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A Desktop Screen Analysis for Wind Farm Siting

By Mark Zellman, Chris Hitchcock, Ranon Dulberg, and David Slayter

Fugro-William Lettis & Associates
1726 Cole Blvd, Suite 230
Lakewood, CO 80401
Telephone: (720) 836-4880 extension 153
email: *m.zellman@fugro.com*

Introduction

A site suitability analysis conducted in a geographic information system (GIS) requires data appropriate for the type, and scale, of analysis being conducted. GIS data that had been created in the public domain, often available at little to no cost to users, is an essential commodity for GIS projects. These data are an ideal fit for projects with small budgets and fast turn-around times. We commonly conduct projects that lack the budget and (or) timeframe to acquire new data. In these situations, free data that are made available to the public through Federal, State, and local government organizations, universities, and other entities can be the only feasible means to complete a project. An example of this was a wind farm screening study conducted by Fugro-William Lettis & Associates, Inc. (FWLA) in 2008. For this study FWLA conducted a site selecting screening analysis for two potential wind farm sites using freely available data. The analysis was conducted knowing that the data used had limitations related to scale and resolution. These limitations were made clear to the client. These data provided FWLA with the ability to conduct a desktop site suitability analysis for both potential wind farm sites.

Methodology

The desktop assessment of site suitability involved the review of available topographic, geologic, and geotechnical properties. The quality of this assessment is often dependent on available data. For the two wind farm sites being studied, our analysis included:

- Site geology assessment
- Soils assessment
- Topography and slope assessment
- Determination of rock rippability
- Calculation of an estimated volume for rock material that would need to be excavated for construction of an access road.

Both sites are located within the State of California but differ significantly in terms of site geology, topographic slope, and access issues.

- Site 1 was situated along the coast of central California. This site was located atop coastal ridges with moderate to steep, vegetated slopes. The site has few bedrock exposures as these ridges are mostly covered with soil. A network of established dirt roads along the ridges would provide access to most of the proposed wind turbine locations.
- Site 2 was located in the Mojave Desert of Southern California. This is a bedrock and alluvium site with steep to very steep slopes in bedrock, and gentle to moderate slopes in alluvium. Unlike Site 1 this area lacks a network of developed roads. To gain access to the proposed wind turbine sites, new roads would need to be constructed. Most new road construction and all proposed wind turbines were located over bedrock of varying lithologies. The only access roads located over alluvium would be those located at the foot and flanks of the mountain.

Data Acquisition

The first step of our desktop analysis was to build the GIS data library. Our data search included sources of topographic, geologic, soil, and aerial imagery. Aside from scanned copies of U.S. Geological Survey (USGS) 1:24,000-scale topographic quadrangle maps that we annotated with preliminary road alignments and wind turbine sites, all data were downloaded from a variety of U.S. Government agency Web sites. These Web sites were designed with well-organized user interfaces and provided relatively easy access to the data.

The digitally scanned copies of USGS 1:24,000-scale topographic quadrangle maps provided by the client proved to be warped by the scanning process. New files were obtained from California's Cal-Atlas Geospatial Clearinghouse (*http://www.atlas.ca.gov/*). Digital Orthophoto Quarter Quadrangles (DOQQs) also were downloaded from the Cal-Atlas site. GIS databases in the Environmental Research Systems Institute's (ESRI) shapefile format, representing mapped soil units, were obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Services (NRCS), via the Soil Data Mart Web site (*http://soildatamart.nrcs.usda.gov/USDGSM.aspx*). Digital elevation models (DEMs) from the National Elevation Dataset (NED) at a 10-meter resolution were downloaded from the USGS National Map Seamless Server (*http://seamless.usgs.gov/*). Geologic data for Site 1 were downloaded from the San Louis Obispo County's SLO DataFinder page (*http://lib.calpoly.edu/collections/gis/slodatafinder/*). Site 2 was previously mapped by the USGS as part of Miscellaneous Field Studies Map MF-2344 by Howard (2002). The geologic map and associated shapefiles were downloaded from the USGS Publications Warehouse (*http://pubs.usgs.gov/mf/2002/2344/*).

Site Soils Assessment

Processing began with the soil shapefiles, using the USDA Soil Data Viewer (*http://soils.usda.gov/sdv/*). This tool can be downloaded from the USDA and operates as an extension in ArcMap. The tool allows for an end user to easily access the complex database that is associated with each soil map unit shapefile. In this case, the Soil Data Viewer was used to access the concrete and steel corrosion values for soil units exposed at Site 1. Corrosion values are grouped by the USDA into qualitative values of low, medium, and high. These groupings were used to reclassify the soil shapefile, which then was intersected with the wind turbine sites. This analysis was conducted only for Site 1 because of the lack of soil mapping at Site 2.

Rippability Assessment

An assessment of rock rippability was performed for both sites to estimate levels of difficulty to be encountered during the construction of the access road and wind turbine foundations. The original plan for determining rippability was to reference the Caterpillar, Inc., rock rippability charts (Caterpillar, 1995), which requires measured seismic velocities of the underlying bedrock units. Site specific seismic velocity measurements were not available for either site, so velocity values were estimated for each rock type based on velocity charts found in Barton (2006) and Rahn (1996). However, because a measured velocity value was not available, it was determined that a relative rippability chart would be more appropriate. For Site 1, where bedrock conditions are less complex, bedrock types were divided into groups of "less rippable" and "more rippable." An attribute field was added to indicate the level of rippability and the geologic units were attributed appropriately. The "more rippable" units were mostly surficial deposits of Quaternary age, whereas the "less rippable" were Tertiary-age sandstone, shale, claystone, siltstone, and tuff. Site 2 was more geologically complex and was broken into four groups of relative rippability. From most rippable to least rippable the units were (1) alluvium and windblown sand, (2) intrusive dacite, (3) aplite, granite gneiss, breccia, and granite, and (4) tectonic schist and basalt (fig. 1).

DEM data were processed and analyzed to estimate the amount of rock material to be excavated during access road construction. The 10-meter DEM base was also used to create slope maps for access road and wind turbine pad siting analysis. For these studies, higher resolution elevation data such as LiDAR (Light Distance and Ranging) would have been preferred, but the limited project budget and short turn-around time prevented acquiring such data. The next best available data were the 10-meter NED data provided by the USGS. Slope studies at both sites utilized 10-meter DEMs and 1:24,000-scale USGS topographic maps. The DEMs were processed using the ArcGIS 3D Analyst extension to display values of slope as a percentage. These maps symbolized percent slope using 5-percent intervals overlain with the proposed roads, wind turbine sites, and topographic maps. This process quickly revealed sections of roads that needed to be considered for rerouting.

Cut Volume Analysis

Analysis of cut volume proved to be more complicated. We investigated whether ArcGIS had built-in tools that would allow us to analyze a road (line feature) and a DEM to determine an estimate of earth material volume that would need to be removed to create the road, but found that no such tool existed. A process was developed which began by assuming the access road width would be 30 feet, or the approximate width of a single 10-meter DEM cell. To make this process work we also had to assume that all cuts would be made along the slope and at an angle because cuts of different shapes cannot be calculated easily with this method. To begin the process, a line feature representing the access road was intersected with the slope map (by percent) raster. The corresponding raster cells were saved, with slope attributes, as a new file and converted to a shapefile. This process created a network of grid cells measuring 30 feet by 30 feet, with slope values, arranged in the pattern of the access roads. The attribute table of this new shapefile was arranged to calculate an estimated amount of material to be removed for 1:1 and 1:2 cut slopes for each cell. Using the slope determined by the slope map, and knowing the width of the road to be 30 feet, a hypothetical wall height of a 90-degree cut could be determined. These

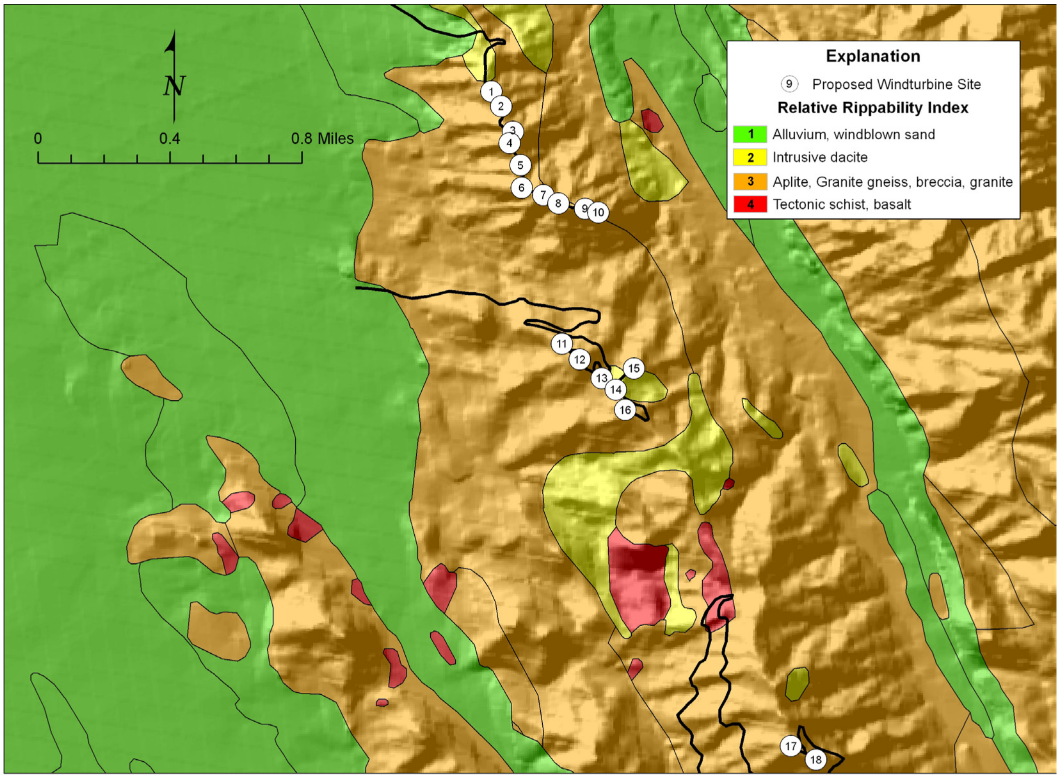

Figure 1. Relative rippability map of Site 2 showing proposed access roads (thick, black lines) and wind turbine sites. Geologic map from Howard (2002).

values were then used in simple trigonometry equations to calculate the volume of material to be removed with 1:1 and 1:2 cuts. This analysis was conducted only at Site 2. At Site 1, existing roads, relatively level approaches, and exposed soil at the ground surface rather than bedrock made it unnecessary to calculate the amount of material to be removed.

Another tool which proved to be very helpful in site analysis and presentation was Google Earth. Shapefiles representing roads, wind turbines, geology, and soil were exported as KML (Keyhole Markup Language) format from ArcGIS and opened within Google Earth. Wind turbine icons were created using Google SketchUp and placed over proposed wind turbine sites (fig. 2). This process aided in the visual evaluation of site road conditions and slope. Three-dimensional screen images were also exported and used to demonstrate site conditions during presentations to the client.

Results

For both sites, conditions were evaluated using ArcGIS, 3D Analyst, and Google Earth. The combination of these software packages allowed us to analyze available data and to address our primary assessment tasks:

- Site geologic conditions were assessed using published geologic maps. These data were combined with published information regarding rippability to created relative rippability assessments for both sites.
- Using USDA soil shapefiles and the Soil Data Viewer, Site 1 was analyzed for corrosive conditions.
- To evaluate slope conditions and proposed access road routes, DEMs and orthophotos were analyzed in ArcMap, and relevant files were imported into Google Earth for enhanced visualization.

In addition to the results listed above, for Site 2 the shapefile representing the gridded road (which was used to calculate cut volumes) was intersected with the rippability index map. Rippability values were spatially joined to the shapefile that represented the road. The attribute table containing relative rippability values, seismic velocity ranges, road segment length, bedrock types, and cut volumes was exported and summed in a spreadsheet. That summary (table 1) allowed the client to easily see the rock units they could expect to encounter during construction activities, the length of road to be constructed over each unit, excavation difficulty compared with other units, and estimated volumes of rock material they would be cutting from the slope. A similar table was created

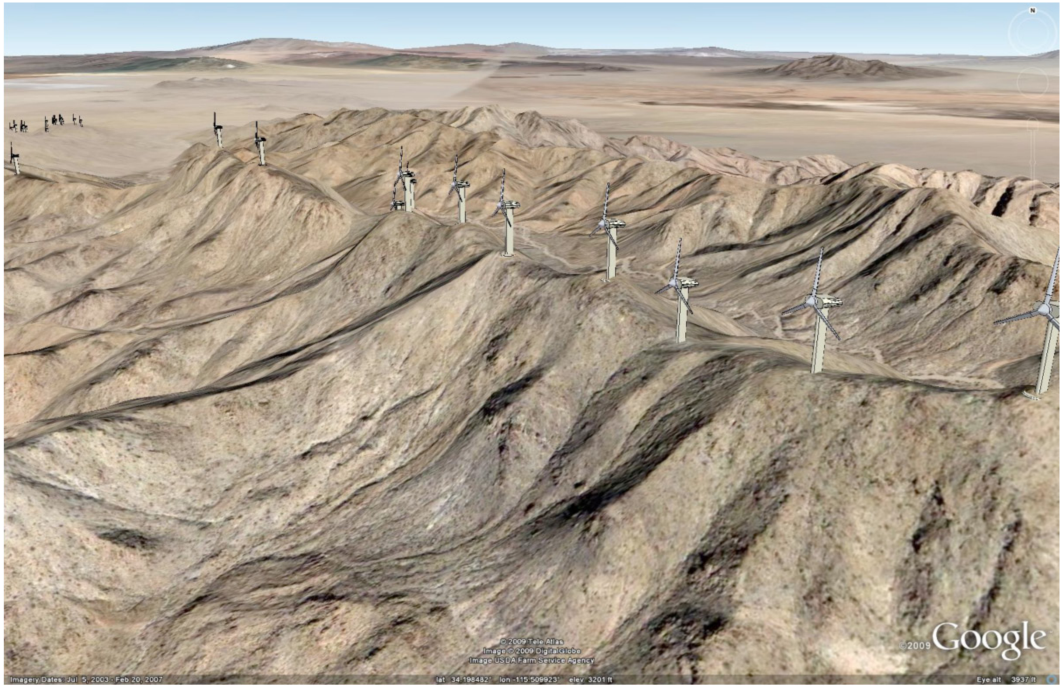

Figure 2. Three-dimensional scene of Site 2 taken from Google Earth with simulated wind turbines created in Google SketchUp.

Table 1. Site 2 relative rippability values and cut volume estimates.

Rock Type	Relative Rippability (1-4)	Velocity Range (kilometers per second)	Road Length (feet)	1:1 Cut Volume (cubic yards)	1:2 Cut Volume (cubic yards)
Tectonic Schist	4	6.0–6.7	18,807.62	235,905.41	139,775.45
Older Alluvium	1	0.5–2.5	4,326.09	9,091.08	8,112.71
Iron Granodiorite Gneiss	3	6.0–6.5	53,608.72	543,735.75	304,268.09
Intrusive Dacite	2	5.4–5.8	2,244.05	69,629.24	31,898.15
Granite Pass Granite	3	6.0–6.2	12,203.39	112,837.99	75,562.03
Danby Lake Granite Gneiss	3	6.0–6.2	31,370.18	489,979.16	264,438.38
Basalt in Iron Mountain	4	5.3–6.5	914.45	5,739.65	4,578.33
			123,474.5	**1,466,918.27**	**807,331.29**

for Site 1 that summarized the same data with cut volume estimates excluded. Excavation for roads was unnecessary at Site 1 because of the existing road network and relatively level approaches to the proposed wind turbine locations.

Limitations

While working with data produced and distributed by many sources, it is important to be aware of the scale of the data. Often the scale will vary, and it is important to convey the limitations of the data to the client. It is also important to clearly indicate the scale in the metadata of any derivative products that are produced. In addition to data scale, it is also important to be aware of any other data limitations. Data gaps, errant values, accuracy issues, and other such problems should be understood and evaluated prior to use. All calculations and analyses were completed with the knowledge that detailed estimates and results would be unobtainable with such coarse data. Work proceeded with the caveat that all estimates on cut volume and slope would be rough estimates.

Summary

This exercise shows how public domain data can easily be used to supply a project with a wide variety of data when time and budget limit the ability to collect custom datasets. Typically, enough public domain data can be gathered to satisfy project requirements. In many cases data will need to be gathered from a variety of locations administered by varying agencies. As a result of different management styles, budgets, and other constraints, one can expect to encounter a variety of user interfaces when attempting to find and download the data. Likewise, inconsistency in data quality, age, metadata detail, and scale can be expected to be encountered. Because these data are distributed by a variety of agencies, significant effort and time may be invested to actually find it. The more experienced a user is with searching the Internet for data, the easier this task becomes. Knowledge of the possible issues listed above can help the user deliver a better product to the client.

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