Visual Impact Risk Assessment and Mitigation Mapping System for Utility-scale Wind Energy Facilities

Submitted by

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Abstract

The selection of optimal wind energy development areas and siting of individual wind facilities requires that land use and project planners consider concurrently the different sensitivities of potentially affected visual resource areas and viewpoints along with the effect of viewing distance in determining the magnitude of visual contrast associated with these facilities. Argonne National Laboratory, with assistance from the University of Arkansas Center for Advanced Spatial Technologies and the United States Department of Interior Bureau of Land Management, has developed the Visual Impact Risk Assessment and Mitigation Mapping System (VIRAMMS), a prototype geographic information system-based software tool for creating maps of relative visual impact risk associated with wind energy development. VIRAMMS' visual impact risk maps incorporate differing sensitivity levels of multiple visual resource areas and sensitive viewing locations, while simultaneously accounting for the effects of distance from a proposed facility site to resource areas and viewing locations. Relative visual impact risk is determined by distance- and sensitivity-weighted analysis of overlapping viewsheds from potentially affected viewpoints. Other VIRAMMS capabilities include identifying visual impact mitigation measures based on placement of specific wind facility components and advanced viewshed analyses that calculate the height of a structure that could be concealed from a sensitive viewing location based on vegetative/topographic screening. Currently, the prototype VIRAMMS system is being tested in a Bureau of Land Management-sponsored project to identify wind energy priority areas in Wyoming.

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1 Introduction

1.1 Visual Impacts of Wind Energy Projects

Utility-scale wind energy development is associated with large visual impacts that, depending on project-specific circumstances, may result in public opposition to proposed projects. Utility-scale wind turbines may easily exceed 122 m (400 ft) in height and have large moving blades that draw visual attention. For low-altitude flight safety reasons, wind turbines must be white, making them conspicuously visible during the day, and they must be topped by flashing red lights at night. Furthermore, they are sited in arrays of hundreds or as many as one thousand turbines that can cover hundreds of square miles for the largest projects (e.g., see BLM 2011). Finally, wind turbines have strong regular geometry that generally contrasts with the natural elements of most landscapes. In particular, the pronounced vertical lines of wind turbine towers may contrast with the generally flat, strongly horizontal landscapes where they are sometimes sited. The large size and strongly contrasting visual characteristics of utility-scale wind turbines, as well as the large land areas typically covered by commercial wind turbine arrays, may cause these facilities to be visible for long distances in both daytime and nighttime views.

Visual impacts are among the most commonly expressed concerns about wind energy development projects in the United States and Europe, in both onshore and offshore settings (AWEA 2008; NRC 2007; Firestone and Kempton 2007; Mickelburgh et al. 2004; Pasqualetti et al. 2002). Increasingly, public concerns regarding visual impacts are resulting in lawsuits (e.g., Early 2009), the denial of permits for proposed projects (e.g., Johnston 2006), and the passing of ordinances to ban or restrict wind energy development (e.g., Dulek 2007; Town of Blowing Rock 2006). Given the forecasted and continuing rapid growth of wind energy in the United States and the growth in new and upgraded electric transmission capacity that must accompany the expansion of wind energy, visual impacts will increase in importance as an area of public concern. There is a very real potential that concerns over visual impacts will impede wind energy development in general and may halt specific projects in some locations.

1.2 Visual Resources Considerations in Land Use Planning and Project Siting

Because of the recent rapid growth of utility-scale wind development in the U.S. , many federal, state, and local planning agencies currently are faced with numerous applications for wind energy development on lands these agencies manage or for which they have regulatory authority or permitting responsibility. Within land management agencies, both land use planners (persons with responsibility for land use planning for a given area) and activity planners (staff tasked with managing energy development activities on agency-managed lands) have roles in siting wind energy developments. Land use planners are responsible for determining where—within a given area—would be the most and least favorable locations for siting wind energy developments and other land uses, but would not have responsibility for siting individual projects. Activity planners

are tasked with managing energy development activities on agency-managed lands and may be involved in siting specific projects and establishing appropriate permitting and mitigation requirements.

While land use and activity planners work typically at different landscape scales, and each group has some unique concerns to address with respect to development siting, there are shared visual resource considerations that both groups must address in siting activities, including *visual sensitivity*, *visual absorption capability*, *scenic integrity*, and *scenic quality*. While the two major federal land management agencies, the BLM and the U.S. Department of Agriculture's Forest Service, have programs in place for inventorying visual resources and setting visual resource management objectives on lands they manage (BLM 1984; FS 1995), most other federal, state, and local land management or planning agencies do not have a systematic process for evaluating visual qualities of the lands they manage, or for which they have regulatory or permitting responsibilities.

1.2.1 Visual Sensitivity

The *visual sensitivity* of landscapes to wind energy development (NRC 2007) is a key siting consideration. Sensitivity, for these purposes, is defined as the importance of a particular landscape to society, whether the importance arises from the values associated with features of the landscape itself, such as its inherent scenic quality, or the features of historical or cultural importance that it contains. Visual sensitivity may also be related to the viewers and the viewing experience, such as being viewed by large numbers of viewers, being viewed by highly sensitive viewers, or being subject to views of long duration.

The issue of sensitivity of viewed landscapes is growing in importance as the U.S. embarks on ambitious programs for large-scale deployment of wind energy facilities and associated transmission infrastructure in onshore and offshore settings. Increasingly, highly visible wind and transmission facilities are encroaching on the viewsheds of important scenic, historic, or cultural resource areas, such as national parks, national historic trails, landscapes important to Native Americans, or non-scenic, but sensitive landscapes near populated places where Americans work and live. These encroachments may give rise to conflicts between agencies with differing management objectives with respect to the preservation of scenic values or between agencies and the potentially affected public that may be strongly opposed to "living with" the visual impacts of wind facilities on public lands.

The BLM and Forest Service visual resource inventory and management programs establish relative visual values for lands to which they are applied, which is useful at a general level to indicate lands more or less suitable for development of various types. These programs include sensitivity measures in general assessments of relative visual values, and agency land use management decisions should incorporate sensitivity considerations. However, these systems are not optimized for determining specific locations within a given area that are most or least sensitive to the visual impacts associated with wind energy and electric transmission facilities. This finer-scale analysis requires consideration of physical landscape factors, such as visibility of

potential development areas from multiple sensitive viewpoints, as well as tools for assigning differing levels of sensitivity for specific viewpoints and landscape features.

The topic of visual impact risk has rarely been addressed systematically in published literature. Fairhurst (2010), for instance, discussed visual impact risk in the context of landscape *apparency*, a measure of the visibility of landscape features based on strictly physical visibility parameters, such as the angle of visual incidence and view duration. Fairhurst's approach addresses *landscape vulnerability*, described as "the risk or likelihood of visible change occurring in the landscape." However, Fairhurst's study does not address the issue of sensitivity of the viewed landscape, a key consideration in land use planning and project siting.

1.2.2 Visual Absorption Capability

In addition to sensitivity, there are other important visual considerations for determining optimal locations for wind energy development, including *visual absorption capability*, a measure of the ability of a given landscape to accept human alteration without loss of landscape character or scenic condition. In essence, visual absorption capability indicates the ability of a landscape to "hide" development, such as a wind energy facility and associated roads and transmission lines. Visual absorption capability is largely determined by biophysical factors, including the following:

1) The degree of visual penetration, i.e., the distance into the landscape one can see from a vantage point, and

2) The complexity of the landscape as determined by various physical factors including slope, vegetative pattern, color and diversity, vegetative screening ability, site recoverability, soil color contrast, landscape diversity, land stability, water form diversity, and soil erodibility (Yeomans 1979).

Landscapes with low visual penetration will have higher visual absorption capability values. Landscapes with such characteristics as low slope, complex vegetative patterns, good vegetative screening ability, low soil color contrast, high landscape diversity, low soil erodibility, and the ability to recover quickly from damage will also have high visual absorption capability values. For example, forested areas with a good mix of plant species in rolling terrain might have high visual absorption capability values because they would have low visual penetration with good screening, and complex coloring and textures that would make it harder to see man-made infrastructure. Flat, monoculture grasslands generally would have low visual absorption capability values because they would have high visual penetration, poor screening capabilities, and uniform color and texture that would make it easier to see infrastructure. Landscapes with high visual absorption capability values would be expected to be able to accommodate wind energy facilities more readily than landscapes with low visual absorption capability values.

1.2.3 Scenic Integrity

Another visual consideration for determining optimal locations for wind energy development concerns *scenic integrity*, defined as: "The state of naturalness or a measure of the degree to which a landscape is visually perceived to be 'complete.' The highest scenic integrity ratings are given to those landscapes that have little or no deviation from the landscape character valued by constituents for its aesthetic quality" (FS 1995). Essentially, landscapes with visually conspicuous disturbances have lower scenic integrity values than landscapes that are natural appearing and/or have little visible disturbance. Landscapes with low scenic integrity values would generally be preferred locations for siting wind energy developments because siting facilities in already visually degraded landscapes would generally be preferable to siting facilities in more visually intact landscapes.

1.2.4 Scenic Quality

In addition to visual absorption capability and scenic integrity, another important visual consideration for determining optimal locations for wind energy development concerns *scenic quality*, defined by BLM as "a measure of the visual appeal of a tract of land…which is determined using seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications" (BLM 1986a). BLM rates scenic quality through a systematic evaluation process based primarily on professional judgments of these factors by persons trained in BLM's Visual Resource Management program procedures.

Landscapes with low scenic quality values would generally be preferred locations for siting wind energy developments because siting facilities in less attractive landscapes would generally be preferable to siting facilities in more visually attractive landscapes.

1.3 Visual Impact Risk Assessment and Mitigation Mapping System

1.3.1 Product Concept

The Visual Impact Risk Assessment and Mitigation Mapping System (VIRAMMS) is a multi-user geographic information system- (GIS-) and web-based prototype application designed to assist land planners and developers with early assessment and avoidance of visual resource issues, and mitigation of unavoidable visual impacts of wind-energy facilities and their associated energy transmission components. VIRAMMS was developed to provide a tool for land use and activity planners to use when screening land areas for sensitivity to visual impacts from wind energy development and associated grid-connection electricity transmission development.

Sensitivity screening within VIRAMMS is accomplished primarily through visual impact risk mapping. VIRAMMS visual impact risk mapping is based on a *distance-weighted sensitivity analysis*, a sophisticated GIS-based analysis that combines the calculation of visibility of the landscape from multiple key observation points with consideration of the visual sensitivity of both the key observation points and features of the viewed landscape. The analysis is adjusted to account for distance, a major factor in determination of visual contrasts and associated impacts. VIRAMMS also provides simple tools for screening lands based on visual absorption capability, scenic integrity, and scenic quality.

Other VIRAMMS capabilities include identifying location-specific visual impact mitigation measures and best management practices, and conducting advanced viewshed analyses for determining the topographic screening capabilities of landforms. These tools are discussed in more detail below.

The original concept for VIRAMMS originated from discussions initiated by Argonne with BLM in response to the *20% Wind by 2030: Overcoming the Challenges* Program Announcement issued by DOE in 2008. BLM agreed to partner with Argonne on the project, with BLM playing an active participant role through in-kind donation of staff time. The University of Arkansas Center for Advanced Spatial Technologies was selected as the GIS and software development subcontractor on the VIRAMMS project. Argonne, BLM, and the Center for Advanced Spatial Technologies jointly collaborated on the VIRAMMS system design. In addition to design input and review, BLM provided a GIS dataset for use in developing and testing VIRAMMS. The test dataset covered BLM-managed and other lands within and near the San Luis Valley in south central Colorado.

The capabilities for visual impact risk mapping and location-specific mitigation analysis that a fully developed version of VIRAMMS could provide are not currently available to land use and activity planners. The overall goal of the VIRAMMS project was to develop a basic prototype system for testing the feasibility and utility of a full-scale production system that would provide these types of capabilities.

As envisioned, the fully-developed VIRAMMS product could be used by land management and planning agencies in proactive land use planning for wind energy development and transmission siting through identifying areas at greatest or least risk for visual impacts, prior to or independent of project-specific evaluations. This knowledge could be used to inform land use decisions regarding locations for future energy developments. In addition, when a wind energy development project is proposed for a specific location, the visual impact risk maps generated by VIRAMMS could be used to immediately identify high-value visual resources and sensitive viewing locations that might be impacted; thus, reducing the time required for impact identification and analysis, potentially leading to faster resolution of siting concerns.

Planners could use VIRAMMS as a screening tool early in the siting process to rapidly assess the risk of visual impacts from siting a project at a particular location. Even if visual impacts are not the primary driver for project siting (AWEA 2008), identifying visual impact risk early in the siting process would allow planners to begin assessing opportunities to mitigate potential impacts and to incorporate visual considerations earlier in the planning process, a practice that has been

identified by the BLM as important to minimizing impacts from development (BLM 2008). Identifying visual impact risk early in the planning process would also allow planners to assess the probability for land use plan conformance and the potential for public opposition to a particular project; both which could delay significantly or prevent successful siting, with obvious cost implications.

Visual impact mitigation is also an important factor in planning and siting wind energy developments (NRC 2007). Successful mitigation planning not only results in minimizing the ultimate impact of a project, but also may be important in gaining approval for building the project and for gaining long-term public acceptance of the overall concept of wind power development. Planning agencies usually require, and the public sometimes demands, that developers agree in advance to mitigate potential impacts and agree to implement best management practices as a condition for approval or acceptance. Often, mitigation measures and best management practices are specific to a particular geographic setting, such as avoiding cuts and fills for access roads in steeply sloped areas or siting turbines to take advantage of topographic or vegetative screening in areas where topography or vegetation type and maturity permit.

VIRAMMS would provide a tool for land management and planning agencies to identify location-specific visual impact mitigation measures and best management practices. Knowing which mitigation measures and best management practices are appropriate for an area under consideration for wind energy development is useful for activity planners because it quickly identifies actions that may be appropriate to protect resources early in the planning process; thus, helping to insure that planners are informed when discussing mitigation measures with developers and other stakeholders. Implementing post-planning reactive mitigation may incur increased costs; identifying potential mitigation earlier in the project siting process is also useful to developers, as it supports a preliminary assessment of potential mitigation and associated costs. These up-front efforts may ultimately streamline project siting and help curb long-term costs, particularly if the assessment results in moving project components to locations where less mitigation is required.

2 VIRAMMS Product Description

2.1 System Overview

VIRAMMS is a multi-user web-based application designed to assist land planners and developers in assessing and mitigating the visual impact of wind-energy facilities and their associated energy transmission components. Major system capabilities include visual impact risk map creation and site infrastructure analyses. Land use planners can utilize the system to develop a risk map for an area of interest. Activity planners can use these risk maps and other geospatial data layers to interactively site wind facility infrastructure elements within the area of interest

and receive suggestions from VIRAMMS for location- and component-specific mitigation measures and best management practices to avoid or reduce visual impacts.

Furthermore, users can create a custom viewshed analysis for a proposed development from user-defined key observation points. The resulting viewshed analysis will also indicate the maximum building height potential for areas where the ground itself may not be visible from those key observation points.

For both the visual impact risk map and the site infrastructure analyses (i.e., the mitigation mapping and build height calculator tools), users may record analytical results by exporting maps as portable document files (PDF) or printing directly from the application. Additionally, infrastructure features that are created by the user may be exported and saved locally as GIS shapefiles.

2.2 System Architecture

The pilot VIRAMMS product utilizes client-server architecture and was developed using the ESRI ArcGIS Server platform. Users access VIRAMMS through a Web browser client, which displays VIRAMMS maps, menus, software tools, reports, and analytical results. Users request maps, information, and analyses from the server through their Web browsers. With the exception of the *build height calculator* (See Section 2.3.3.3), data and code to execute VIRAMMS functions reside on the ArcGIS Server, which retrieves the requested data and/or executes requested analyses and sends the results back to the users' Web browsers for display. The build height calculator is a C++ application that runs on a separate Linux server.

Analytical datasets used by VIRAMMS can be divided into two groups: one that requires on-the-fly computation (e.g., computation of the viewshed from a user-defined key observation point) and a larger group that can be pre-computed (e.g., vegetation types, or viewsheds from predefined key observation points and towns). For both groups of datasets, GIS intersection operations must be run in real or near-real time. However, pre-computing as many datasets as possible makes user interaction with the tool much faster.

A typical VIRAMMS usage scenario would include a dataset for a region, such as a BLM field office or a National Forest covering a portion of a state. Because of the specialized nature, complexity, and volume of data required for VIRAMMS operation, a GIS specialist would "preload" much of the spatial data used by the system into the GIS, including data layers consisting of pre-computed data, such as viewsheds run from established key observation points.

2.3 VIRAMMS Components and Functionality

The following discussion describes the user interface and major functional components of the VIRAMMS prototype system; the descriptions do not include every feature or tool in the system.

2.3.1 User Interface

The VIRAMMS Web interface is dominated by a map of the region of interest, and the user interacts primarily with the map and accompanying dialog boxes. The VIRAMMS Web client interface at system startup is shown in Figure 2.3-1. Menus are available to select analyses, import and export data, print maps, select GIS data layers for display, navigate and interact with the maps, and get online help. Dialog boxes associated with the main menu choices are used to specify parameters for the analyses, to input data related to those analyses, and in some cases, to view output from the analyses.

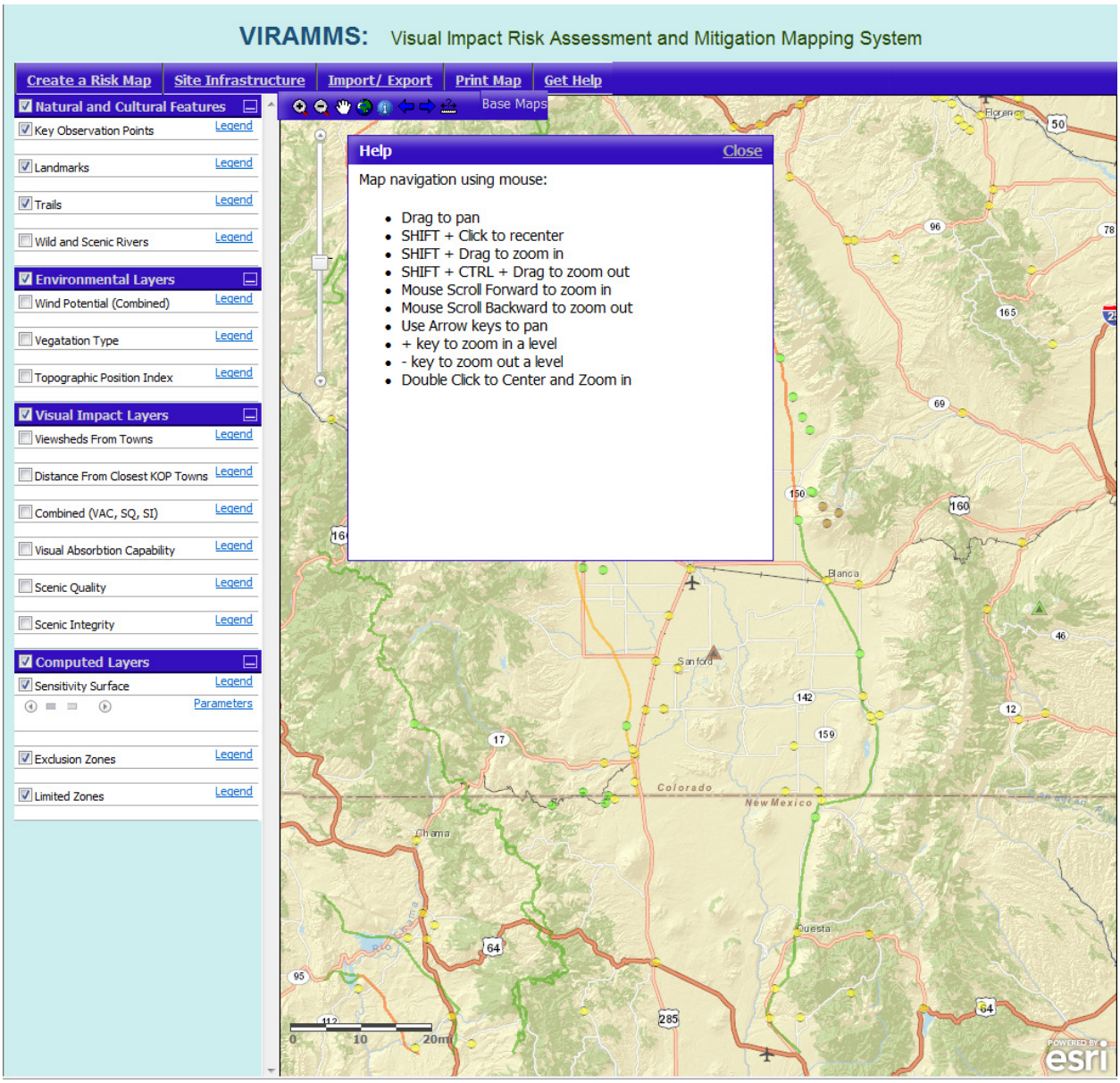

Figure 2.3-1 *The VIRAMMS Web client interface shown at system startup, showing various menus for such tasks as selecting analyses, importing and exporting data, printing maps, selecting GIS data layers for display, navigating and interacting with maps, and getting online help.*

The VIRAMMS map-centric interface provides access to geospatial data layers (map layers) that provide information used to place and view key observation points and sensitive visual resource areas and to display relevant contextual information. Map layers are divided into four functional categories:

- **Natural and Cultural Features** — This category contains map layers describing pre-defined key observation points and sensitive visual resource areas. This information is

provided prior to application deployment (pre-loaded) and cannot be modified by the VIRAMMS Web client user.

- **Environmental Layers** — This category contains three pre-loaded map layers (wind potential, vegetation type, and topographic position index [a topography classification layer]), which provide an environmental context for VIRAMMS analysis and may be used in the computation of the Visual Impact Layers and on-the-fly Computed Layers, as described below.

- **Visual Impact Layers** — Map layers in this category have been processed using static data (elevation, land cover, and town locations) and cannot be modified. These layers are used in the Sensitivity Surface calculation and the Mitigation Modeling components of VIRAMMS. Visual impact layers include viewsheds from preloaded key observation points, distance zones from pre-loaded key observation points, and visual absorption capability, scenic integrity, scenic quality, and related layers (see section 2.3.2 below).

- **Computed Layers** — This category contains a variable number of map layers computed from user input provided in the visual impact risk map (see Section 2.3.2) and site infrastructure (see Section 2.3.3) analyses. In essence, these layers are output maps from VIRAMMS analyses.

2.3.2 Visual Impact Risk Mapping

2.3.2.1 Distance-Weighted Sensitivity Analysis

VIRAMMS allows users to adjust, execute, and evaluate a complex model of visual impact risk for a given project area. Visual impact risk map creation is based primarily on a distance-weighted sensitivity analysis. The analysis considers visibility of points within a region of interest from one or more key observation points, as well as the differing visual sensitivities of the key observation points. All points within the viewshed of each key observation point are assigned a sensitivity value based on the key observation point's importance as a sensitive viewing location. Points in the viewshed of more sensitive key observation points have higher sensitivity values. The sensitivity value for each point in the viewshed is then modified based on its distance from the key observation point, with sensitivity decreasing as a function of distance. Where key observation point viewsheds overlap, values are combined additively to generate an overall sensitivity surface that reflects the sensitivity of each point based on its distance from all visible key observation points.

Users may select GIS entities such as roads, water bodies, or protected areas to define *exclusion zones*, where development would be prohibited, and *limited zones*, where development is not

prohibited but is sensitive, with optional offset distances to create buffers around the zones. Users may add custom key observation points for evaluation or utilize preloaded key observation points. Users may add *landmarks*, which are point features that correspond to visual focal points in the viewed landscape, near which wind development should be avoided, and for which users can specify sensitivity values. Users may use a set of tools to adjust key observation point and landmark sensitivity values and sensitivity distances.

There are four basic steps to conducting a distance-weighted sensitivity analysis to create a visual impact risk map:

1. **Define Exclusion Zones –** In this first step, users optionally identify GIS entities that should be delimited as unsuitable for wind infrastructure siting. For each layer listed, users may indicate whether wind infrastructure siting should be completely ***excluded*** from consideration in the distance-weighted sensitivity analysis, or simply marked as ***limited*** to indicate that it should be avoided or identified as sensitive. For each entity, users also specify an exclusion ***offset*** distance, which will create a buffer zone around each instance of the entity in the GIS layer.

2. **Add Other Observation Points and/or Landmarks –** Although typically key observation points and other sensitive visual resource areas are preloaded into VIRAMMS, some users may wish to insert additional key observation points or critical landmarks into the model. In this second step, users optionally identify additional key observation points and/or landmarks to add to the predetermined, pre-loaded key observation points and landmarks.

3. **Adjust Visual Sensitivity Ranking –** In this third step, users optionally adjust sensitivity values for one or more classes of key observation points and for landmarks. Variables include maximum impact distance, impact weight score, and impact weight (sensitivity-distance) curvature (i.e. the rate at which the weight drops off as a function of distance).

4. **Execute the Sensitivity Model –** In the final step, VIRAMMS runs the distance-weighted sensitivity analysis.

Output from the distance-weighted sensitivity is a *visual impact risk map*. The risk map is a color coded GIS map that indicates the relative risk of visual impacts for all points within the combined key observation point viewshed regions; it is based on the distance-weighted sensitivity of all points within the combined key observation point viewsheds from all visible key observation points and from all landmarks within the region. A simplified, example VIRAMMS visual impact risk map is shown in Figure 2.3-2. A more complex visual impact risk map closer to that which might be generated in a realistic usage scenario is shown in Figure 2.3-3.

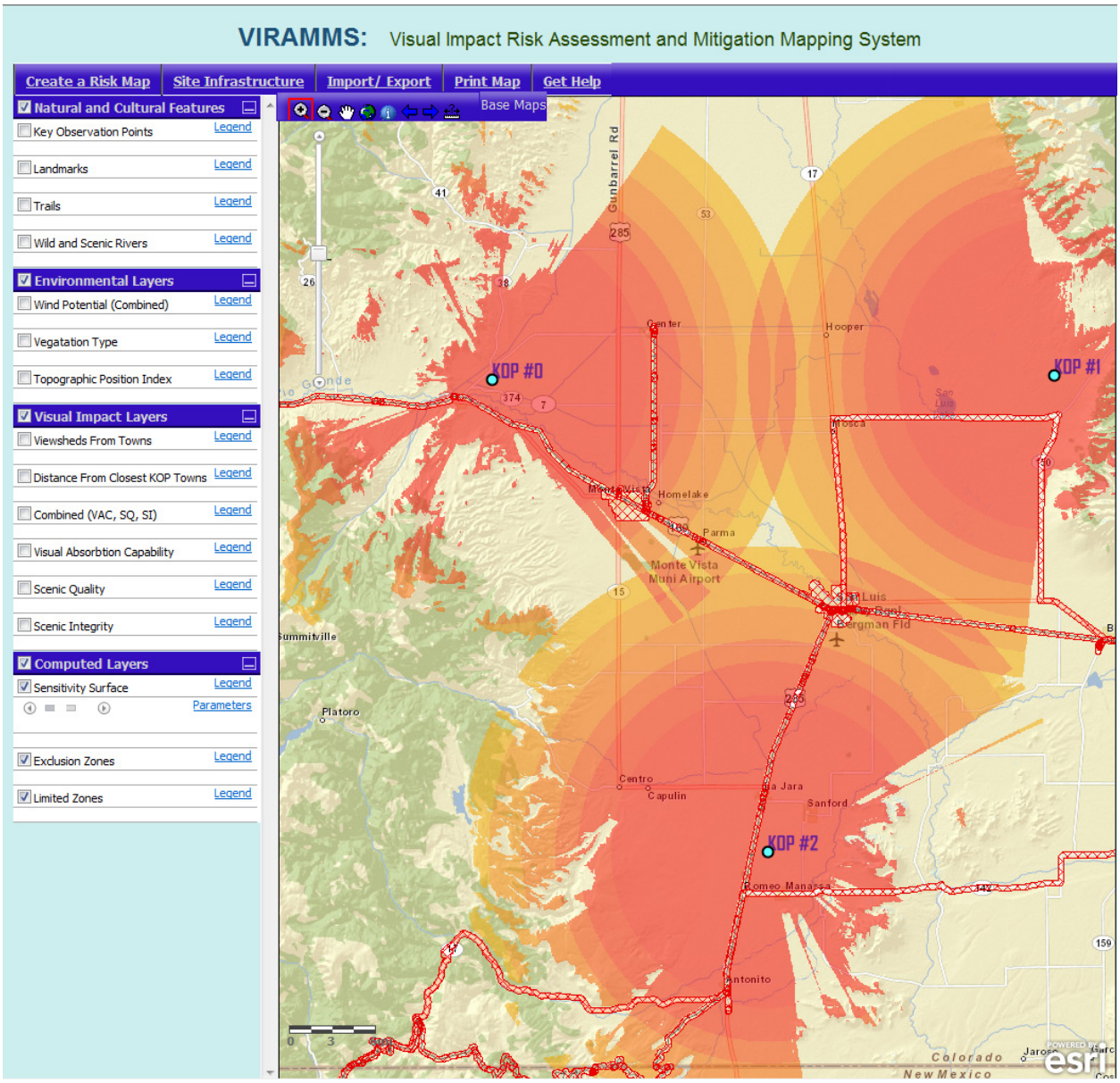

Figure 2.3-2 *A simplified VIRAMMS visual impact risk map with three key observation points (labeled KOP#0, KOP#1, and KOP #2).Key observation points are approximately 40 mi (64 km) apart. Areas shaded red to orange are key observation point viewsheds with a radius of analysis of 25 mi (40 km). Color ramps indicate relative visual impact risk, with red indicating higher relative risk, and orange indicating lower relative risk. Red hatching indicates wind facility exclusion areas of radius 0.25 mi (0.4 km) around scenic highways, railroads, and urban areas. Placement of wind facilities in shaded areas closer to key observation points results in higher visual impact risk. Placement of wind facilities in areas of overlap between viewsheds also results in higher visual impact risk because facility would be visible from multiple key observation points.*

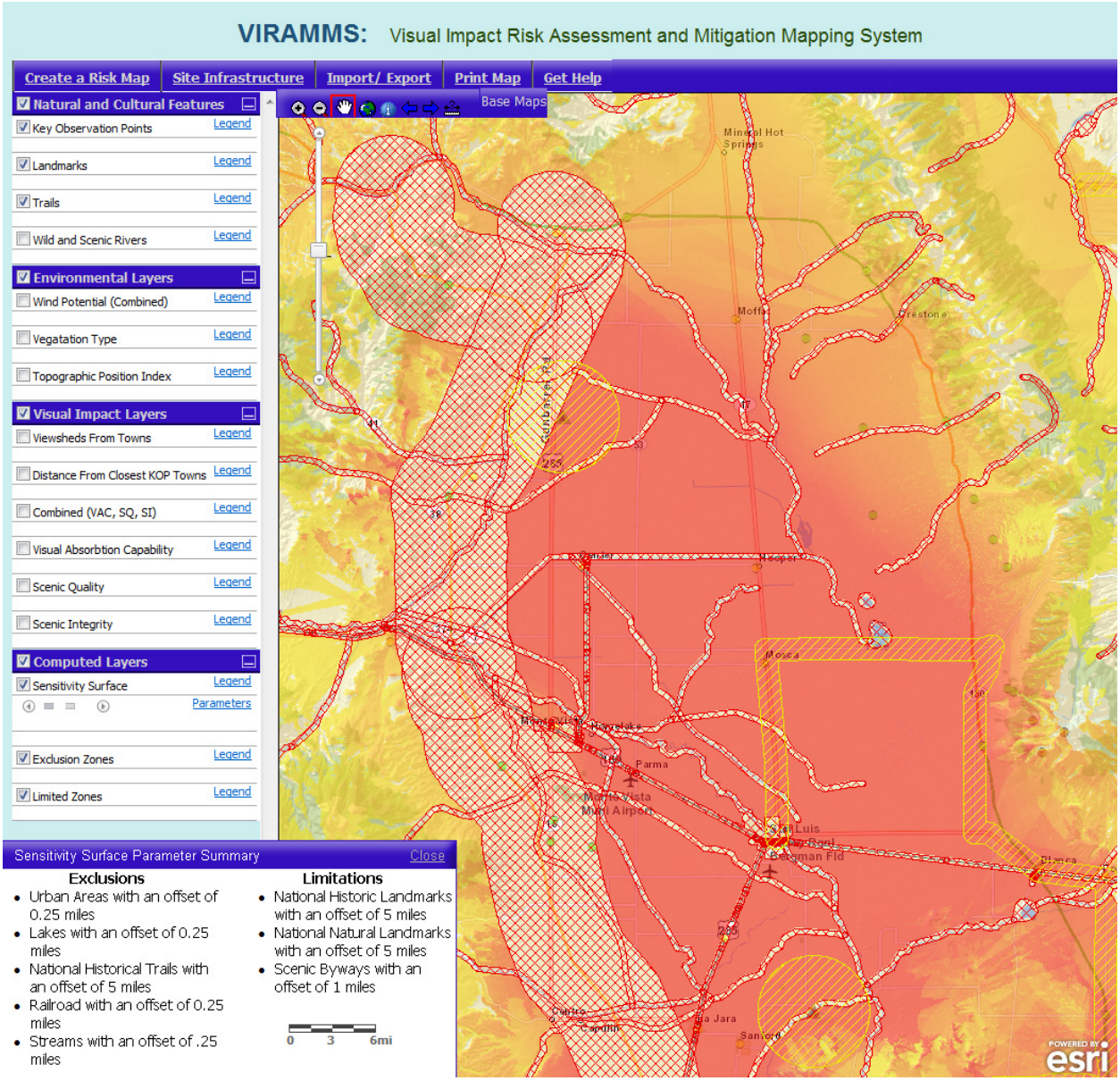

Figure 2.3-3 *A complex VIRAMMS visual impact risk map with key observation points (green dots)and landmarks (triangles). Areas shaded red to orange-yellow are key observation point viewsheds with a radius of analysis of 25 mi (40 km). Color ramps indicate relative visual impact risk, with red indicating higher relative risk, and yellow indicating lower relative risk. Red hatching indicates wind facility exclusion areas of radius 5 mi (8 km) around a national historic trail, and 0.25 mi (0.4 km) around railroads, streams, lakes and urban areas. Yellow hatching indicates sensitive areas of radius 1 mi (1.6 km) around scenic highways and 5 mi (8 km) around national natural landmarks. Risk mapping indicates lower potential risk from placement of wind facilities in rougher elevated terrain where topography limits visibility, and in northernmost portion of valley, away from key observation points.*

A typical usage scenario for visual impact risk map creation using VIRAMMS can be described as follows: A land use planner (i.e., the user) wishing to determine where in the region of interest are the best or worst places for siting wind facilities to minimize visual impacts would click one

or more points on one of several available base maps to specify desired custom key observation points (in addition to the existing predetermined key observation points), which can be of several types (e.g. scenic, cultural, or town). The user would use VIRAMMS tools to assign sensitivity distances and weightings to the various classes of key observation points, including the custom key observation points the user specified. In addition, the user could add landmarks — visual focal points near which wind facilities should not be located — and then assign sensitivity distances and weights to the landmarks. The user also could specify exclusion areas and avoidance areas where wind energy development would not be permitted or would be discouraged. When all custom key observation points and landmarks were added and their sensitivity weights assigned, and exclusion and avoidance areas defined, the user would push a button to have VIRAMMS conduct the distance-weighted sensitivity analysis.

In a few minutes, VIRAMMS would display a color-coded map showing areas of high, medium, and low relative visual impact risk, based on the simultaneous analysis of visibility of each point in the region from the various key observation points, the distance from each point in the region to every key observation point, and the varying sensitivities of the key observation points. The user could overlay this map with VIRAMMS data layers showing visual absorption capability, scenic integrity, and scenic quality (discussed in Section 2.3.3) to explore the spatial coincidence between areas of low visual impact risk and these other factors that are relevant to determining the optimum locations for siting wind energy development from a visual impact perspective.

2.3.2.2 Visual Absorption Capability, Scenic Integrity, and Scenic Quality Screening Toolset

In addition to the distance-weighted sensitivity analysis that culminates in the visual impact risk map, VIRAMMS offers an additional screening toolset that may be used in conjunction with or separately from the distance-weighted sensitivity analysis; this toolset includes visual absorption capability, scenic integrity, and scenic quality screening layers. Each of these landscape descriptors addresses landscape characteristics relevant to siting of energy infrastructure; the ability of a landscape to visually conceal infrastructure (i.e., visual absorption capability); the visual “unity” or “intactness” of a landscape (i.e., scenic integrity); and the visual attractiveness of the landscape based on its physical characteristics (i.e., scenic quality). Values for these descriptors can be derived from commonly available GIS data layers, such as elevation and vegetative cover. Methods for deriving basic values of these descriptors were developed and implemented for the VIRAMMS prototype product. This effort led to the development of separate GIS data layers for these descriptors that were pre-computed and incorporated into VIRAMMS as visual impact layers.

The visual absorption capability, scenic integrity, and scenic quality descriptor GIS layers described above were also combined in a pre-computed composite layer. The composite layer is a complex layer that captures the values for the three landscape descriptors. Each cell has three values, each of which describes the cell’s visual absorption capability, scenic integrity, and scenic quality as Unknown, Low, Moderate, or High. The layer facilitates simultaneous screening for multiple landscape characteristics.

2.3.3 Site Infrastructure Analyses

A primary function of VIRAMMS is the mitigation mapping process, by which VIRAMMS identifies location- and component-specific mitigation measures and best management practices to reduce or avoid visual impacts from a proposed wind energy facility. VIRAMMS users interactively place schematic representations of wind infrastructure components directly onto a map of the region of interest, and VIRAMMS then identifies mitigation measures appropriate for the specific geographic location and the specified infrastructure components. A related function is the *maximum build height* calculator that runs an advanced viewshed analysis to identify infrastructure concealment opportunities based on topographic screening.

2.3.3.1 Siting Infrastructure

The *Site Infrastructure* tools allow users to place specific proposed infrastructure features directly onto the map for the region of interest. The following types of infrastructure can be placed using onscreen drawing tools:

- Access roads;
- Buildings;
- Substations;
- Transmission lines;
- Transmission towers; and
- Wind facilities, defined either by individual wind turbines or by a bounding polygon.

In the VIRAMMS prototype, the drawing tools are simple, but they allow the flexibility to specify any size or shape for the facility components. They are “smart” tools, in that VIRAMMS stores the infrastructure component type with the drawn object, and uses the component type information to identify mitigation appropriate to that component in the mitigation mapping analysis (see Section 2.3.3.2 below). Onscreen placement of infrastructure in VIRAMMS is shown in Figure 2.3-4.

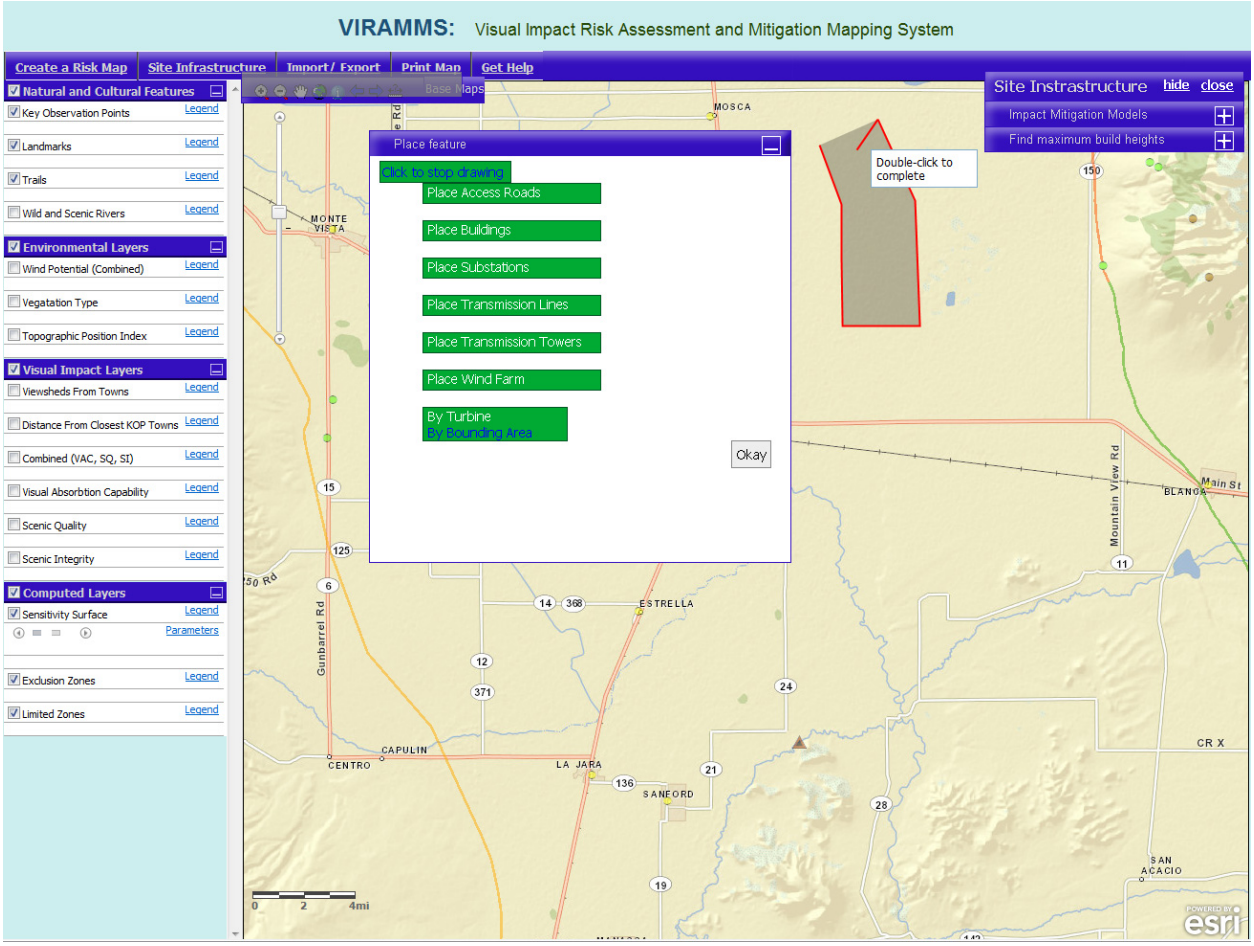

Figure 2.3-4 *Onscreen placement of wind energy facility in VIRAMMS, using a simple onscreen drawing tool.*

2.3.3.2 Mitigation Mapping Analysis

After placement of infrastructure using the *Site Infrastructure* tools, VIRAMMS executes the mitigation mapping function by analyzing various GIS data layers to determine physical factors such as slope, vegetative cover, and proximity to roads to determine if they occur close enough to the placed infrastructure components (i.e. within a specified buffer distance) to trigger a mitigation measure that applies if certain conditions are met, e.g., “slope exceeds 5%.” The mitigation measures, the infrastructure components to which the mitigation measures apply, and the trigger conditions are stored in a database table that VIRAMMS queries when the mitigation mapping analysis is run. The mitigation measures were derived from a variety of sources commonly used for environmental impact statements, and the triggering conditions were determined through consultation with an engineer. If the triggering condition is met, the tool returns the recommended mitigation measures applicable to the specified infrastructure component. The mitigation mapping analysis can be run for individual infrastructure components selected by the user or for all components that have been placed. The list of appropriate potential

mitigation measures, along with explanatory text and triggering conditions, is displayed onscreen. The mitigation measures are sorted by project phase or topic area.

A typical usage scenario for visual impact mitigation mapping using VIRAMMS can be described as follows: An activity planner (i.e., the user) wishing to determine potential mitigation measures for a specific proposed wind project that would take into account the geographic context of the project, such as its proximity to screening vegetation or location on a steep slope, would use VIRAMMS infrastructure placement tools to interactively place specific wind energy facility components, such as wind turbines, maintenance buildings, substations, or transmission lines in the region of interest. The user would then push a button to have VIRAMMS conduct the mitigation mapping analysis, which would query a database for mitigation triggers, i.e., conditions that would suggest the use of a specific mitigation measure that is appropriate in a specific geographic context or setting.

VIRAMMS would examine various GIS data layers in the VIRAMMS dataset to see if the triggering conditions are met within a specified buffer distance from the placed infrastructure component (e.g., VIRAMMS would query a slope map to determine which areas in the region exceeded a specified slope level that would trigger a mitigation measure about cut and fill practices in areas of high slope). If the triggering condition existed within the specified buffer distance from the appropriate wind facility component, VIRAMMS would retrieve the full text of the mitigation measure from a database and display it onscreen. The user could then suggest to a developer that the mitigation measure is required or should be considered if the project is sited in the proposed location, or use the VIRAMMS mitigation mapping tool to explore alternate locations for the facility components that would eliminate the need for the specified type of mitigation.

2.3.3.3 Build Height Viewshed Analysis

VIRAMMS also includes an advanced and very powerful viewshed analysis tool, hereafter referred to as the *build height calculator*. The build height calculator allows a user to define a key observation point and then run a custom viewshed model from the key observation point. The results assess each non-visible location (referred to as a *pixel* in the GIS analysis) within the viewshed radius to return a "*maximum build height*", an elevation value, which indicates the maximum height that an object can be at that location <u>without</u> being visible from the key observation point.

The build height calculator includes the ability to calculate build height viewsheds from multiple key observation points defined either as individual points or as connected linear features. The results indicate the percentage of key observation points within view of each pixel within the analysis radius, and the tool also assesses each non-visible pixel to return a "maximum build height" indicating the maximum height that an object can be at that location without being visible from *any* of the key observation points. Any structure higher than that height would be visible from one or more of the key observation points.

A typical usage scenario for build height viewshed analysis using VIRAMMS can be described as follows: A user, for example an historic trail manager, wishing to determine where wind turbines, substations, and other wind facility infrastructure could be placed to best take advantage of topographic screening that would conceal the infrastructure from view of the trail would use VIRAMMS drawing tools to specify individual key observation points on the trail or trace the trail centerline to make a linear key observation point. The user would then push a button to have VIRAMMS conduct the build height viewshed analysis. VIRAMMS would run a viewshed analysis from each individual key observation point and from specified intervals along linear key observation points. VIRAMMS would identify all visible pixels within a specified radius and would also determine which pixels are not visible from the key observation points. For every non-visible pixel, VIRAMMS would conduct a line-of-sight analysis that would determine the height of a structure that if it were placed in that location, it would just be visible from the key observation points. Any structure lower than that height would not be visible from the key observation points; thus, it would be concealed from view of the trail. VIRAMMS would display a color-coded map showing height zones corresponding to the maximum build heights. With this information, the trail manager could suggest alternative infrastructure siting locations to developers that would fully or partially screen the infrastructure from view of the trail.

3 Conclusions

VIRAMMS prototype development and testing was completed in October 2011. Testing results show that the VIRAMMS prototype met or exceeded all of the design and performance objectives.

The BLM Wyoming State Office has agreed to test the VIRAMMS prototype product on the Wyoming Wind and Transmission Study, a BLM project to identify wind energy development priority areas on BLM-administered lands throughout the state of Wyoming. The multi-year, multiphase project involves screening lands for wind energy development across a variety of criteria, including wind resource and other technical constraints (including transmission), land use, and a variety of environmental constraints, including ecological, visual, paleontological, cultural resources, and Native American concerns. VIRAMMS will be tested using real data for a small area of BLM-administered lands in the southern portion of the state.

The prototype VIRAMMS product has functioning versions of the major tools that would be in the production version. While enhancements are needed, future work would be primarily to improve the existing tools rather than build new ones. Additional funding for completion of a production version of VIRAMMS is being sought. Phase II development work would focus on a major upgrade to the user interface, implementation of account management and security, refinement of the distance and sensitivity curve manipulation tools, the addition of location-specific mitigation measures to the existing set, and refinement of the visual absorption capability and scenic integrity models.

There is currently an important need for the capabilities of VIRAMMS in the planning community. There are immediate, potential real-world applications for a production-level VIRAMMS product. VIRAMMS provides unique and powerful new capabilities for visual impact risk assessment. In particular, the VIRAMMS distance-weighted sensitivity analysis tool allows sophisticated analysis of visual impact sensitivity. VIRAMMS tools need not be limited to wind energy applications; the system has the flexibility to be applied to almost any type of development, with only minor modifications required. The VIRAMMS prototype has demonstrated that the technical and practical challenges of implementing distance-weighted sensitivity and visual impact mitigation mapping analyses can be successfully addressed by currently available computer technology, using commonly available data, and at an acceptable performance level.

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