builds base datasets from Landsat archives. The NGAP produces three primary data sets: 1) National Land Cover; 2) Protected Areas Data; and 3) Predicted Distributions of Terrestrial Vertebrates. Essentially, the NGAP provides national, seamless and categorically consistent data sets that are interoperable and serve as core assets in determining the relative level of protection of broadly defined land cover types and terrestrial vertebrates.

The NGAP data products provide a broadscale assessment of the status of biodiversity, and intersect Protected Areas Data with individual elements of biodiversity, such as classified types of land cover or a species distribution. This allows for an objective assessment in which a percentage of protection can be stated based on the acres inside and outside protected areas. Based on this analysis, managers can identify potential threats to the long-term sustainability of ecosystems by identifying relatively unprotected elements of biodiversity. The NGAP applies accepted methodologies to large areas using massive spatial datasets within analyses that fundamentally rely on two principles. First, theory from island biogeography that assumes that biodiversity is proportional to abundance of suitable habitat is accepted as valid. Second, the NGAP analysis assumes that wildlife and habitat sustainability are more stable on protected lands, defined as lands with permanent legal protection against conversion to other uses, than on unprotected land.

The NGAP data products are provided through a dedicated geoportal (gapanalysis.usgs.gov) that maintains a site with a dedicated viewer for each of its three major data sets, Land Cover, Protected Areas and Species Distributions. The NGAP viewers allow users to quickly find, view and understand the potential uses of the data sets; and all major NGAP data products and intermediate products, such as forest edge or wetlands data products created for use in a GIS are available for download.

In line with the NGAP objective to maintain national scope, seamless and consistent data, standardized periodic updates to identify trends are planned. Another planned NGAP enhancement includes new products that identify the most important threats to biodiversity, tied to specific land cover types, ecoregions, or species habitat requirements, broadcasted in standard reports. As a move towards promoting awareness and the most effective use of NGAP geodata, data management and on-line data product information are slated for upgrade, and further research on the most important threats to the least protected elements of biodiversity are under consideration.

<u>The Geospatial Platform – A Foundation for Mitigation-Related Applications:</u>
The Geospatial Platform (www.geoplatform.gov) initiative is the embodiment of the federal government's efforts to expand the utilization of geospatial data and tools to facilitate decision-making across all levels of government. This shared services initiative provides trusted geospatial data, services and applications for use by the public, government agencies and their partners to meet specific requirements and needs. The Geospatial Platform is a major initiative of the Federal Geographic Data Committee (www.fgdc.gov), and is currently managed by the Department of the Interior as a part of their commitment to furthering the development and expansion of the National Spatial Data Infrastructure.

The Geospatial Platform includes three major technology components: (1) a collaboration website that can be utilized by many different user communities to present geospatial data, maps and tools in a number of different ways; (2) a national geospatial data and tool catalog where users can search tens of thousands of registered geodata and geotools to discover and learn more about capabilities that they can access, and; (3) a shared cloud computing infrastructure that can be utilized by Geospatial Platform partners to make their geodata and tools available to users of the Platform. While the Geospatial Platform is designed to broker access to data and tools that support the widest possible variety of user requirements, a number of the features and capabilities of the Platform are potentially useful for supporting increased transparency, efficiency and effectiveness as it pertains to mitigation decision-support. For example, in partnership with NOAA, NASA, DOI and the White House Office of Science and Technology Policy, the Geospatial Platform has provided support for the Climate Data Initiative, and currently hosts a number of key national geodata sets that are being leveraged across the government for supporting landscape-scale planning and assessment. These data and tools, featured in a "community" on geoplatform.gov (http://www.geoplatform.gov/climate-resources) can not only be used to support regional assessment activities, but may also serve as an example for how geospatial data and tools can be organized to meet the specific needs of a defined community of interest or practice.

Recommendations for Geospatial Services for Regional Assessments
Much evidence suggests that the Earth's biosphere is currently experiencing the 6th great extinction in geologic history, and in contrast to all prior such events, the current decline in biodiversity is being driven by human activities (May et al., 1995). Observed extinction rates are currently 100 to 1000 times the rates documented before the rise of human societies, and the primary driver implicated in this decline in species is the loss of habitat due to the global spread of the human footprint and associated development. As discussed above, the USGS National GAP Program (NGAP) sponsors the widespread mapping and quantification of the Nation's remaining habitat, with an aim to protect and preserve critical areas. The NGAP Program creates data products that are essential to regional assessments by sponsoring "GAP analyses".These analyese construct species distribution maps for overlay with land management data to reveal and locate gaps in the conservation of critical habitats within established protected areas. Creating National GAP datasets also identifies areas that will yield

long-term benefits in maintaining critical levels of biodiversity if left intact into the future, and should aid species-specific conservation efforts, forestalling the decline of species to endangered or threatened status (Chapin et al., 2000; Larson and Sengupta, 2003; May et al., 1995; Pimm et al., 1995; Sala et al., 2000).

The importance of NGAP Data Products to regional assessments notwithstanding, Workshop discussion and other critics have pointed out several shortcomings in NGAP methods and resulting geospatial products. For example, the abrupt boundaries between vegetative communities on NGAP Land Cover maps obviously do not properly portray the diffuse transitions and intra-community variations that occur in natural systems. The validity of the models and expert opinion used in constructing species distributions has not been determined through rigorous error analysis, weakening their value to mitigation decision-makers. NGAP modelling of distributions typically assumes that widely varying species behave alike, and ignores scale dependencies, coarse assumptions that are sure to introduce errors. Finally, procedures used to create NGAP habitat maps do not fully admit the effects of fragmentation, yet this process may result in patches too small to be viable for larger species populations, and moreover, the long distances between patches may isolate organisms (Larson and Sengupta, 2003; Scott, 2000). The Workshop participants recognized the unique and high value of USGS NGAP Data Products in conducting regional assessments, and also identified the weaknesses cited above, resulting in the following recommendation:

Recommendation 1: Improve National GAP Land Cover and Vertebrate Species Distribution models and data products as follows:

- Provide greater specificity on the location of priority habitats by incorporating habitat fragmentation indices and vegetation canopy metrics from above-ground LIDAR point clouds such as those being collected through the USGS 3D Elevation Program (3DEP);
- Update and evaluate species distribution models, and extend to a wider range of species;
- Add the classification of wetland regions with high restoration potential to Land Cover data products, and
- Apply field observations to validate the accuracy of Vertebrate Species Distribution data products.

Building on the foundations of the Geospatial Platform, and from the example communities of practice that have been implemented to support the Climate Data Initiative and other cross-agency programs, the Geospatial Platform team could create a collaboration space to support the specific needs of the mitigation community. With guidance from the geospatial knowledge curators proposed in Recommendation 2 below, this community of practice would enable geospatial practitioners with mitigation-relevant geospatial data and tools to publish, register and highlight their unique capabilities for the benefit of mitigation practitioners around the country. This community could include hosted geodata services and tools for those individuals and organizations that are working on mitigation actions and assessments, and could also provide capabilities for those practitioners to provide interactive stories, lessons learned and recommendations for future efforts that could be shared with all community members.

Recommendation 2: Use the Geospatial Platform to create a Mitigation GDI Community of Practice and online presence for geospatial practitioners working to advance landscape-scale mitigation. Moreover, use this Mitigation GDI Community of Practice to organize, mentor, and manage a working group of expert geospatial knowledge curators for the mitigation-relevant GDI, with diverse membership representing federal and state agencies and NGOs, who will serve to guide geospatial analysts to the geodata, authoritative derived maps and geotools best suited for specific regional assessments. Provide the support needed to enable this group to undertake the following actions:

- Ensure that metadata includes information on data accuracy, strengths and limitations to help users to identify and make best use of the most suitable geodata for regional assessments.
- Establish standard approaches for the acceptable quality and sanctioned application of geospatial datasets to maximize appropriate use in the mitigation context.
- Create educational resources and case study tutorials to build skill within the landscape-scale mitigation community, and to provide training on the use of geospatial products in regional assessments and geospatial decision-support models.

CHAPTER 3 - REGIONAL CONSERVATION AND DEVELOPMENT STRATEGIES AND PLANS

The proponents of large projects on public lands typically contend with the jurisdictions of multiple DOI bureaus, and therefore a consistent, unified process to plan for permitting and mitigation is desirable to increase efficiency for both land users and bureaus. The second step in this DOI Strategy's four-step process to implement a landscape-scale approach to mitigation is *(II) to develop landscape-scale strategies and plans*. Although DOI bureaus have not previously focused on landscape-level impacts in considerations of ***compensatory mitigation***, DOI bureaus do have a history of pursuing landscape-level conservation. A recent example is DOI's initiative to establish Landscape Conservation Cooperatives (LCCs) that constitute science partnerships aimed at informing conservation at landscape-scale, and in addition, landscape-level strategies for understanding and managing for climate change were developed by DOI bureaus as directed by Ken Salazar during his tenure as DOI Secretary (Burke, 2014).

Additionally, DOI bureaus have independently developed landscape-scale approaches in response to their immediate management responsibilities. For instance, the US Fish and Wildlife Service (USFWS) has approached the ecoregional conservation of habitats by formally endorsing "Strategic Habitat Conservation." To promote the avoidance and minimization of impacts from wind energy infrastructure development, USFWS has similarly issued landscape-level strategies such as the Land-Based Wind Energy Guidelines and the Eagle Conservation Plan Guidance. Note that the 15 BLM Rapid Eco-regional Assessments (REAs) that examine "large, connected areas that have similar environmental characteristics" mentioned in Chapter 2 herein are designed to build the geospatial knowledge foundation for landscape-level strategies. Also, BLM has established Solar Energy Zones (SEZs), large regions in the western US deemed well suited for utility-scale production of solar energy, and has developed the multi-state programmatic environmental impact statements essential for planning renewable energy transmission across broad expanses. BLM has begun to plan for mitigation on a large regional scale by conducting a pilot effort to develop a Solar Regional Mitigation Strategy for the Dry Lake SEZ, and intends to extend the development of such landscape-wide strategies to the other 16 SEZs. Another example of BLM progress on landscape-level conservation is the Desert Renewable Energy Conservation Plan that protects wildlife, recreation areas and open space across more than 20 million acres of southern California desert while also identifying focus areas well-suited for renewable energy projects (Burke, 2014; Hayes, 2013).

Examples of Significant Geospatial Services for Geodata Integration and Collaboration

The mitigation-relevant GDI geospatial services most applicable to constructing regional conservation and development strategies and plans are (1) web-enabled interactive mapping tools for ***collaborative integration*** of agency conservation priorities and cooperation with developers in exploring mitigation opportunities, and (2) GIS-resident ***multi-criteria decision-support models*** needed for conservation targeting in mitigation. Brief descriptions of salient examples of geospatial services that promote openly available integration of diverse data layers and collaboration among all actors in the mitigation community, the Maryland Watershed Resources Registry, the Landscape Conservation Management and Analysis Portal (LC MAP), Data Basin's Integrated Landscape Conservation Cooperative (LCC) Planning Atlases, and LandScope America, are provided below.

<u>The Maryland Watershed Resources Registry:</u>
The Maryland Watershed Resources Registry (WRR) is a Green Highways Partnership project among agencies that advances the integrated management of watersheds within a framework anchored by eight GIS-enabled suitability analyses. The WRR allows agencies, project proponents, and conservation organizations to streamline decision-making and locate areas where mitigation actions would advance multiple preservation goals, supporting wise and effective investments in environmental protection. A primary goal of the WRR is the integration of actions undertaken by agencies responsible for the administration of the Clean Water Act; noteably the CWA Sections that deal with nonpoint source pollution, pollutant discharge, and the discharge of fill material into waterways. These suitability analyses result in maps that depict the scoring of Maryland's geography with respect to importance for preservation and ecological value for restoration. The WRR used statewide GIS analysis to identify and score candidate areas for either the preservation of pristine wetlands or habitats, or for the restoration of impacted natural resources (Bryson et al., 2010; Bryson et al., 2013).

A WRR Technical Advisory Committee defined suitability analyses that were carried out by the WRR, resulting in GIS data layers that provided spatially distributed rankings for Wetland Preservation, Wetland Restoration, Riparian Zone Preservation, Riparian Zone Restoration, Upland Preservation, Upland Restoration, Natural Stormwater Infrastructure Preservation, and Compromised Stormwater Infrastructure Restoration. The WRR Technical Advisory Committee included staff from numerous partnering agencies who guided the design of the suitability analyses to insure reasonable compatibility with the priorities of the most interested agencies. Consequently, the WRR geotool often serves to either replace or enhance existing internal agency work, resulting in high efficiencies and lower costs (Bryson et al., 2010; Bryson et al., 2013). Moreover, permit applicants are able to access the WRR geotool on-line with the same privileges granted to regulators, enabling them to streamline the permit approval process by avoiding high impact areas; additonally training for project proponents is under consideration (Bryson et al., 2010; Bryson et al., 2013).

The WRR can be accessed through a public website, offers interactive mapping tools and is being applied within the regulatory and planning frameworks of WRR state, federal, local and other partnership agencies. Keyed for application in the early planning stages of private sector development projects or public infrastructure modifications, the WRR is quite useful in selecting sites for mitigation of projects that damage wetlands, or degrade high-value aquatic resources, and is often used to find locations for the retrofitting of stormwater systems to enhance water quality. The WRR can be applied to develop mitigation frameworks, for example, the Maryland Department of the Environment has plans to use the WRR to design an "in-lieu fee" program to offset wetland loss (Bryson et al., 2010; Bryson et al., 2013).

The Office of Environmental Design within the Maryland State Highway Administration (SHA) is obligated to avoid, minimize, or provide compensatory mitigation for wetland loss caused by highway construction and maintenance, and accordingly the SHA makes extensive use of the WRR geotool to create designs acceptable to the USACOE and the Maryland Department of the Environment (MDE) quickly and at low cost. Notably, the SHA is making heavy use of the WRR in planning its operations to adhere to total maximum daily load (TMDL) requirements established by the EPA in 2010. These EPA TMDL limits on nitrogen, phosphorus, and sediment pollution must be achieved through a process of land use planning required of the District of Columbia and all states that cover a part of the Chesapeake Bay Watershed. The WRR geotool is being employed by the SHA to efficiently locate and rank candidate sites for activities aimed at meeting EPA TMDL goals, such as, constructing or upgrading stormwater management facilities, improving highway grading, stabilizing erosion, reforestation, wetland creation, impervious surface replacement, and shoreline stabilization (Bryson et al., 2010; Bryson et al., 2013).

Following the completion of all eight suitability analyses across Maryland, establishment of the WRR web-mapping site in 2011 and full quality control in 2012, training on the WRR geotool for its multiple-agency user community, begun in 2012, is ongoing. Although the WRR has thus far been applied only across Maryland, a long term goal is to expand this comprehensive geospatial service that integrates regulatory and permit applicant planning on the scale of full watersheds to other states, progressing toward national implementation using comparable and common format data layers (Bryson et al., 2010; Bryson et al., 2013).

The Landscape Conservation Management and Analysis Portal (LCMAP):
The Landscape Conservation Management and Analysis Portal (LCMAP) provides Landscape Conservation Cooperative (LCC) projects ways to preserve, collaborate on, document, publish and share data, and allows other researchers to search for and discover these data. All of these capabilities are critical for scientific data lifecycle management, a critical need for large landscape analyses and consistent with the Open Data Initiative. Through this capability, LCC coordinators can ensure data products delivered as a part of funded projects are captured and shared with all LCCs, other landscape conservation efforts, and the public at large.

LCMAP is part of the USGS ScienceBase project, a data and application sharing environment developed by the USGS Core Science Analytics, Synthesis, and Libraries (CSAS&L) Program. The LCMAP web application provides both occasional and expert user functionality. For the occasional user, a web-based interface allows researchers and data managers to upload, document, and define access constraints on their datasets. Other researchers can then use the web-based interface to discover, view, and download these datasets. Expert users can take advantage of the web services provided by ScienceBase, and each dataset and metadata file loaded into ScienceBase can be accessed through the ScienceBase Applications Programming Interface (API). This API transforms spatial datasets into Web Mapping, Feature and Coverage Services, and metadata in a variety of output formats. Together these services provide developers with unique ways to load, access, manage, view and expose ScienceBase items.

Consequently, a user no longer has to download data and metadata for later exploitation; instead, all items can reside in ScienceBase and can be viewed the way the developer wants to present them in their own portal.

Landscape Conservation Cooperatives, Climate Science Centers, and over 40 regional projects use ScienceBase to both build and distribute datasets. Due to this capability, these projects have a service-driven collection point for their data and metadata, allowing researchers to find and use these items through any number of viewers. Examples are numerous and widespread:

- Geospatial specialists and modelers access ScienceBase data through ArcGIS;
- Python and R programmers develop models that use ScienceBase data through custom libraries; and
- Web portal developers turn ScienceBase items into project-specific analyses and displays.

Consistent with the mission of Project Open Data, ScienceBase makes data available, discoverable and usable. That promotes efficiency and effectiveness in conservation, as well as creating new research opportunities.

LCMAP and ScienceBase serve an important data management function for large landscape conservation activities. However, new research methods, project needs, and data formats present challenges that cannot be addressed within the current technical framework. For that reason, ScienceBase is partnering with the National Science Foundation EarthCube Program to develop the next generation of tools for researchers. ScienceBase 3.x, the next version of the application, is designed to address the challenges of larger files, data and model linkages, and the treatment of many more data and metadata formats. This effort will provide science data lifecycle support for a much broader range of landscape conservation and mitigation projects.

Data Basin and Integrated Landscape Conservation Cooperative (LCC) Planning Atlases

Data Basin (databasin.org) is a web-based, science support and mapping platform managed by the Conservation Biology Institute. Thousands of researchers, conservation practitioners, policy makers, educators, and engaged citizens are downloading spatial datasets, engaging with networks of experts and stakeholders, and utilizing non-technical, open-access mapping and collaboration tools. Well-documented biological, physical, and socio-economic datasets are available for download and dynamic integration. Users can explore and conduct summary analysis of the distribution, status, trends, risks, threats, factors affecting priority wildlife, plants, cultural resources, and ecosystems.

Multiple organizations have launched customized branded sites powered by Data Basin to provide easy access to curated datasets and increase stakeholder engagement. Examples include US Fish and Wildlife Service Pacific Southwest Region, the Desert Renewable Energy Conservation Plan, Adaptwest, and Heart of the Rockies. Many Landscape Conservation Cooperatives (South Atlantic, North Atlantic, Gulf Coastal Plains and Ozarks, Gulf Coast Prairie, North Pacific, Desert, Pacific Island Climate Change Cooperative, Western Alaska, Aleutians and Bearing Sea, Arctic, and Boreal) have created customized Conservation Planning Atlases to leverage the complementary aspects of Data Basin and USGS ScienceBase. These Conservation

Planning Atlases provide a central resource for multiple agencies, organizations, and individual users to view, retrieve, and perform analyses on spatial information with their own conservation goals in mind. Users can conduct planning and evaluation from common datasets and users without desktop GIS can use basic mapping tools in a collaborative environment. All the Conservation Planning Atlases benefit from additional partner-driven enhancements to datasets, tools, and best practices.

The methods and technologies developed by CBI and the LCC Conservation Planning Atlases can be used to improve mitigation practices because they are designed to reduce social and technical barriers to collaboration and negotiation for stakeholders (local, state, federal, and national agencies, universities, non-profits, tribes, citizens, and industry). The common data standards and methods for organizing information established by the Conservation Planning Atlases provide a standard for documentation and attribution. All datasets have an overview page that displays associated information (e.g., credits, description, use constraints, tags, usage statistics, attribute definitions, and associated reports or other files). Users can access and visualize datasets hosted within a Conservation Planning Atlas and on compatible external servers through map services. Users can define custom styles and filters, analyze hosted datasets, draw and comment interactively on maps, and save and export maps to use later or share with colleagues. Groups can be created and managed to share public and private data. Together the tools available on Data Basin and the Conservation Planning Atlases provide a means to organize, visualize, review, and enhance communication regarding multiple aspects of the mitigation process.

CBI and Data Basin have demonstrated the added value of creating interoperability with government datasets (e.g., USFS, USFWS, NOAA, etc.) and catalogs (e.g., ScienceBase). The success of security enhancements required for a collaborative project with USFWS Pacific Southwest (psw.databasin.org) web mapping portal is dependent on further collaboration and integration with USGS ScienceBase. Priority enhancements also include creating shared methods, tools, and/or application programming interfaces (APIs) with the national Geospatial Platform, Bureau of Land Management, USFS, and other agency resources. The Data Basin platform has unrealized potential to support data collection associated with inventory, monitoring, restoration, mitigation, and resource management. Enhanced investment and support for mobile viewing and data collection will further empower a growing and diverse audience seeking to better inform resource management decisions.

LandScope America:

LandScope America (www.landscope.org) is an online geospatial tool that supports landscape-scale mitigation, particularly in the early phases of conservation planning. LandScope minimizes the time and effort involved in accessing mitigation-relevant, decision-quality geospatial datasets by integrating authoritative data layers from federal and state agencies and NGOs depicting conservation priorities, protected areas, species and ecosystems, threats, energy, recreation and other reference layers into one publicly accessible online platform. Decision-makers need no technical expertise to have one-click access in LandScope's mapping interface to preview curated maps for their area of interest (Figure 2). Communities of practice use LandScope to save and share custom map views enhanced with annotation, and also narrative and visual stories that help illustrate the conservation values on the landscape. LandScope includes state and regional hubs that further advance the collaborative conservation objectives of these communities of practice.

LandScope Chesapeake is the shared conservation priority system supporting the Chesapeake Conservation Partnership, a consortium of more than 50 federal, state and NGO partners working together to protect and restore the Chesapeake Bay Watershed. LandScope Chesapeake provides a central, watershed-wide clearinghouse for mapping data, with over 200 data layers depicting cultural, natural and recreational resources. Guided by the June 2014 Chesapeake Bay Watershed Agreement (CBWA) and associated management strategies for achieving agreed land conservation outcomes, partners are using LandScope to make data-driven, cross-jurisdictional prioritization decisions about land protection. LandScope Chesapeake also provides the primary mechanism for tracking progress toward the CBWA goal of protecting 2 million additional acres by 2025. LandScope incorporates regular updates to a comprehensive watershed-wide GIS dataset of protected lands; users can visualize the data on the map and can generate a report showing land protection statistics for the entire watershed or by jurisdiction.

In 2014 LandScope upgraded its mapping interface and published its entire geospatial catalog to ArcGIS Online. As a result of the tool's new architecture, LandScope dynamically shares geospatial services to and from federal and state agencies and other data partners. For example, LandScope Chesapeake sources the authoritative land protection dataset for the watershed directly from the Bay Program data source, reducing latency from the time of update to public access. Similarly, LCC collaborators can access, analyze, and integrate LandScope's map services with other geospatial services from other sources like the Geospatial Platform and USGS ScienceBase.

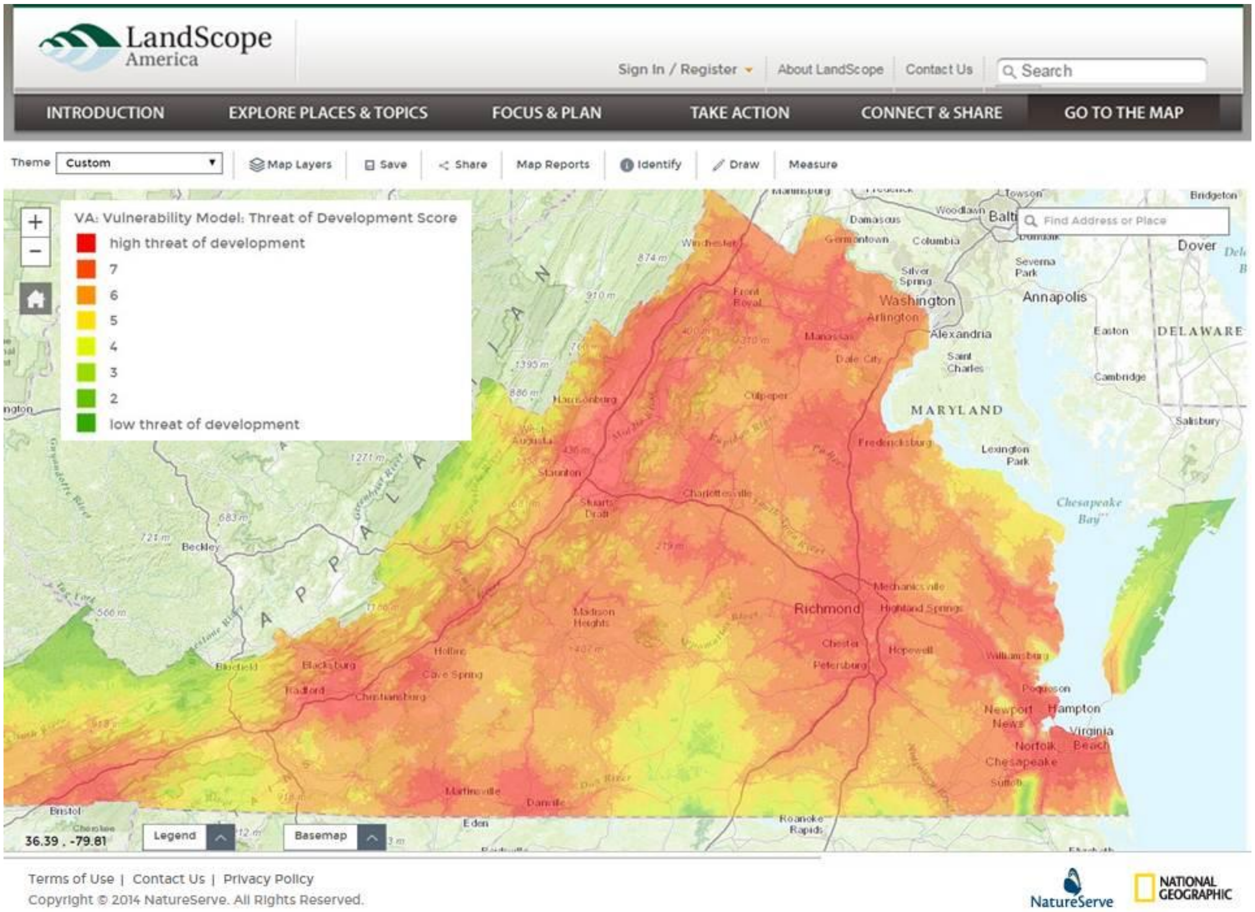

Figure 2. LandScope America's map layer for Virginia Threat of Development based on vulnerability modelling (Courtesy of Lori Scott, NatureServe).

Examples of Highly Useful Decision-Support GIS Models

The examples below are concise presentations of highly regarded decision-support GIS models, namely, the Chesapeake Conservancy's Precision Conservation Landscape Analysis and the Western Governors Association Crucial Habitat Assessment Tool, describing the inception, functional utility, prime applications, and planned future enhancement of these geotools.

The Chesapeake Conservancy's Precision Conservation Landscape Analysis:

Precision Conservation (PC), or "getting the right practices, in the right place, at the right scale," uses emerging technologies and available high resolution aerial imagery and LiDAR (Light Detection and Ranging) derived elevation data to determine landscape characteristics across entire watersheds. Land use and land cover (LULC) are among the most important spatial datasets needed for conservation targeting in mitigation. To achieve a high level of detail in LULC mapping, the Chesapeake Conservancy (CC) has developed a methodology that uses regularly collected aerial imagery from the USDA's National Agriculture Imagery Program (NAIP) and LiDAR elevation data from the USGS in an object-oriented feature extraction workflow. Combined with PC 1-meter land cover geodata, the Conservancy's LiDAR-derived Concentrated

Flow Path (CFP) maps help land managers understand surface water flow and rate flow paths based on upstream land cover composition and potential nutrient and sediment loads (Figure 3). Thereby, the Conservancy's CFP datasets identify priorities for conservation and restoration, help target outreach and education efforts, and inform property owners on the most effective potential restoration or mitigation actions. These decision-support products allow Best Management Practice (BMP) implementation by targeting the areas that will create the greatest reductions in nutrient and sediment runoff. CFP-identified flow paths with higher weighted flow accumulations are ranked on the Conservancy's datasets as the most critical landscapes on which to focus BMPs such as planting cover crops, restoring streamside buffers and wetlands, or creating retention ponds.

The Chesapeake Conservancy has been working with local partners on a number of applications that implement our Precision Conservation data products to improve their conservation targeting capabilities including:

- Identifying hotspots within priority watersheds that would benefit from conservation and restoration based on current landscape conditions,
- Directing project funding to where it will have the greatest impact on improving water quality or critical habitats,
- Designing BMPs based on the landscape to maximize performance,
- Calculating or comparing the anticipated outcomes of potential projects in a high-priority watershed,
- Working with landowners to locate a potential project where it will maximize water quality or critical habitat benefits, and
- Targeting education and outreach to landowners in high priority areas to help them understand what they can do to reduce the impact of their land and improve ecosystem services.

Access to the high resolution geodata created by the Chesapeake Conservancy provides users with a greater understanding of what resources will be impacted by a proposed project, and informs appropriate compensatory mitigation. In addition to improving the validity and accuracy of conservation modeling efforts in the near term, PC high-resolution land cover data products provide a baseline for detailed land use change analyses over time to track critical habitats and where land conversion impacting high-functioning watersheds. Despite the challenges associated with creating PC data products, access to detailed and accurate land cover datasets is highly advantageous for landscape-scale mitigation. The high-resolution land cover and hydrology PC geodata have the potential to improve many aspects of environmental management by helping land managers to site even quite small projects at optimal locations. In summary, the Chesapeake Conservancy's work to improve the resolution of regional LULC and elevation data products, and to increase access to these data, will allow managers to make decisions on a much finer scale, thus improving the accuracy and validity of mitigation efforts.

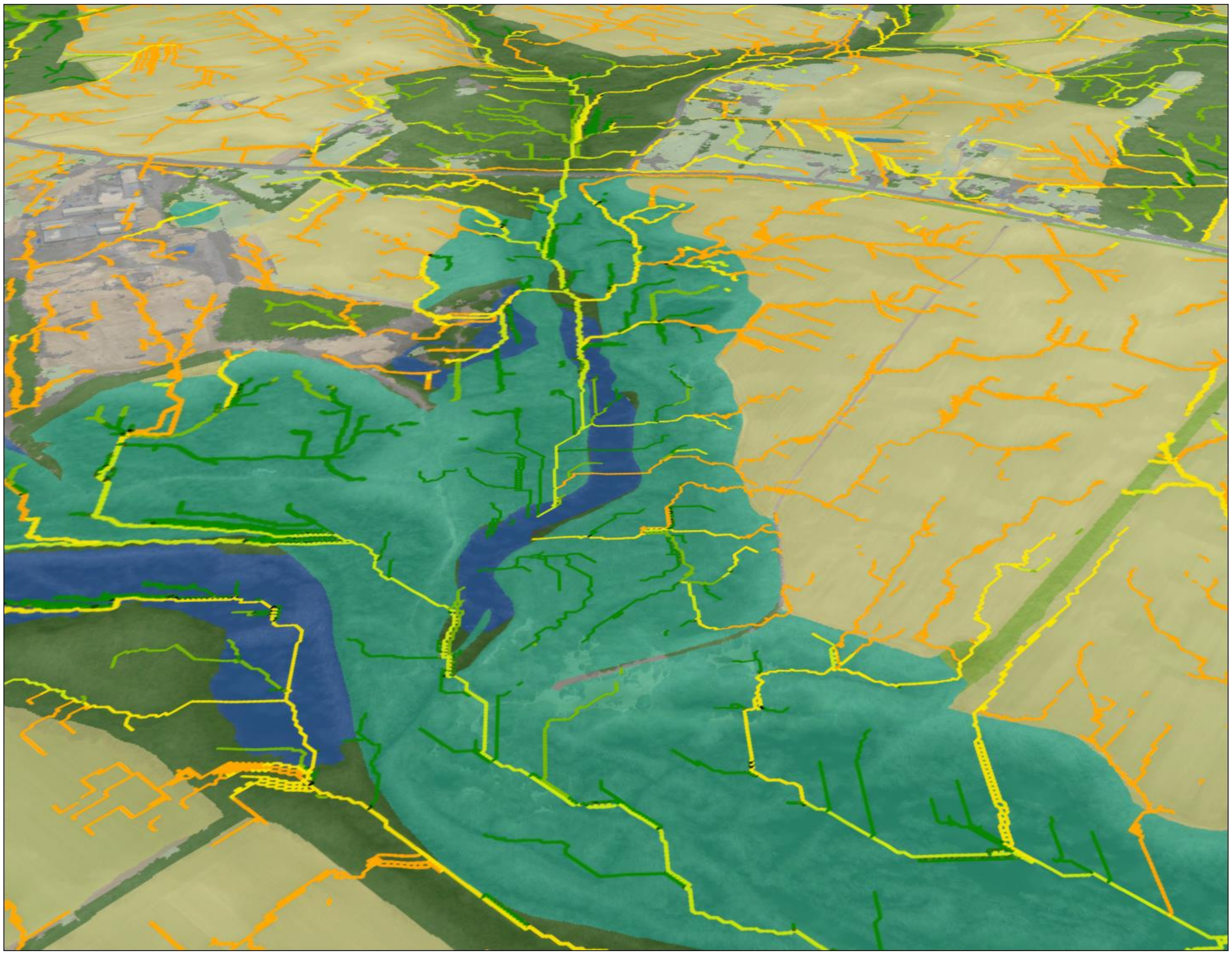

Figure 3. A perspective view of the Chesapeake Conservancy's Precision Conservation 1-meter land cover data layer (based on the USDA's National Agriculture Imagery Program (NAIP) aerial photography), overlain by the Conservancy's LiDAR-derived Concentrated Flow Path (CFP) maps (Courtesy of Jeff Allenby, Chesapeake Conservancy).

The Western Governors Association Crucial Habitat Assessment Tool:
Crucial habitat is defined as areas on the landscape containing important natural resources for fish and wildlife species, including food, water, cover, shelter and important wildlife corridors; all of which contribute to the survival and reproduction of aquatic and terrestrial species and are necessary to prevent unacceptable declines, or facilitate future recovery, of species populations. In 2007, recognizing the value in landscape conservation and the need for consistent representation of high priority natural resource information, the Western Governors Association (WGA) requested that Western states, in partnership with stakeholders, identify key wildlife corridors and crucial wildlife habitat. To meet this request, the WGA established the Western Governors' Wildlife Council (WGWC), a group that works to provide habitat and corridor information to federal, state and local governments, stakeholders, and partners; and promotes the uniform mapping of this information in a GIS format for all to use (www.westgov.org/wildlife-corridors-and-crucial-habitat). In December, 2013 the Crucial Habitat Assessment Tool (CHAT, www.westgovchat.org) was launched, providing public online

access to non-regulatory delineations of high priority crucial habitat in a consistent dataset that spans 16 states: Alaska, Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming.

Developed in collaboration with a stakeholder committee, the WGA-CHAT Project was designed to provide access to non-regulatory crucial habitat information early in project pre-planning phases. WGA-CHAT geodata can be viewed online during the initial phases of project planning, to provide an initial overview of important natural resources in a proposed project area. If warranted, a GIS Analyst can then use available web services, or download the data to run additional complex queries, statistical summaries, or spatial analyses to highlight areas where a project may especially impact fish and wildlife habitat. The WGA-CHAT provides easily accessible abilities to investigate potential impacts to high priority natural resources, drastically increasing both the timeliness of project impact assessment, and the transparency of working with state agencies. Further, WGA-CHAT data is updated and maintained by the responsible state agencies, ensuring that users are accessing the best available data, and that the same data are used within state agencies for their own more localized analyses and assessments. Although the potential audience for CHAT is extremely varied, emphasis is placed on planning for large landscape projects that frequently span across state borders, and often center on energy and transportation development.

To delineate crucial habitat, the WGWC and technical representatives from state fish and wildlife agencies across the Western United States worked in collaboration to develop the following standardized ecological data input layers (Figure 4):

- Species of Concern;
- Native and Unfragmented Habitat (including Landscape Condition, Large Natural Areas, and Landscape Connectivity);
- Wildlife Corridors, Riparian and Wetland Habitat; and
- Species of Economic and Recreational Importance.

Each state determined their “best available” data, which was aggregated into applicable data input layers and then used to produce an overall “roll-up”, classifying crucial habitat into a rank of 1 (most crucial habitat) to 6 (least crucial habitat). All layers within the WGA-CHAT use a consistent ranking scheme and consistent base data (assessment units), resulting in seamless maps of crucial habitat and data input layers, spanning across the entire Western United States. These maps can be viewed within the WGA-CHAT mapping application via a simple web browser, and can also be accessed through GIS software for additional functionality. Detailed documentation and metadata on each state’s aggregation process, data inputs, and species information are available through the WGA-CHAT website, and accompany geodata upon download.

Figure 4. Diagram depicting the standardized ecological data input layers used to delineate crucial habitat by the WGA-CHAT (Courtesy of Arthur Rodriguez, Oregon ODFW).

The WGA-CHAT Project has been leveraged to support state fish and wildlife mapping applications, and as of early 2015, nine of the sixteen Western states participating in CHAT have released their own mapping applications, and at least two more states plan to release mapping sites within the next year. The WGA-CHAT Project required states to compile and aggregate a variety of species and habitat GIS and tabular data into common formats, steps intended to allow aggregation of these data into crucial habitat layers. For many states, this allowed data previously maintained in hard copy file cabinets to be reformatted into standardized, centralized databases. The resulting improvement in data management, and subsequent development of state mapping applications, drastically improves the accessibility of state developed and maintained fish and wildlife data to partners, stakeholders, the public, and internally within the participating state agencies. Providing consistent data, in accessible formats, increases the incorporation of state fish and wildlife priorities within project planning by industry, as well as partner federal and state agencies and conservation groups. A primary value of the CHAT project is providing multiple ways to access streamlined, compiled, and prioritized information, spanning across large landscapes, that has been vetted by state fish and wildlife agencies.

The WGA-CHAT has quickly proven its ability to improve access to state fish and wildlife data for partners, stakeholders, and other customers. Industry is currently using the WGA- CHAT to streamline project planning, and federal agencies and conservation groups are also using the WGA-CHAT to access crucial habitat information covering large areas across the Western landscape. Not all states use the same data input layers, however, the WGA-CHAT Project will strive to ensure higher consistency between the similar data input layers between states, to allow users to access larger expanses of multiple data input layers across multi-state landscapes, rather than just access the "canned" overall aggregated crucial habitat. As states continue to update and refine their analyses, additional opportunities to build more consistency throughout the WGA-CHAT project area will arise.

Recommendations for Geospatial Services that Aid Strategies and Plans

The Workshop participants were unanimous in perceiving a pressing need to reduce barriers that prevent or inhibit all-source data sharing between DOI bureau field offices, small NGOs and the larger mitigation community. In response, Recommendation 3 below is intended to stimulate a shift away from operating within individual programs and offices towards operating on a national scale across federal and state agencies and all relevant NGOs:

Recommendation 3: Inventory and where appropriate, collect, locally managed, project-specific geodata collected and maintained by federal and state agency field offices and NGOs, and make those datasets readily available through the most appropriate centralized geoportal(s). Register the relevant contents of these geoportals as a part of the Mitigation GDI Community of Practice, thereby reducing the barriers for DOI field offices and NGOs to share their data with the broad mitigation community and stimulate a shift towards operating at a national scale across federal and state agencies and NGOs.

The concept of critical habitat "intactness" within the ecosystems that populate landscapes lies at the core of the analyses that underlie many GIS decision-support models, and the Workshop participants identified the lack of consistent geodata for roads and federal land parcels as a major shortfall. The recommendation below is offered to correct this major and pervasive limitation in conducting regional assessments and decision-support modeling for regional conservation strategies and plans:

Recommendation 4: Support the construction of merged and comprehensive high quality national data layers of land cover and land use (LANDFIRE, GAP, NLCD) along with the depiction of federal land parcels and roads to enable consistent and broad analysis of habitat "intactness" within regional assessments and decision-support modeling beyond jurisdictional boundaries.

CHAPTER 4 - COMPENSATORY MITIGATION PROGRAMS

The Department's new landscape-scale mitigation Strategy does not involve changes to regulatory or legal requirements; instead, it presents a more holistic philosophy that will be implemented through streamlined operations, focused geospatial capability improvements, and by the issuance of insightful guidance and enhanced policies. The Strategy seeks to expand use of the "full mitigation hierarchy" approach, a progression from avoidance to minimization and finally to required impact offset, beyond its prior application under the Clean Water Act to also cover remediation mandated by the Endangered Species Act and the National Historic Preservation Act that has historically focused mainly on only avoidance (Law360, 2014). The legal responsibility to minimize and, where unavoidable, compensate for, the negative environmental impacts of major development projects, was initiated by the Fish and Wildlife Coordination Act of 1934. Over the decades that followed, the concepts and requirements for environmental mitigation have been imbued into many other statues and implemented programs. The practice of mitigation has been improved by remarkable scientific advances during those decades, and has been refined through long experience with the implementation of the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the wetlands protection afforded by Section 404 of the Clean Water Act, the National Historic Preservation Act (NHPA) and a wide range of other federal and state laws.

Compensatory Mitigation within the DOI Landscape-Scale Strategy

As used herein, the term "mitigation" refers to the entire range of actions taken to avoid, minimize, and compensate for the adverse consequences of development, not simply required compensatory mitigation. As a result of experience in implementing the NEPA and the Clean Water Act (CWA), a preferred sequence of steps, referred to as a "hierarchy", has been established for mitigation-related planning and serves to underpin the Department's landscape-scale mitigation Strategy. The progressive steps in this hierarchy, ordered below from most to least desirable, are defined as:

1) Avoidance: Defined as the siting of projects such that no negative impacts prevail. Avoidance is the preferred option, as this is the best possible conservation outcome and there is no need for project proponents to minimize or offset environmental damage.
2) Minimization: Should there be no option to avoid impacts altogether, and the projected impacts are tenable, the minimization of associated negative consequences is accepted as the best possible mitigation approach.
3) Compensation: If there remain impacts that cannot be either avoided or minimized, the next step is to compensate for, or offset, those residual negative impacts. Herein this least desirable approach is referred to as "compensatory mitigation", which may involve attempts to restore, enhance, create or preserve wetlands or habitats to offset the loss or degradation of like resource values.

Acquiring and arranging the indefinite conservation of wetlands or other critical habitats can also serve as an offset to unavoidable impacts under the ESA, but this approach has not typically been employed under the CWA. Further, note that while the favored sequence for considering mitigation actions is first avoid, second minimize, and third compensate, circumstances do arise in which the highest conservation benefit, or the most benefits per cost, does not derive from rigidly adhering to this hierarchy.

The Department's Strategy encompasses the full use of three well established forms of compensatory mitigation termed, "permittee-responsible", wetland or habitat "banking", and "in-lieu fee", which are applied in summation cross geographically broad regions. In the most historically common form of compensatory mitigation, called "permittee-responsible", the permit recipient performs the required offset actions, or directly contacts another party to perform the actions. A second form of compensatory mitigation, termed "banking", is used where offset actions are more economical or have improved conservation outcomes if undertaken prior to development projects. Under the third type of compensatory mitigation, known as "in-lieu fee" (ILF), a project proponent pays a fee to a third party, with the understanding that those funds will later be applied to appropriate conservation activities.

In the past, compensatory mitigation practiced by DOI bureaus, principally the Bureau of Land Management and the Fish and Wildlife Service, have mostly been project-by-project efforts tied to individual project sites. Historically, the USACE and the EPA have made much heavier use of compensatory mitigation under Section 404 of the Clean Water Act then has the DOI. Driven by expanding renewable energy development, active infrastructure siting, and the need to plan for climate change, the DOI Strategy signifies a full embrace of compensatory mitigation. The impetus for this shift towards increased DOI use of compensatory mitigation to accommodate renewable energy development aligns with Section 211 of the Energy Policy Act of 2005, 2001 Executive Order 13212, and the Renewable Portfolio Standards and the Energy Independence and Security Act of 2007, as all encourage the development of renewable energy. Rapid renewable energy development is driving a need for improved infrastructure, and in response 2012 Executive Order 13604 states the intent *"to significantly reduce the aggregate time required to make decisions in the permitting and review of infrastructure projects . . . while improving environmental and community outcomes"* (Burke, 2014).

Although the practice of compensatory mitigation and related private sector enterprise has grown over roughly the last 20 years to total about $2.9 billion in annual expenditures for stream and wetland restoration alone, the net success of compensatory mitigation in restoring and protecting natural resources is not well established. For example, studies by both the National Research Council and the US Government Accountability Office have suggested that current practices of compensatory mitigation do not adequately conserve aquatic resource functions and services (Bronner et al., 2013). Planning and decision-making in compensatory mitigation could be improved by enhanced geospatial resources at requisite space and time resolutions, and by geospatial services for strategically directed resource assessments, optimization analyses, and predictive modeling. Two specific geospatial services that are deeply meshed with compensatory mitigation practices, the USACE Regulatory In-Lieu Fee Bank Information Tracking System (RIBITS) and the USFWS Tracking and Integrated Logging System (TAILS) are candidates for enhancement, and are described below.

The RIBITS Geoportal for Compensatory Mitigation Data

RIBITS, the Regulatory In-Lieu Fee Bank Information Tracking System, is a US Army Corps of Engineers database that tracks third-party compensatory mitigation in the form of mitigation banks and ILF programs. RIBITS is a uniquely comprehensive working database for compensatory mitigation because it collects information on banking activity from a broad and diverse user base that includes bank sponsors, Corps bank managers, interagency review teams, and others. The USACE Engineering Research Development Center (ERDC) teamed with the US Environmental Protection Agency's Region 4 to initiate RIBITS with the aim of tracking mitigation banking within the USACE Mobile District. Subsequently, in 2007 the USACE and EPA jointly pursued a nationwide expansion of RIBITS, thereby creating a repository for a wide range of information related to third-party mitigation that provides public access to this information parsed by district or state. Project proponents and other users can locate banks that serve specified projects, identify areas underserved by mitigation banks or ILF programs, download bank-specific instrument documents and monitoring reports, and can access documents that provide national or local-level guidance for conducting compensatory mitigation. Specifically, information regarding bank contracts, service areas, status, credit type, availability and ledgers is all readily available to RIBITS users (Martin, 2009; Martin and Brumbaugh, 2011).

RIBITS relies on a Google Earth plug-in for mapping functions that support roads, and state and local boundaries, as well as USACE district boundaries hydrologic unit boundaries and the locations of banks. In order to support targeted retrievals, RIBITS incorporates database query functions that allow searches of ledgers, and geospatial filtering by state, Corps district, mitigation type (restoration, enhancement, preservation or other) and compensation type (wetland, stream or species). RIBITS holds bank data for most, if not all, 38 Corps districts, and most of these districts make their bank data available to the public through RIBITS. The popularity and value of RIBITS has been enhanced by an open-source philosophy that has resulted in ready access by mitigation bank sponsors, permit applicants, non-governmental organizations, representatives of federal, state, and local agencies, academic researchers, and the general public (Martin, 2009; Martin and Brumbaugh, 2011).

USFWS's Tracking and Integrated Logging System (TAILS)

The Fish and Wildlife Service's Tracking and Integrated Logging System (TAILS) was borne of grassroots efforts to provide timely recordation of Field Office environmental review efforts under such authorities as Section 7 of the ESA, FWCA, CWA, MBTA, the Federal Power Act, NEPA, the Sikes Act, CBRA, BGEPA and others. Since 2006 TAILS has been a nationally-mandated system for staff engaged in these environmental review processes and is currently the most heavily-used internal USFWS tracking system (based on daily access data). TAILS also allows USFWS offices to record their spill response efforts and to track work performed under NRDA and other authorities related to environmental contaminants. Additionally, TAILS serves as the USFWS central and exclusive repository for records of field office work in both Environmental Review and Environmental Contaminants processes. As of February, 2015, TAILS hosts over 600,000 project records, including 372,000 Section 7 consultation records. It is important to note that regardless of where a record of engagement through Section 7 originates, whether it is from a public user accessing the USFWS Information, Planning and Conservation System (IPaC), or by USFWS field staff directly adding it to TAILS, the record is routed to and stored in TAILS in all cases. A basic on-line mapper in TAILS allows USFWS staff to visualize compensatory mitigation sites, as well as the spatial relationship between project sites across the country. Standard rudimentary mapping tools are provided in the on-line mapper, and underlying spatial references available through the mapper include standard spreadsheet, Google Earth, and GIS-readable options that allow ingest to GIS for further analyses.

Recommended Improvements to Geospatial Services for Compensatory Mitigation Programs
Documented and objective geospatial resources and services provide a common neutral basis for knowledge-based and transparent resolution of conflicts, and ensure that policies and agency decisions are defensible on a factual basis. Moreover, geospatial capabilities allow for the course corrections called for by adaptive management, justified by an open, non-partisan and on-going evaluation of success in achieving the best possible conservation outcomes. The October 2014 Workshop resulted in numerous practical suggestions for optimizing the GDI that would indirectly enhance the success of compensatory mitigation. Although these suggestions have broad utility and thus are mostly covered by recommendations included in other Chapters of this Report, several are worthy of mention in the immediate context of compensatory mitigation.

A comprehensive and merged baseline national data layers depicting roads (including roads on public lands) and federal land parcels should be constructed to fill a gap in the foundational geodata needed for regional assessments that initiate the mitigation cycle (see Recommendation 4). Second, the discrimination of wetland candidate regions with high restoration potential as an enhancement to National Land Cover Dataset Maps and LANDFIRE / National GAP Analysis Program (GAP) Geospatial Products would serve to increase the effectiveness of wetland mitigation banking siting, design and subsequent value (see Recommendation 1). Wetland mitigation bankers lack clear and unambiguous guidance in the evaluation of bank effectiveness, a deficiency that could be rectified through developing and sharing authoritative ecological performance and monitoring standards (see Recommendation 6). Third, training on the use of geospatial products in regional assessments and geospatial decision-support models should be made readily available to ILF mitigation sponsors to improve site selection and the accuracy of ILF cost estimates (see Recommendation 2).

The mapping capabilities that are incorporated within TAILS are in need of improvement, but any enhancements to the TAILS mapper should be placed in the context of upgrading and better unifying the top-level mapper in the USFWS Environmental Conservation On-line System (ECOS) to allow easier deployment of mapper advancements and capabilities throughout all ECOS modules. Fortunately, recent advancements in web-mapping services and the ease of posting such services has significantly increased options to realize the needed enhanced ECOS mapper layer availability. Publication of TAILS web-mapping services would also enable USFWS field staff without extensive GIS training to more easily overlay project reviews over recovery plans, watershed plans, resource data, past work and other layers that can aid in ranking their engagements in improving the status of particular resources on the landscape. Recognizing this need, the October 2014 Workshop yielded the following high priority recommendation:

Recommendation 5: Add mapping capabilities to databases used to track compensatory mitigation habitat plans (for example, the USFWS Tracking and Integrated Logging System (TAILS)) to increase the sophistication of geographic information that DOI staff can associate with each project-review record stored in a centralized and accessible archive. Additionally, explore possibilities for improving the linkages, interoperability, and geospatial data-sharing between the USFWS TAILS and the USACE Regulatory In-lieu Fee and Bank Information Tracking System (RIBITS) online databases to better provide a widely accessible inventory of the location, nature, history, and performance of all U.S. conservation banks.

CHAPTER 5 - MONITORING FRAMEWORKS

The DOI Strategy supports aggregation of decision-making through the collaborative development of regional conservation plans that unavoidably incorporate much uncertainty regarding the likelihood that the planned mitigation actions will actually bring about the intended results (Clement et al., 2014; Moore et al., 2011). The DOI Strategy considers mitigation actions to be sequential and potentially iterative, allowing for the accumulation of insights that can improve understanding of ecosystems, and thus lead to improved mitigation actions. Most broadly stated, the DOI Strategy is an expression of *adaptive management*, an approach to conservation decision-making that originated out of operations research conducted in the 1950s (Walters and Hilborn, 1978).

Basic scientific inquiry is not the central focus of adaptive management, rather, the goal is to gradually accumulate knowledge about the success of applied actions, ultimately leading to improved strategies and subsequent actions. The primary innovation of adaptive management is to integrate learning about natural systems with land management planning, so that decisions can be made even as uncertainty is being resolved. Continuous and persistent *monitoring* of the eco-region is essential, because it drives the improvement of regional assessments, essentially GIS-modeled understandings of the eco-region, leading to revised conservation plans that impose better mitigation performance. Adaptive management supersedes the traditional one-way science-to-management relationship, but still allows the construction of defensible plans, even if research questions have not yet been definitively answered. The DOI Strategy is quite compatible, because *adaptive management is scalable* from the project-level to the ecosystem to the fullest landscape-scale, and therefore is well suited for solving complex mitigation problems across expansive eco-regions in spite of uncertainties about ecological structure and processes (Williams et al. 2009).

During the last decade the Department has adopted the Decision – Theoretic approach to adaptive management, a version that stresses communication among all involved parties, and focuses on defining land management problems, objectives and actions prior to the development of complex ecological models (Williams et al., 2009). As implemented within the DOI Strategy, adaptive management is a structured decision-making framework that has several requisite components (Williams et al., 2009; Lyons et al., 2008; Nichols et al., 1995; Kendall, 2001). First, scientific findings are extrapolated across the landscape using geodata layers and standardized GIS operations, yielding regional assessments that capture the current understanding of the structure and ecological function of the eco-region. Note that management uncertainty is represented by competing, or improving, versions of the regional assessment, and that the selection, or acceptance, of a version of the regional assessment lies at the core of the development of conservation strategies and compensatory mitigation plans, the second and third requisite components. Second, a system of monitoring is established to inform on the ecoregion state, and to provide feedback on the relative performance of the actions taken under the accepted conservation and compensatory mitigation plans. The DOI Strategy requires that the suite of monitoring metrics is judiciously chosen to both inform on progress towards mitigation goals and provide the observations needed to resolve lingering uncertainties in the regional assessment of the eco-region. Accordingly, as applied by the DOI Strategy, adaptive management defines clear purposes for monitoring and allows the easy discrimination of relevant monitoring metrics from less well targeted observations (Nichols and Williams, 2006; Lyons et al., 2008).

The final step in the DOI Strategy four-step process within the landscape-scale approach to mitigation is *(IV) monitoring* and evaluating progress, followed by adjustments, as necessary, to ensure that mitigation is effective despite changing conditions. Specifically, the DOI Strategy states that in concert with development project implementation, a monitoring strategy must be developed that permits: 1) accurate and transparent assessment of the current status of the resources of concern, 2) an appraisal of how the development project has affected those resources, and finally, and 3) an indication of progress towards achieving the specific mitigation objectives for the resources and values impacted by the project. The DOI Strategy recognizes that a successful monitoring framework within the adaptation management process requires the establishment of management benchmarks to ensure progress toward mitigation goals and to establish protocols for evaluating progress relative to the benchmarks. Finally, adhering to the Strategy requires the commitment, fiscal resources, and ability to make adjustments in response to on-going monitoring that persists over the duration of development impacts (Clement et al., 2014).

Examples of Effective Monitoring Frameworks

Condensed descriptions of well-established and effective existing monitoring frameworks are provided below as "best practices" examples. First, experience within the NPS on managing national inventory and monitoring data, landscape dynamics monitoring and the tracking of air and water quality and quantity is presented. Next, the LANDFIRE partnership that produces nationally consistent, accurate, complete, and comparable data on fire fuel, vegetation and biophysical conditions by combining Landsat imagery with biophysical data and existing ground plots gathered from various sources is briefly reviewed. Finally, the Bureau of Land Management (BLM) Assessment, Inventory, and Monitoring Strategy (AIM) that provides high-quality information about ecosystem conditions and trends at multiple scales and thereby allows effective BLM management of renewable resources is presented.

NPS Natural Resource Geospatial Data for Inventory and Monitoring at Landscape-Scales

Integrated Resource Management Applications (IRMA) Services: NPS inventory and monitoring (I&M) data are delivered where possible via an integrated suite of applications (http://irmaservices.nps.gov/). At present they include: (1) NPSpecies – A system dedicated to documenting the occurrence and status of species in NPS units; (2) Units - Names, codes, and affiliations of NPS units; and (3) DataStore – A metadata and file repository for the management and discovery of all types information including reports, maps, and data sets. I&M 'vital signs' monitoring data (Table 1) are housed and distributed via the DataStore. The DataStore is also the primary discovery mechanism for other data services hosted by the NPS and is the primary agent to publish data APIs to other federal clearinghouses including data.gov. The I&M Program is also evaluating options for creating Data Marts that would make all I&M monitoring information available. This technology is very scalable and may facilitate analysis and reporting in regional assessments.

NPScape: Landscape Dynamics Monitoring: NPScape is a national long-term NPS landscape dynamics monitoring project that provides landscape-level data, tools, and evaluations for natural resource management, planning, and interpretation (http://science.nature.nps.gov/im/monitor/npscape/index.cfm). The target audience for NPScape spans the range from GIS specialists who benefit from the technical geospatial products, to ecologists and natural resource specialists interested in the landscape variables presented in a local and regional context, to park superintendents and other land managers who can incorporate the maps and graphics into reports or briefings. NPScape variables fall into six major categories (human population, housing, roads, land cover, landscape pattern and conservation status) that broadly address the human drivers, natural systems, and conservation context of park units and other neighboring lands. Additional variables are being developed for climate, land surface phenology, sound and nocturnal light levels. Data are collected, analyzed, and reported every 2-10 years, depending on availability of source data. While NPScape products are developed to support NPS I&M activities, all data and tools are made publically available to support similar monitoring by other organizations. In addition to the GIS data (http://science.nature.nps.gov/im/monitor/npscape/gis_data.cfm), NPScape offers map services (http://irmaservices.nps.gov/ArcGIS/rest/services/NPScape), ArcGIS toolboxes and SOPs for implementing analytical methods, landscape ecological guidance for interpreting results, and example NPS applications, placing park units in a landscape context (see NPScape website).

Air Quality Monitoring and Scenic Views: Air resource data consist of both air quality measurements from nationwide networks and information concerning how air quality affects park resources such as visibility or ecosystems. Air quality data are collected at a number of national parks across the country in conjunction with national networks supported by the Environmental Protection Agency (EPA) and the National Atmospheric Deposition Program (NADP). Air quality parameters that are measured or calculated with the data from these networks include ozone concentration, visibility index, wet and dry deposition of sulfur and nitrogen compounds, and deposition of mercury. These data are continuously reported from hourly to weekly time scales and aggregated or averaged to appropriate metrics. The data are generally available from the Federal Land Manager Environmental Database (FED) (http://views.cira.colostate.edu/fed/). Specific data sets are available through the EPA Air Quality System (AQS) for ozone (http://www.epa.gov/ttn/airs/airsaqs/), the EPA CASTNet site for dry deposition (http://epa.gov/castnet/javaweb/index.html), and the NADP site for wet deposition (http://nadp.sws.uiuc.edu/). The FED also serves as the primary repository for visibility data. Spatial GIS presentations of these parameters are available at http://nature.nps.gov/air/Maps/AirAtlas/index.cfm.

Critical loads are a tool the NPS uses to assess and understand the impacts of atmospheric deposition to park ecosystems and help inform policy decisions to protect them. A critical load is the amount of atmospheric deposition below which no harmful effects to an ecosystem are expected. GIS layers of critical load exceedances have been developed and are presented at http://www.nature.nps.gov/air/Studies/criticalLoads/Ecoregions/index.cfm. Visual resources data of park scenic views, including those that extend beyond park boundaries, are available via IRMA. The data are based on tailored GIS analyses and on actual site specific ground inventory and evaluation effort. The data collected by individual parks cover selected views within and around the unit. Parks are in initial stages of ground data collection and reporting and mapping features.

Water Quality and Quantity Monitoring: Discrete water quality data collected as part of all short- and long-term monitoring are made publically available through both Environmental Protection Agency's (EPA) STORET Data Warehouse (http://www.epa.gov/storet/) and the National Water Quality Monitoring Council's (NWQMC) Water Quality Portal (http://www.waterqualitydata.us/). Continuous water quality and quantity data are available in the NPS' Aquarius WebPortal (http://irma.nps.gov/aqwebportal). Park hydrographic and state Clean Water Act impairment statistics are made publically available through a website (http://nature.nps.gov/water/his/) and as a service (http://irmaservices.nps.gov/arcgis/rest/services/NRSS/HIS/MapServer). An example service-based analysis and reporting of water quality monitoring data is available at http://science.nature.nps.gov/im/units/ncrn/monitor/water_quality/visualizer.cfm.

Indicator Category	Example Measures	Number of Parks
Weather and climate	Temperature, precipitation, wind speed, ice on/off dates	246
Water chemistry	pH, temperature, dissolved oxygen, conductivity	211
Land cover and use	Area in each land cover and use type; patch size and pattern	203
Invasive/exotic plants	Early detection, presence/absence, area	200
Birds	Species composition, distribution, abundance	189
Surface water dynamics	Discharge/flow rates, gauge/stage height, lake elevation, spring/seep volume, sea level rise	158
Ozone	Ozone concentration, damage to sensitive vegetation	140
Wet and dry deposition	Wet deposition chemistry, sulfur dioxide concentrations	114
Visibility and particulate matter	IMPROVE network; visibility and fine particles	113
Fire and fuel dynamics	Long-term trend of fire frequency, average fire size, average burn severity, total area affected by fire	105

Table 1. Top ranked indicators Indicator categories and example observation measures defined within the US National Park Service's long-term monitoring program (Courtesy of William Monahan, NPS).

LANDFIRE Data Products for National to Regional Monitoring:

LANDFIRE is a decade-long partnership between the USDA Forest Service, the Department of the Interior, and The Nature Conservancy that produces a nationally consistent all lands data set of fuel, vegetation land cover, and biophysical conditions that seamlessly covers all 50 states, insular areas and territories. LANDFIRE creates 24 standard Landsat-based products, a rich array of data layers and databases (vegetation type, cover, and height; successional state and transition models and database; to national plot and polygon databases) that have fundamentally improved the information integration and decision-support available to land managers (Table 2). In its national extent, spatial detail, land cover – vegetation classification, moderate resolution and continuous updating, LANDFIRE data products differ from the coarser spatial detail of the National Land Cover Database (NLCD). The GAP Analysis Program had a similar spatial extent but lacked the national extent and updating of data products like LANDFIRE. LANDFIRE and GAP have entered into a MOU for integrated services and products.

The LANDFIRE partnership was developed to respond to the need for accurate, complete, and comparable data on fire fuel, vegetation land cover, and biophysical conditions. LANDFIRE combines Landsat imagery with existing biophysical data (topography, fire ecology, soil, climate, and other variables) and existing ground plots gathered from various sources (over 800k plots from over 600 sources, including the USFS Forest Inventory and Analysis Program and now the NRCS National Resource Inventory). The algorithms used were developed based on plot conditions to predict conditions in areas without plots. The LANDFIRE partnership also provides tools and training to help customers understand and make fuller use the available geodata. LANDFIRE information and produced geodata are available at the program web site (http://www.landfire.gov/index.php), the distribution site (http://landfire.cr.usgs.gov/viewer/), and at data.gov (http://www.data.gov/). The LANDFIRE websites and viewers allow users to rapidly find, view and download or intersect data in a GIS.

LANDFIRE geodata and databases are available through the internet, and are routinely accessed for fire applications (WFDSS, IFTDSS, and Cohesive Strategy) and by natural resources management communities (for example BLM Rapid Eco Regional Assessments, LandScope, The Nature Conservancy's Development by Design as identified in this report). Moreover, the data has been widely used to support analysis of carbon budgeting, forest sustainably, state risk assessments, wildlife habitat, insurance adjustment, and ecological restoration. States and Universities are also common data downloaders, and a sampling of non-fire uses can be explored at "WHAM!" (Web Hosted Application Map - http://maps.tnc.org/landfire/).

The LANDFIRE data products provide a depth of classified vegetation types of land cover (over 700 unique types across the country) in a wall-to-wall approach allowing entire landscapes to be assessed. This detail of data allows for objective assessments and analyses where managers can identify risks to the resiliency of ecosystems due to the intersection of consistent data from vegetation (forest, rangeland, grassland, and wetlands) to fuels. Furthermore, the data cross boundaries allowing managers to manage for resources beyond artificial jurisdictional units. The LANDFIRE program applies science based methodologies to national spatial datasets.

LANDFIRE geodata is updated on a routine basis (every two years), and thus supports timely decision-making and environmental assessment and analysis. The LANDFIRE partnership is working to promote and increase coordination with other related efforts (NOAA-CCAP, NLCD, and the EPA). LANDFIRE continues to research ways to improve the product suite and the processes and is planning the next update to be released in 2016. Beyond the next update, the program is excited about improvements and innovations in a base map remap.

LANDFIRE	LF National	LF 2001	LF 2008	LF 2010	LF 2012	LF 2014	LF Remap
Completed	2009	2011	2011	2014	2015 Estimated	2016 Estimated	TBD 18 maybe 19
Imagery Date	1999-2003	99-03 Base	99-03 Base 99-08 Change	99-03 99-10 Change	99-03 11-12 Change	99-03 Base	2013-2015 base
Extent	Conus, AK, HI	Conus^, AK, HI	Conus, AK, HI	Conus, AK, HI & ~ Insular	Conus, AK, HI & Insular Areas	Conus, AK, HI & ~ Insular	Conus, AK, HI & ~ Insular

Table 2. Projects of the LANDFIRE Program, showing product delivery completion, dates of Landsat imagery used and US regions served (Courtesy of Henry Bastian, DOI).

The BLM Assessment, Inventory, and Monitoring (AIM) Strategy

The Bureau of Land Management (BLM) Assessment, Inventory, and Monitoring Strategy (AIM) provides high-quality information about ecosystem conditions and trends for decision-making. To effectively manage renewable resources, the BLM needs monitoring information at multiple scales: 1) at the *field office level*, to develop land use and activity plans and design/assess virtually all resource management projects (i.e., vegetation treatments, fire recovery efforts, livestock grazing, energy development and extraction, recreation activities, etc.), 2) at the *regional level* to detect landscape-level resource status and trend and to help focus and coordinate field management efforts within and across jurisdictional boundaries, and 3) at the *national level* for periodic reporting on overall resource status, condition, and trend and to direct management capacity where it's most needed. In contrast, past monitoring efforts have focused on small-scale resource management projects and could not inform larger scales. AIM seeks to remove this barrier, and thereby serves as a key component of the BLM's Landscape Approach to managing public lands.

The first principle of the AIM Strategy is to collect a consistent set of quantitative indicators using standard measurements. These "core indicators" comprise the AIM dataset, which contains data from thousands of sample locations from 2011-present. The core indicators for terrestrial and aquatic ecosystems were identified by interagency teams that included the Natural Resource Conservation Service (NRCS), Agricultural Research Service (ARS), US Forest Service (USFS), Environmental Protection Agency (EPA), and others. The core terrestrial indicators are: bare ground, vegetation composition, plant species of management concern, nonnative invasive plant species, vegetation height, and plant canopy gaps. The core aquatic indicators are: acidity, salinity, temperature, pool dimensions, streambed substrate, bank stability and angle, floodplain connectivity, macroinvertebrates, riparian vegetation cover and structure, and canopy cover. The AIM dataset of terrestrial and aquatic core indicators is being used to estimate resource status and condition at multiple scales on BLM lands as well as across jurisdictional boundaries.

Another principle of the AIM Strategy is to collect data electronically and store in a centralized database. This facilitates access to and application of monitoring data through geoportals and geotools. The Database for Inventory, Monitoring, and Assessment (DIMA) was developed by the USDA Agricultural Research Service (ARS) – Jornada Experimental Range to collect the terrestrial core indicators (and many supplemental indicators) and is used by the Bureau of Land Management. AIM terrestrial data is distributed BLM-wide via a centralized database called TerrADat (Terrestrial AIM Database), which displays all of the AIM core indicators as well as some common supplemental indicators (soil stability, Interpreting Indicators of Rangeland Health). The aquatic side of AIM also has a central database in development (called AquADat) with similar plans for data access. These systems are driven by Microsoft SQL Server databases with ArcGIS mapping interfaces that will allow for end-user analysis and customized reporting.

AIM aquatic and terrestrial data are collected using simple database interfaces that require minimal technical skillsets and training. Indicator summaries for each sample location are calculated using SQL Server with ArcGIS Desktop software which provides powerful geospatial analysis capabilities for the end-user. Indicator summaries across an area may require a statistical program (e.g., R) and expertise as well as additional information about the sample design. The end-user can use prepared summaries and analyses (requiring few technical skillsets) or the end-user can create customized analyses which would require some GIS and statistical analysis skills. The AIM systems (DIMA , TerrADat, and AquADat) are not public products but are restricted to BLM and partnering agencies (see above). However, the AIM program provides publicly available summaries and reports, and regularly shares data with others through data sharing agreements. It is also under consideration to make some of the raw data available to the public in the future.

The BLM is currently using AIM data to make a variety of resource management decisions at multiple spatial scales. For example, three northeastern California field offices (Eagle Lake, Alturas, and Surprise) are using AIM data to evaluate grazing permit renewals, assess the effectiveness of vegetation treatments, and understand post-fire recovery of sage grouse habitat, as well as ascertain the status of resources across nearly three million acres of BLM lands. AIM data provides both local and regional level data to help guide these decisions. The BLM is also using AIM data to help assess the status and trend of Greater Sage Grouse habitat range-wide by measuring the percentage of BLM lands achieving quantitative objectives such as the percent of native herbaceous plant cover in sagebrush-dominated areas. Additionally, BLM is working with the NRCS National Resources Inventory, which uses consistent terrestrial indicators and methods, to produce first-ever range-wide estimates of sage grouse habitat conditions on BLM and private lands combined.

The number of data collection sites for the AIM program has steadily grown since its inception and the BLM plans to continue adding to the terrestrial and aquatic core indicators dataset as

AIM implementation expands. The AIM systems (DIMA , TerrADat, and AquADat) are not public products but are restricted to BLM and partnering agencies (see above); however, the AIM program provides publicly available summaries and reports and regularly shares data with others through data sharing agreements. It is under consideration to make some of the raw data available to the public in the future. Ongoing work is also focused on creating geotools that will extend users' capabilities beyond any current technical skill limitations they might face (e.g., GIS, statistics). For example, a web-based GIS tool is in development that would put the dataset as well as pre-made, statistically valid analyses in the hands of the user without having to open ArcGIS or a statistical package.

Recommendation for Monitoring Frameworks that Aid Adaptive Management

Reliable broad extent yet high resolution data are needed to capture the status and trends in the condition of key resources impacted by development, in order to understand where landscape-level opportunities for mitigation exist, and to gauge the long-term effectiveness of mitigation actions. Data collected in a consistent way over long periods are fundamental to meeting this objective, but the track record for initiating, coordinating, and sustaining effective long-term monitoring has been poor. Furthermore, large-scale monitoring programs designed to provide regional or national inferences often do not provide sufficient information relevant to mitigation actions implemented at a local level. A DOI example of attempting to overcome this challenge is coordinated monitoring through the NPS and FWS I&M programs, where national and field offices are collocated, and protocols and field crews are shared.

Recommendation 6: Establish best practices and standards for broadly applicable and coordinated monitoring to support interoperability. This includes the establishment of robust and broadly applicable data management procedures relevant to collection and management of monitoring data.

CHAPTER 6 – SYNOPSIS

In response to Secretarial Order 3330, "Improving Mitigation Policies and Practices of the Department of the Interior", in April 2014 the DOI Office of Policy Analysis released "A Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior" (Clement et al., 2014). This Strategy specifies the following Near-Term Policy Deliverable:

> *Develop Geospatial Data Tools for Landscape-Scale Mitigation - Q4 2014. The Department, with leadership from the Geospatial Information Officer and the USGS, will convene a workshop of partners and experts to identify and evaluate existing landscape analysis data and tools and issue guidance for their use in mitigation decision-support.*

Subsequently, the USGS Core Science Systems Mission Area collaborated with the DOI Office of the Chief Information Officer to plan and convene a workshop entitled "*Optimizing and Improving Geospatial Services to Support Landscape-Scale Mitigation*" that sought to answer the following question: "*How can the Department of the Interior better utilize geospatial resources and services to develop landscape-scale strategies and better manage resources, values, and functions through the mitigation hierarchy at multiple scales?*" The Strategy outlines a landscape-scale approach to mitigation in four key steps, all highly dependent on geospatial capabilities:

1) Identify key landscape-scale attributes, and the conditions, trends and baselines that characterize these attributes, by conducting ***regional assessments***;
2) Develop landscape-***scale strategies and plans***;
3) Conduct efficient and effective ***compensatory mitigation programs*** for residual impacts, and;
4) Craft ***monitoring programs*** that adaptively manage mitigation investments to ensure effectiveness despite changing conditions.

This Report presents that Workshop's findings by examining in turn the current use and gaps in geospatial capabilities within each of the 4 key steps in the Strategy's approach to landscape-scale mitigation. The preceding chapters of this Report provide numerous examples of the "best practices" use of the mitigation-relevant GDI in conducting regional assessments, developing landscape-scale strategies, building compensatory mitigation programs, and ensuring effectiveness through administering monitoring frameworks.

Similarly, a description of The Nature Conservancy's Development By Design Framework, a well-conceived approach which is relevant to implementation of the Department's landscape-scale mitigation Strategy, is included below as a comprehensive overview example. Lastly, this final synopsis chapter of the Report concludes by summarizing the previously described six recommendations for actions to fulfill high priority requirements that are not addressed by the currently available suite of geospatial resources and services in use across the Department and its network of partners.

Development By Design – An Example Full Framework for Landscape-Level Mitigation
(Contributed By Joe Kiesecker, Bruce McKenney and Jessica Wilkinson)

A major challenge for the coming decades is how to meet the demand for energy, minerals, and infrastructure of a growing global population while ensuring the health of our lands and waters for future generations. Consider the energy sector, where global demand has increased by more than 50 percent in the last half-century, and a similar increase is projected by 2030 (US EIA 2013). In the United States, directives for renewable energy, energy security and technological advancements such as horizontal drilling in conjunction with hydraulic fracturing have spurred a rapid increase in alternative and unconventional energy production over the last decade (Kerr et al., 2010, Naugle, 2010). Energy development is reaching every corner of the United States: natural gas development in Appalachia, oil development in North Dakota, solar farms in the Mojave Desert and wind turbines on the Great Plains. Energy development is poised to continue its upward trajectory, with over 200,000 km^2 of new land projected to be developed in the US alone by 2035 (McDonald et al., 2009). In light of this new energy future, understanding and mitigating the impacts of energy development will be one of the major challenges in the coming decades (Wilkinson et al., 2009, Kiesecker et al., 2010, Villarroya et al., 2014).

The Nature Conservancy's Development by Design (DbD) framework seeks to transform traditional mitigation by using a whole system, science-based approach that addresses the effects of development at landscape levels. Landscape conservation planning provides a framework to ensure that mitigation efforts are consistent with conservation goals; this often includes the maintenance of large, resilient ecosystems to support both healthy wildlife habitats and the needs of human communities. Blending the mitigation hierarchy with landscape planning offers three distinct advantages over a traditional project-by-project approach. Landscape mitigation-planning (1) takes into account the cumulative impacts of current or projected development projects; (2) provides regional context to better guide which step of the mitigation hierarchy should be applied to proposed development (i.e. avoidance versus offsets); and (3) offers increased flexibility in choosing offsets that maximize conservation returns by providing resources for the most threatened ecosystems or species. To illustrate the steps used by DbD, we present a series of examples from work conducted within the Wyoming Basins Ecoregion.

The Wyoming Basins ecoregion (WBE) comprises 13.3 million hectares of basin, plain, desert, and mountains in Wyoming, Montana, Idaho, Colorado, and Utah (Bailey, 1995). The ecoregion provides critical habitat for migratory big game, songbirds, and raptors within the Greater Yellowstone ecosystem. The area is a stronghold for the greater sage-grouse (Centrocercus urophasianus), an emblematic native game bird that the US Fish and Wildlife Service has determined is warranted for listing under the Endangered Species Act, but precluded from listing by the need to address other agency priorities. The WBE is also home to some of the richest oil and gas deposits in the western US (Copeland et al., 2009). In fact, the number of producing oil and gas wells in the ecoregion has nearly tripled since the 1980s and is expected to increase further over the next 30 years (Copeland et al., 2009). Conservation of the biological diversity in this area will be challenging with over 4 million of the 8 million ha (52%) of the federal mineral estate within the ecoregion leased for exploration (Kiesecker et al., 2013). Next, landscape-level conservation planning work done in the WBE (Freilich et al., 2001, Sochi et al. 2013) is presented to demonstrate how the mitigation hierarchy can be applied to balance conservation objectives with impacts associated with future oil and gas development.

The 4-step DbD framework (Table 3) aligns closely with the Department's landscape-scale mitigation Strategy, makes varied and abundant use of geospatial capabilities, and is described below.

DbD Step	Scale	Development by Design Framework	DOI Landscape-Scale Mitigation Framework Step
Step 1	Landscape-level	Set priorities and develop conservation plan	Regional Assessments
Step 2	Landscape-level	Project potential cumulative impacts and adjust conservation plan	Regional Conservation and Development Strategies
Step 3	Landscape/project-level	Identify portfolio of best compensatory mitigation opportunities	Compensatory Mitigation Programs
Step 4	Project-level	Determine optimal compensatory mitigation investments and measure progress to goals	Compensatory Mitigation Programs; Monitoring Frameworks

Table 3: DbD alignment to DOI landscape-scale mitigation framework steps (Courtesy of Joe Kiesecker, TNC).

Step 1: Set Conservation Priorities:

Landscape-level conservation planning is the process of identifying the most optimal locations for conservation and how best to configure conservation areas to maintain viability of biodiversity and other natural features (Groves et al., 2003, Pressey and Bottrill, 2008). Key tasks within Step 1 of the DbD Framework are to:

- Identify conservation targets and set conservation goals through stakeholder and/or expert engagement.
- Compile a list of representative biological targets and gather spatial data.
- Develop a landscape-level conservation plan.
- Incorporate ecosystem services and climate change factors.

A conservation portfolio (composed of priority sites), the end product of conservation planning, is made up of a selected set of areas that represent the full distribution and diversity of the ecological systems and species (Noss et al., 2002). Plans often optimize the design of the portfolio to meet the minimum viability needs of each biological target, in a way that minimizes the area required to achieve conservation goals (Pressey et al., 1997; Ball and Possingham, 2000).

At its core, DbD seeks to steer development projects away from conservation priorities and ensure that when offsets are used they are consistent with those broad landscape conservation goals. To initiate DbD we need a plan that identifies conservation goals to which currently proposed or potential future development can be compared (Figure 5). Conservation plans can take the form of a traditional ecoregional assessment, or a type developed by other agencies or organizations, such as the Bureau of Land Management's Rapid Ecological Assessments. The conservation goals serve as the reference point for making a recommendation that impacts should be avoided or minimized or whether the development could proceed and impacts could be offset.

The first step in conservation planning is to identify biological targets based on their ability to approximate the complete biological diversity of the landscape and to indicate key changes in ecological conditions due to predicted development impacts. Common approaches for selecting representative biodiversity targets focus on capturing targets that span multiple spatial scales and levels of biological organization (Groves et al., 2002, Poiani et al., 2000, Kiesecker et al., 2009). Regional targets can relate to habitat or vegetation types, with emphasis on their diversity, rarity, and irreplaceability, while local targets tend to be individual species such as rare, threatened or endangered species, endemics, and habitat specialists (Kiesecker et al. 2009). The selection of conservation targets can be established through stakeholder engagement and/or through expert input. Once the priorities have been selected, TNC works with partners and experts to identify data on the spatial distribution of the priority resources and/or representative biological targets. Based on the assembled data, a landscape-level conservation plan can be developed.

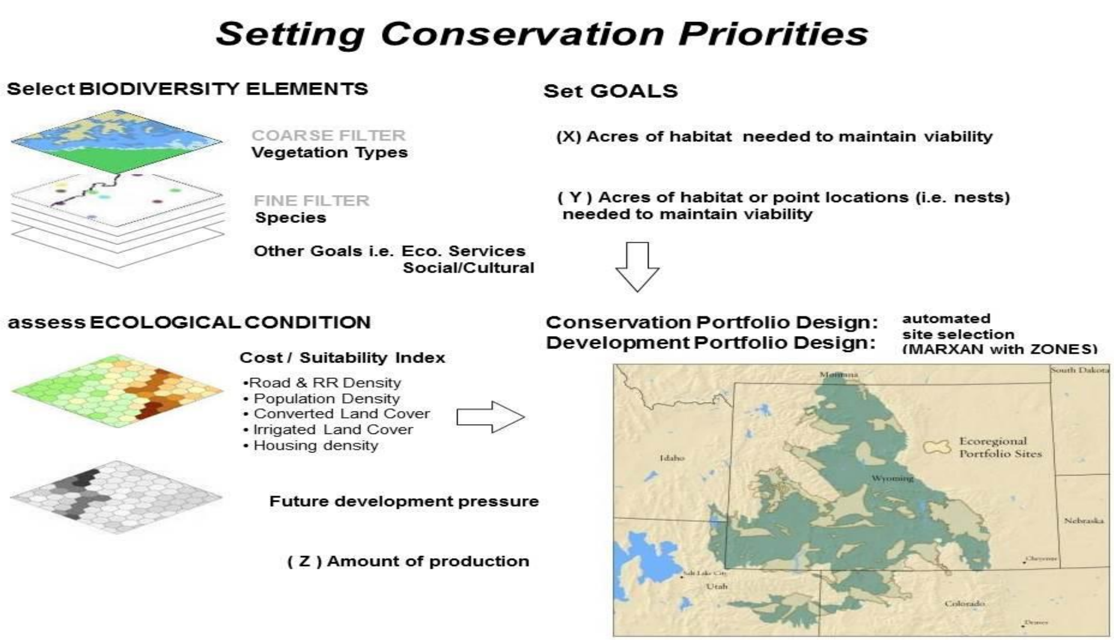

Figure 5. Process for identifying a portfolio of conservation areas in the Wyoming Basins (Courtesy of Joe Kiesecker, TNC).

The primary output of Step 1 is a geospatial conservation plan that identifies priority areas for conservation and ecosystem services. The geospatial resources and capabilities used in the example Wyoming Basins implementation of DbD Step 1 (Regional Assessments) included natural heritage data, state wildlife action plans, TNC ecoregional plans, GAP analysis, US Forest Service LANDFIRE products, the USGS National Elevation Dataset, the USGS National Hydrography Dataset, the MARXAN model and other predictive and deductive models.

Step 2: Project Potential Cumulative Impacts:
Using the DbD framework, the conservation plan developed under Step 1 is analyzed in the context of projected future development. This allows for consideration of the cumulative impacts of both current and projected development and provides regional context to better guide avoidance and compensation. Key tasks within Step 2 of the DbD Framework are to:

- Compile data on existing and projected cumulative impacts for the region.
- Identify conflicts between the conservation portfolio and potential impacts.
- For areas of conflict, explore potential for meeting conservation goals elsewhere in the region.
- Identify priorities for avoidance based on criteria for vulnerability (degree of threat) and irreplaceability (rarity/uniqueness).

Using the DbD framework, the conservation plan developed under Step 1 is analyzed in the context of projected future development (Figure 6). This allows for consideration of the cumulative impacts of both current and projected development and provides regional context to better guide avoidance and compensation. Overlap between conservation priorities and the proposed development may result in a "redesign" of the conservation portfolio to recapture habitat needed to meet biodiversity goals impacted by development. However, if minimum viability needs cannot be met elsewhere within the study area, the development plans would need to minimize impacts to the degree that maintains the viability of the biological targets or development should not proceed (Figure 7). When possible, the identification of spatial conservation priorities should be designed to avoid conflict with potential development at the outset. Through this science-based approach, DbD informs decision-making about impact avoidance, supporting the conservation of areas that are too rare, fragile, or otherwise too important to impact. This identification of landscape-level conservation priorities also supports more effective compensatory mitigation, because these actions can be better targeted to ensure their contribution to landscape conservation goals.

Our case study in the WBE illustrates how the landscape level conservation plan and resulting conservation portfolio can guide the application of mitigation decisions. The priority conservation sites chosen during the ecoregional assessment (Freilich et al., 2000) total 3.5 million hectares, amounting to 27% of the total ecoregion area. To date the WBE is home to over 55,000 oil and gas wells. Looking retroactively, of all the wells drilled, only 2,886 (~7%) were drilled in areas where the DbD analysis would have recommended that impacts be avoided (Kiesecker et al., 2013). If we were to require 3 acres of offset for every acre of impact associated with development and directed this to private land protection we would have generated over 5 times the amount of private land conservation compared to current levels of protection (Kiesecker et al., 2013).

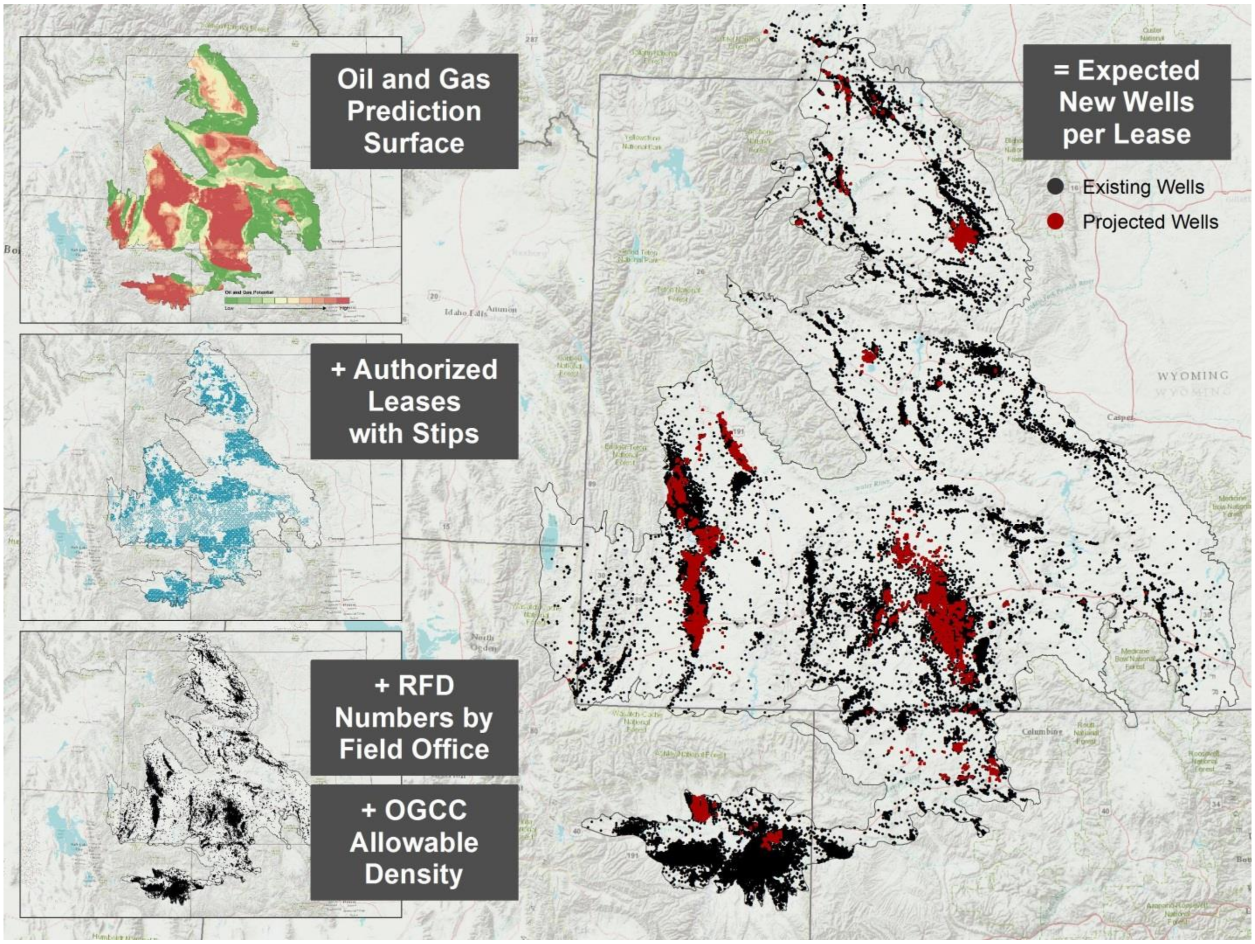

Figure 6. Projection of future oil and gas development in the Wyoming Basin Ecoregion adapted from Copeland et al. 2009. Oil and gas prediction surface generated using random forest was used along with data on authorized leases, well density stipulations and reasonable foreseeable development estimates from BLM field offices to predict the expected number of new wells per lease (Courtesy of Joe Kiesecker, TNC).

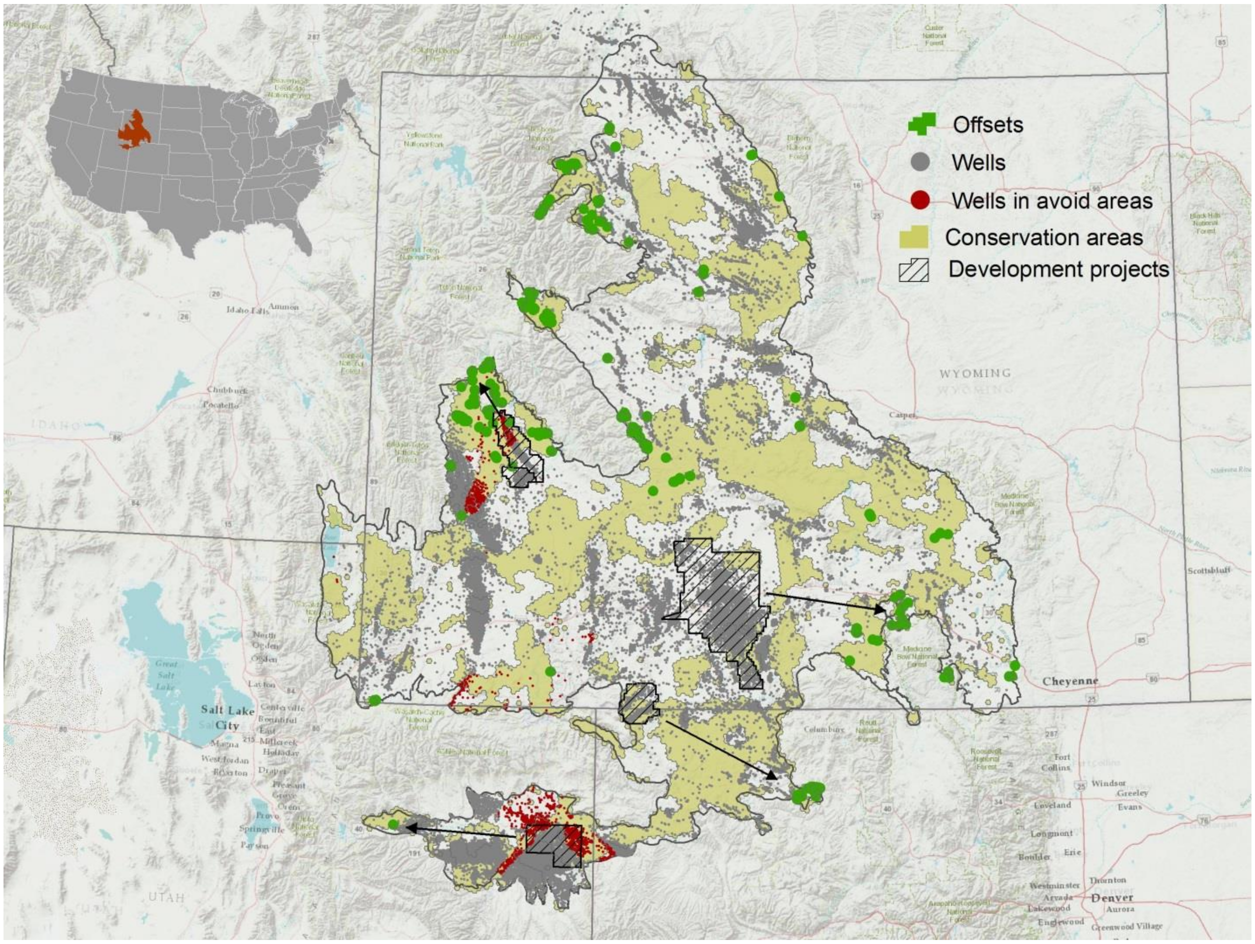

Figure 7. Applying Development by Design in the Wyoming Basins adapted from Kiesecker et al. 2013. Map shows location of all well (wells in red = areas to avoid impacts) and additional private land conservation resulting from offsets in green. For simplicity, private land conservation offsets were clustered around existing private land conservation. Acreage of impacts associated with development based on a 4 ha footprint per well and additional private land conservation resulting from offsets based on a requirement of 3 ha of offset for each hectare of impact (Courtesy of Joe Kiesecker, TNC).

The primary output of Step 2 is a conservation plan that has been adjusted based on projected future development. The aim is to meet both conservation and development goals for the landscape, identifying areas where impacts should be avoided and where compensation can offset impacts. The geospatial resources and capabilities used in the example Wyoming Basins implementation of DbD Step 2 (Regional Conservation and Development Strategies) included Energy Information Administration-Crude Oil and Natural Gas Proved Reserves data, USGS Energy Resource Program data, development-specific projections, and the MARXAN and other predictive models.

Step 3: Identify Best Options for Compensatory Mitigation:
Steps 3 and 4 of the DbD framework are applied at the site-level to guide project-specific decisions based on the landscape-level priorities identified in the preceding steps. Step 3 is carried out after all efforts have been taken to avoid and minimize impacts at the site. Key tasks within Step 3 of the DbD Framework are to:

- Estimate expected direct and indirect project impacts to biological targets; goals for offsets are established based on these impacts.
- Identify optimal offset opportunities using site-selection algorithms (for example, MAXAN) at increasing spatial extents from the project site.

Under the DbD framework, proposed development consistent with conservation goals of a landscape-level conservation plan would move forward, using best management practices to avoid and minimize impacts and harnessing offsets to mitigate for the unavoidable impacts associated with the development. In order to determine how much compensation would be needed to offset unavoidable impacts, decision-makers must understand how proposed impacts will affect the conservation targets. This includes a consideration of the direct, indirect, and cumulative effects of the projects. Determining site-level impacts to biodiversity draws on the outputs of Steps 1 and 2, namely the list of representative biological targets, spatial data for those targets, and goals to ensure long-term persistence of each target. Our objective with DbD is to ensure that offsets are ecologically equivalent to impacts, will persist at least as long as onsite impacts, resulting in net neutral or positive outcomes and are located in a manner consistent with goals of landscape conservation planning. The geographic location of offsets sites can be accomplished as a separate standalone process or as part of a landscape conservation plan. Where a landscape-level plan exists, the ecoregional data provides the currency to assess impacts associated with development and compare which portfolio sites are best suited to serve as offset sites. Where no landscape plan exists, offset sites can still be selected using landscape-level data to ensure offset sites are consistent with broader conservation goals.

Within the WBE the Conservancy has implemented five site-based DbD mitigation projects using the ecoregional planning framework as a guide to make recommendations intended to provide offsets that would result in benefits equivalent to development impacts. For example the Jonah Field located in Wyoming's Upper Green River Valley, is a 24,407-hectare natural gas field with one of most substantial recent discoveries of natural gas in the United States. The field contains an estimated 7 to 10 trillion cubic feet of reserves and over 500 wells in operation (US Department of Interior, 2006). Regulatory approval was granted by the BLM in 2006 to infill the existing 12,343-hectare developed portion of the field with an additional 3,100 wells. As a requirement of the infill project, an offsite mitigation fund of $24.5 million was established. Working with partners from state and federal regulatory agencies, universities, biological consulting firms, and the local agricultural production community, we designed an offset strategy for the Jonah Field (Figure 8) (Kiesecker et al., 2009). Spatial data layers were used for both assessing impacts as a result of development on the field and selecting suitable offset sites. We used a series of Landscape Rules: "Intactness" (Copeland et al., 2007) and "Oil and

Gas Potential" (Copeland et al., 2009) to guide the selection of offset sites with high habitat quality and low oil and gas development potential. The portfolio of conservation priorities has been used by the Jonah Interagency Office to guide the implementation of offset projects targeted to protect or restore over 120,000 acres (Figure 8; http://www.wy.blm.gov/jio-papo/jio/projects/2011_status.pdf).

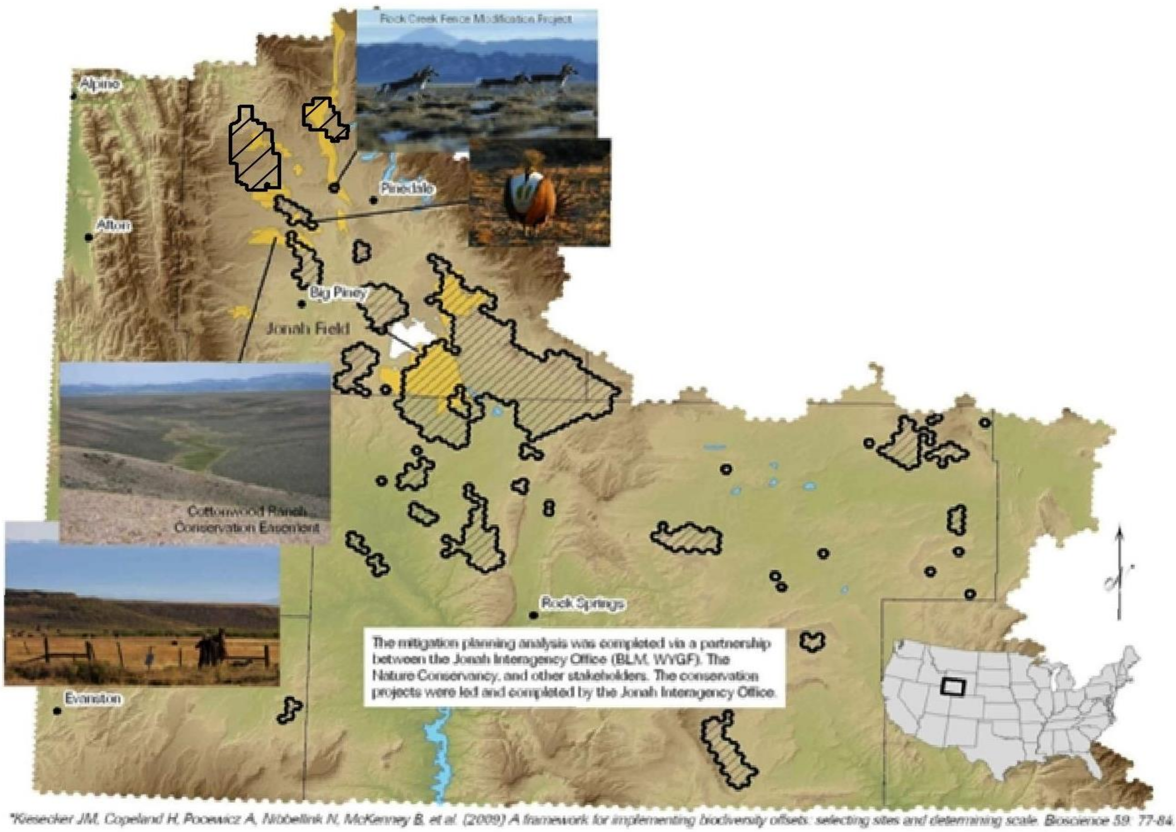

Figure 8. Offsets sites (black hash marks) selected to best compensate for impacts associated with development on the Jonah Field (in white) and restoration and protection projects (in yellow) implemented with mitigation funding by the Jonah Interagency Office (Courtesy of Joe Kiesecker, TNC).

The landscape analysis used on the Jonah Field project helped guide the implementation of offsets. However, the onsite development plan was established prior to the DbD analysis and, as a result, the DbD framework was not used to guide decisions about onsite avoidance or minimization. This type of analysis could be used to guide onsite avoidance and minimization as well as offset design. For example, in 2008, BP proposed an oil and gas infill project in the San Juan Basin, which encompasses 102,000 acres in southwest Colorado (Figure 9). The proposed development coincided with the release of new oil and gas rules by the Colorado Oil and Gas Conservation Commission (COGCC) in 2008. The COGCC revisions allow operators to work with stakeholders to develop voluntary "Wildlife Mitigation Plans" (WMPs) harnessing landscape-level planning prior to starting development. The WMPs create a plan to avoid, minimize and mitigate impacts to wildlife resources. The new rules encourage operators to conduct multi-well plans thereby expediting the permitting process while addressing cumulative impacts.

The San Juan Basin project utilized landscape-level data to highlight onsite features where development should avoid impacts and identify a set of offset sites, the latter similar to the approach utilized on the Jonah Field. At full build-out, it is anticipated that the project will support the protection of 12,000 acres throughout the offset area. Thus far, approximately 400 acres of conservation easements have been established to offset impacts that BP has incurred since the completion of this project. The project also demonstrated offset selection can be conducted in a manner that extends benefits to conservation priorities not covered through current regulatory requirements without creating additional costs for those responsible for implementing mitigation actions (Sochi & Kiesecker, 2011, Sochi & Kiesecker, In Review). Since it is unlikely that regulatory frameworks will change to encompass all aspects of biodiversity, optimization tools like those used as part of this project can identify opportunities to maximize the benefits offsets provide.

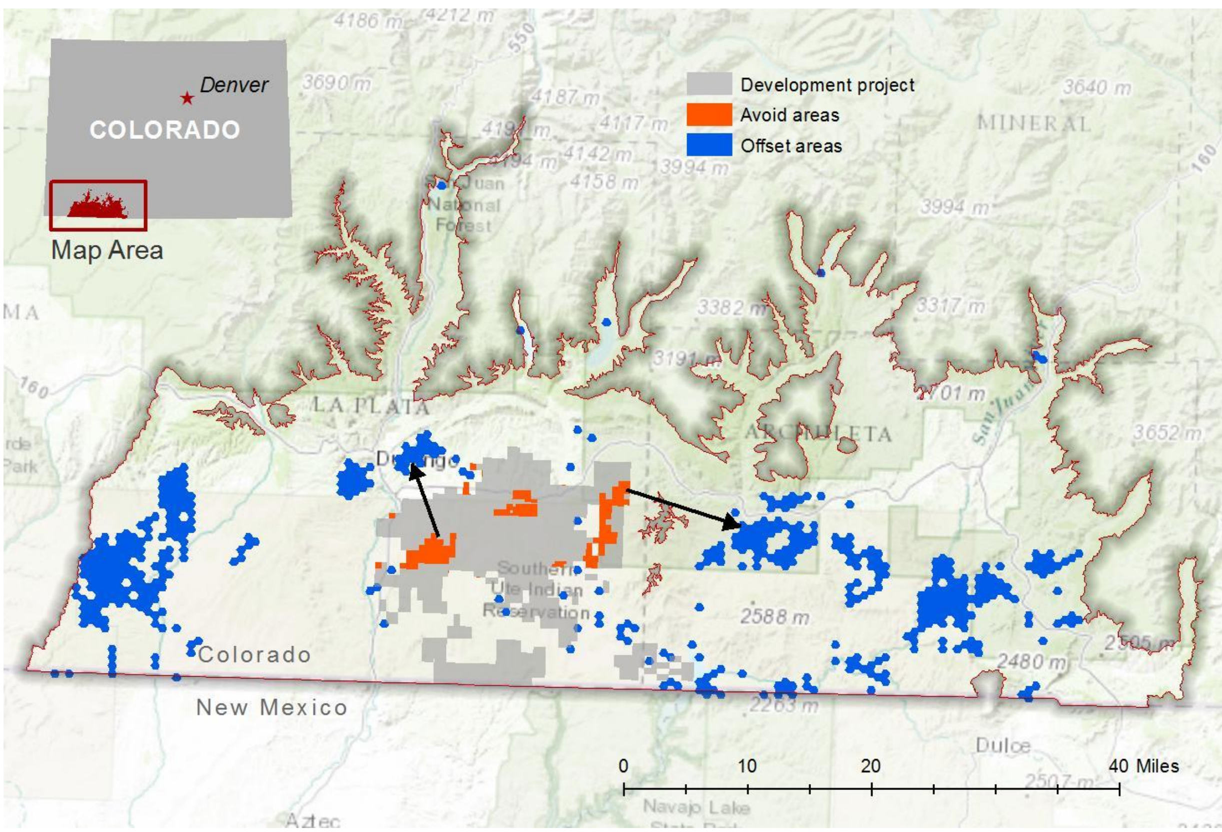

Figure 9. Selection of suitable offsets sites for oil and gas development in the San Juan Basin of Colorado. Spatial data layers were utilized for both assessing impacts as a result of development on the field, selecting suitable offset sites and making recommendations for high value areas onsite. Areas hatched represent the best fit of the Marxan algorithm based on

these specific targets and specified landscape rules. Intactness guided the selection of sites to areas of high habitat quality and low oil and gas development potential. Inset map shows the location of the development area within the state of Colorado. See Sochi and Kiesecker (2011) for details (Courtesy of Joe Kiesecker, TNC).

The primary output of step 3 is geospatial information that identifies a portfolio of offset opportunities – priority areas for compensation that are ecologically equivalent to those lost, appropriately proximate to the impact sites, and that contribute to landscape conservation goals. The geospatial resources and capabilities used in the example Wyoming Basins and San Juan Basin implementations of DbD Step 3 (Compensatory Mitigation Programs) included scientific literature on the displacement/degradation of target resources from disturbance, MARXAN, and Mapping Alternatives for Equivalents – Model Builder ArcGIS 9.0.

Step 4: Measuring Progress:
In the final DbD step, a set of offset accounting principles are applied to support offset selection (from within the portfolio of opportunities identified in Step 3) and to provide a framework for measuring offset progress toward specified goals (e.g., "no net loss"). This approach helps ensure compensatory mitigation provides an optimal outcome in terms of conservation value for the investment. Key tasks within Step 4 of the DbD Framework are to:

- Estimate potential contribution of offset to conservation goals considering additionality, equivalency, location, timing and durability.
- Estimate the costs to implement offsets in the portfolio and the expected conservation value to identify offsets that will provide the highest conservation return.

DbD focuses on four key principles to guide any offset accounting framework: Additionality, Equivalency, Location, Timing and Durability.

In the final DbD step, a set of offset principles are applied to support the selection of offset sites (from within the portfolio of opportunities identified in Step 3) and to provide a framework for measuring offset progress toward specified goals (e.g., "no net loss"). This approach to site selection helps ensure that compensatory mitigation provides the "biggest bang for the buck" in terms of conservation value for the investment. DbD focuses on four key principles to guide any offset framework: Additionality, Equivalency, Location, Timing and Durability.

Additionality for restoration actions is fairly straightforward, particularly if there is an existing methodology that can be used to calculate ecological uplift from restoration actions. When compensation is accomplished through preservation, however, additionality has been based on data on expected background rates of loss. TNC has developed build-out scenarios in the western US sage grouse states, for example, utilizing data provided in the Bureau of Land Management's resource management plans and making reasonable predictions based on past development trends (Pocewicz et al., 2009, Copeland et al., 2009).

Equivalence is the principle that offsets should provide habitat, functions, values, and other attributes that are similar ("in kind" or "like for like") to those affected by the project

(Mckenney and Kiesecker, 2010). In some cases, however, and particularly when it can be demonstrated that out-of-kind compensation better meets landscape-level conservation priorities or addresses past, disproportional losses to specific habitat types, out-of-kind compensation may be preferred. The US federal wetland permitting program, for example, requires that compensatory mitigation decisions be based on a watershed approach that identifies priorities for meeting watershed needs. Several pilot watershed approach projects have been undertaken by TNC, the US Army Corps of Engineers, and the US Environmental Protection Agency, among others (Wilkinson et al., 2014).

The *location* principle is generally expressed as a preference for offset benefits to accrue within the same watershed or ecological unit as the impact to avoid the migration of ecosystem benefits away from of the affected area. Policies guiding compensatory mitigation for wetlands and species in the US, for example, encourage mitigation banks and other forms of compensatory mitigation to be located within the same watershed as the impact site for wetlands and the same recovery unit for species (DoD & EPA, 2008, USFWS, 2003).

The principle of *timing* relates to the desire to minimize the temporal lag between when project impacts occur and when compensatory activities achieve their functional goals. Temporal loss can occur because compensatory projects are completed after project impacts and when the type of habitat being replaced requires a significant amount of time to reach maturity. When mitigation requirements are calculated for impacts from oil and hazardous waste spills under Natural Resource Damage Assessment Programs, for example, that assessment strives to take into consideration the temporal loss of natural resources (Maron et al., 2012).

These principles should be incorporated into offset policies and, where appropriate, accounting systems. Offset programs around the world rely upon accounting systems to assess ecological impacts and ensure that offsets are equivalent (McKenney and Kiesecker, 2010, Villarroya et al., 2014). These systems have been developed for a range of compensatory mitigation programs, most notably those for the federal wetland and stream regulatory program and endangered species program, as well as regional and local offset programs. In addition, offset agreements should be established between the offset provider and the oversight agency and should serve as binding contracts that ensure that required offset actions are taken and conservation outcomes achieved. The offset plan should be required to include, among other things, ecological performance standards, monitoring requirements, and reporting requirements. The regulatory agency should also be granted compliance and enforcement authority over the terms of the offset agreement.

Finally, and importantly, oversight agencies should institute systems that allow for compliance tracking, monitoring and feedback systems so that when required performance standards of specific offset methods do not yield intended results, agency staff can incorporate these lessons learned into future offset agreements. *The primary output of Step 4 is selection of optimal compensatory mitigation actions (providing the highest conservation value at the least cost and risk) and a framework for measuring progress of these actions toward specified conservation* *goals. The geospatial resources and capabilities used in the example Wyoming Basins and San Juan Basin implementations of DbD Step 4 (Monitoring Frameworks / Compensatory Mitigation Programs) included data on background rates of loss/degradation (e.g., BLM Resource Management Plan projections for oil and gas development).*

<u>Development by Design – Concluding Discussion</u>

Landscape-scale mitigation is expected to provide more effective conservation outcomes, reduce regulatory hurdles, and potentially offer cost savings to private developers (Kennedy et al., In Review). In order to achieve these objectives, mitigation decisions should be driven by a landscape vision that has biologically and ecologically important features as a core focus throughout the process. Without this focus, the overarching conservation vision is lost, prioritization becomes difficult, and resources for mitigation may be wasted. It will also require that developers have access to information proactively so that requirements can be incorporated into the business costs of developing. We applied these concepts to wind energy development in Kansas (Obermeyer et al., 2011). This framework identifies areas where impacts to important habitats cannot be offset and, therefore, should be avoided. The framework also provides a method to identify areas where development may proceed without significant ecological concerns, as well as areas where ecological impacts will be significant, but can be offset. Importantly, this approach provides a mechanism to quantify expenditures (in dollars) necessary for offsets where they are appropriate. Because the cost of mitigation varies greatly depending on siting, developers can reduce mitigation costs by siting future development in areas with lower mitigation costs. Overall the DbD framework illustrates that it is presently possible to implement a proactive landscape-scale system that guides development to avoid, minimize, and offset ecological impacts.

Summary of Recommendations to the Department

A Workshop entitled "*Optimizing and Improving Geospatial Services to Support Landscape-Scale Mitigation*" was convened jointly by the USGS Core Science Systems Mission Area and the DOI Office of the Chief Information Officer on October 22, 2014 in association with the National Workshop on Large Landscape Conservation (NWLLC). That Workshop resulted in six focused, pragmatic recommendations for actions to fulfill high priority requirements stemming from Secretarial Order 3330 that are listed below and ranked for relevance to the Guiding Principles (Table 4) defined by the associated 2014 DOI "Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior":

Recommendation 1: Improve National GAP Land Cover and Vertebrate Species Distribution models and data products as follows:

- Provide greater specificity on the location of priority habitats by incorporating habitat fragmentation indices and vegetation canopy metrics from above-ground LIDAR point clouds such as those being collected through the USGS 3D Elevation Program;
- Update and evaluate species distribution models, and extend to a wider range of species;
- Add the classification of wetland regions with high restoration potential to Land Cover data products, and

- Apply field observations to validate the accuracy of Vertebrate Species Distribution data products.

Recommendation 2: Use the Geospatial Platform to create a Mitigation GDI Community of Practice and online presence for geospatial practitioners working to advance landscape-scale mitigation. Moreover, use this Mitigation GDI Community of Practice to organize, mentor, and manage a working group of expert geospatial knowledge curators for the mitigation-relevant GDI, with diverse membership representing federal and state agencies and NGOs, who will serve to guide geospatial analysts to the geodata, authoritative derived maps and geotools best suited for specific regional assessments. Provide the support needed to enable this group to undertake the following actions:

- Create "meta-metadata" covering accuracy, strengths and limitations to help users to identify and make best use of the most suitable foundational geodata and added-value products in regional assessments.
- Establish standard approaches for the acceptable quality and sanctioned application of geospatial datasets to maximize appropriate use.
- Create educational resources and case study tutorials to build skill within the landscape-scale mitigation community, and to provide training on the use of geospatial products in regional assessments and geospatial decision-support models.

Recommendation 3: Gather localized and project-specific geodata collected and maintained by federal and state agency field offices and NGOs, and make those datasets readily available through the most appropriate centralized geoportal(s). Thereby reduce the barriers for DOI field offices and NGOs to share their data with the larger mitigation community and stimulate a shift away from operating within an office-centric mode towards operating at a national scale across federal and state agencies and NGOs.

Recommendation 4: Support the construction of merged and comprehensive high quality national data layers of land cover and land use (LANDFIRE, GAP, NLCD) along with the depiction of federal land parcels and roads to enable consistent and broad analysis of habitat "intactness" within regional assessments and decision-support modeling beyond jurisdictional boundaries.

Recommendation 5: Add mapping capabilities to databases used to track compensatory mitigation habitat plans (for example, the USFWS Tracking and Integrated Logging System (TAILS)) to increase the sophistication of geographic information that DOI staff can associate with each project-review record stored in a centralized and accessible archive. Additionally, improve the linkages, interoperability, and geospatial data-sharing between the USFWS TAILS and the USACE RIBITS online database to better provide a widely accessible inventory of the location, nature, history, and performance of all U.S. conservation banks, inclusive of wetland banks and also banks for habitat used by ESA listed species.

Recommendation 6: Establish best practices and standards for broadly applicable and coordinated monitoring that results in shared interoperable datasets keyed to desired mitigation outcomes by selecting appropriate indicators, developing a common sampling design and establishing robust and broadly applicable data management, analysis, and reporting procedures for monitoring.

Table 4. Ranking of recommendation relevance to Guiding Principles (left column) in the DOI Strategy (1: Not relevant; 10: Extremely high relevance).

Recommendation Number:	1	2	3	4	5	6
Incorporate Landscape Approach	10	10	10	10	10	10
Use the Full Hierarchy	8	NA	NA	8	10	NA
Promote Operational Certainty	NA	8	NA	NA	10	NA
Promote Advance Planning	8	8	NA	8	10	NA
Develop/Use Information and Tools	10	10	10	10	10	10
Foster Resilience to Climate Change	9	8	8	10	NA	10
Ensure Durability	8	NA	8	8	10	10
Promote Transparency	8	10	NA	8	10	NA
Enable Collaboration and Coordination	NA	10	10	8	10	10
Monitor and Evaluate Performance	8	NA	10	NA	10	10
Total Score for Recommendation (100 max)	69	96	56	70	90	60

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