Using GIS for Microwave Coverage Analysis

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Abstract

Contra Costa County, located in Northern California, covers more than 500,000 acres. The terrain varies in elevation from sea level on three sides to Mount Diablo with an elevation of 3,849 feet located approximately in the center of the county. Size and geographic diversity creates numerous obstacles when considering network connectivity and telecommunication methodologies. Dealing with the very specific “line-of-sight” requirements of microwave communication equipment can be a daunting task in planning and designing network changes and enhancements. Advances in wireless technologies will play a key roll in connecting the outlying areas of the county. This paper discusses the methodology used to locate microwave transmission and receiving equipment. ArcGIS and ArcGIS Spatial Analyst are utilized to develop the necessary data required for a viewshed analysis.

Introduction

The Contra Costa County Public Works Department is centrally located in Martinez, California. The large area serviced by the county necessitates the existence of several remote facilities. These facilities include a Maintenance Office, Buchanan Fields and Byron Airport. The Computer Services Division of the Public Works Department administers a Local Area Network (LAN), consisting of a T1 connection between these facilities, with support from the Department of Information Technology.

The Computer Services Division provides computer related and network support services to the Public Works Department, including Geographic Information Systems (GIS) services and network administration. GIS staff maintains numerous local geographic databases of entities and attributes for specific applications in the Public Works Department. They also perform data collection, verification, and mobilization functions for the different division through the use of advanced field equipment such as GPS units and data loggers.

The Maintenance division provides maintenance duties for much of the critical infrastructure throughout the county. These duties include road maintenance, drainage infrastructure maintenance and vegetation management. A robust work order management system has been implemented that allows for proper asset management and efficient tracking of projects and their status.

The Department of Information Technology provides a full range of Information Technology services to the entire Contra Costa County organization. The department manages a countywide Wide Area Network (WAN), numerous Local Area Networks (LANs), and provides business and technical consulting services to departments and managers throughout the organization. The Telecommunications division is responsible for the planning, installation, maintenance and support of Telephone, Voice and Data Connectivity, Voice and Data Cabling, Voice-Mail Systems, 2-way Radio Communication System, and Microwave Communication Systems.

In the summer of 2005 the Computer Services Division was tasked with increasing the bandwidth between the Main office and the Maintenance Division office. The implementation of the new Work Order Management System, housed at the Main office, had placed an increased load on the current T1 connection (Figure 2). Alternatives included both leased and owned physical fiber connections, and wireless connectivity via expansion of current Microwave capabilities.

Through teamwork and cooperation, the project evolved to include the Department of Information Technology who was interested in a Countywide Back-Up Facility located at a remote location. The broadened scope allowed the Public Works Department to consider increasing the bandwidth to many of its remote facilities, including the south-easterly most facility, Byron Airport. High costs associated with a physical connection led to the decision to pursue a wireless solution. Initial estimates for Microwave services were $100,000 per drop.

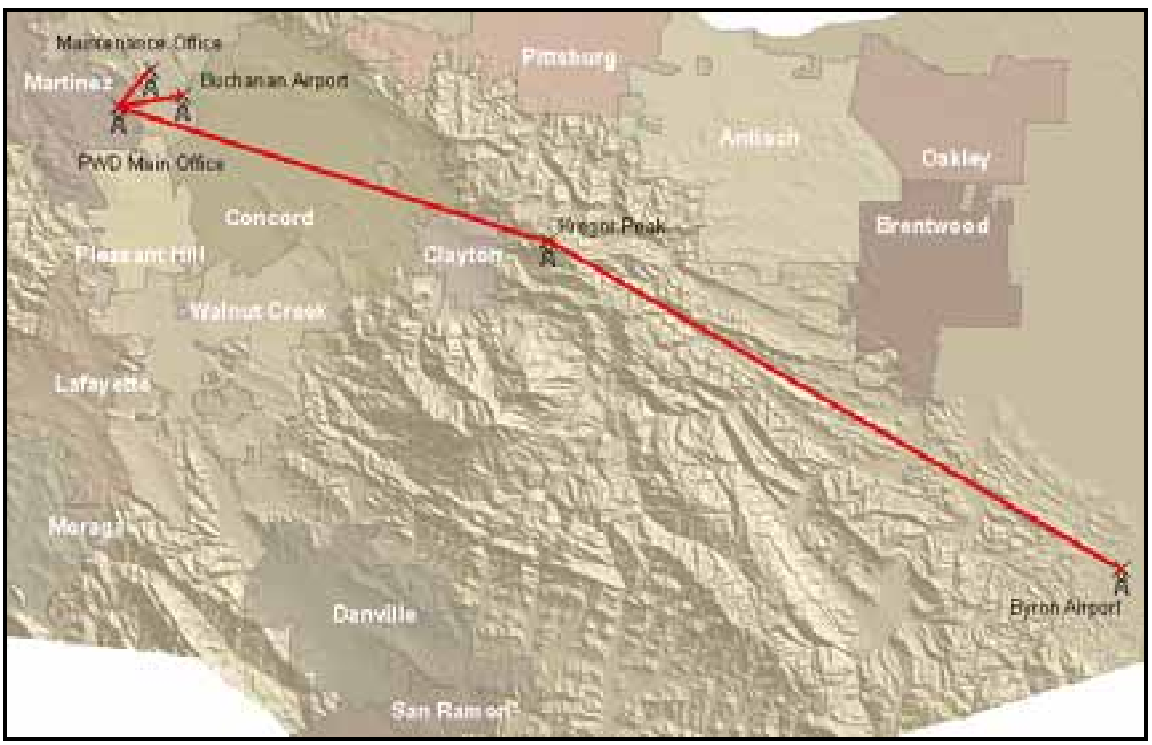

Figure 1. General overview of planned connectivity between central and eastern Contra Costa County.

Microwave frequencies are short wavelengths and require ‘line-of-sight’ for reliable operation. Bandwidth associated with this technology is approximately 134 Megabits per Second (~ 3 X DS3). With the exception of Byron Airport, all facilities were known to be in-sight of existing microwave infrastructure. The inclusion of this remote airport location and the decision to pursue a Microwave Data Transmission solution were the impetus for the viewshed analysis.

Bandwidth Comparison	
Service	**Speed**
DS0	64 Kbps
DS1 (T1)	1.544 Mbps
DS1C (T1C)	3.152 Mbps
DS2 (T2)	6.312 Mbps
DS3 (T3)	44.736 Mbps

Figure 2. Transfer rates for network connection service types.

Analysis

A viewshed analysis considers the relationship of slope, aspect, and elevation of the surrounding topography in order to determine the visibility of any given point from a known observation point. The data required for a viewshed analysis includes a Digital Elevation Model, and knowledge of the location and orientation of the observation points. Additional data specific to this analysis includes field collected points of known visibility between the existing Microwave Tower location at Kregor Peak and Byron Airport, Digital Ortho Photography, a hillshade, and a USGS Quadrangle.

The DEM has long been an integral component of any GIS. Advances in technology have led to increased accuracies of these elevation datasets. The Standard 30 Meter postings offered by the USGS as part of the National Elevation Dataset (NED), were valuable in the development of methodologies relating to the study of topography. However, this data proved to be too coarse for detailed analysis and has given way to readily available commercial datasets with much more vertical and horizontal accuracy (6X). This increased accuracy is evident in both the analysis of the raw data and the improved ortho-rectification of aerial imagery. Topographic analysis can be as simple as determining the slope or aspect of a given location or as complex as identifying all the locations which are visible from an observation point. This ‘visibility’ analysis is referred to as a viewshed analysis.

This project utilized a 10 Foot DEM which was derived from 10 foot contours. The contour data was captured as part of an Ortho Photography project in 2000. A hillshade with a sun altitude of 40 degrees and a sun azimuth 45 degrees, was created for visualization purposes.

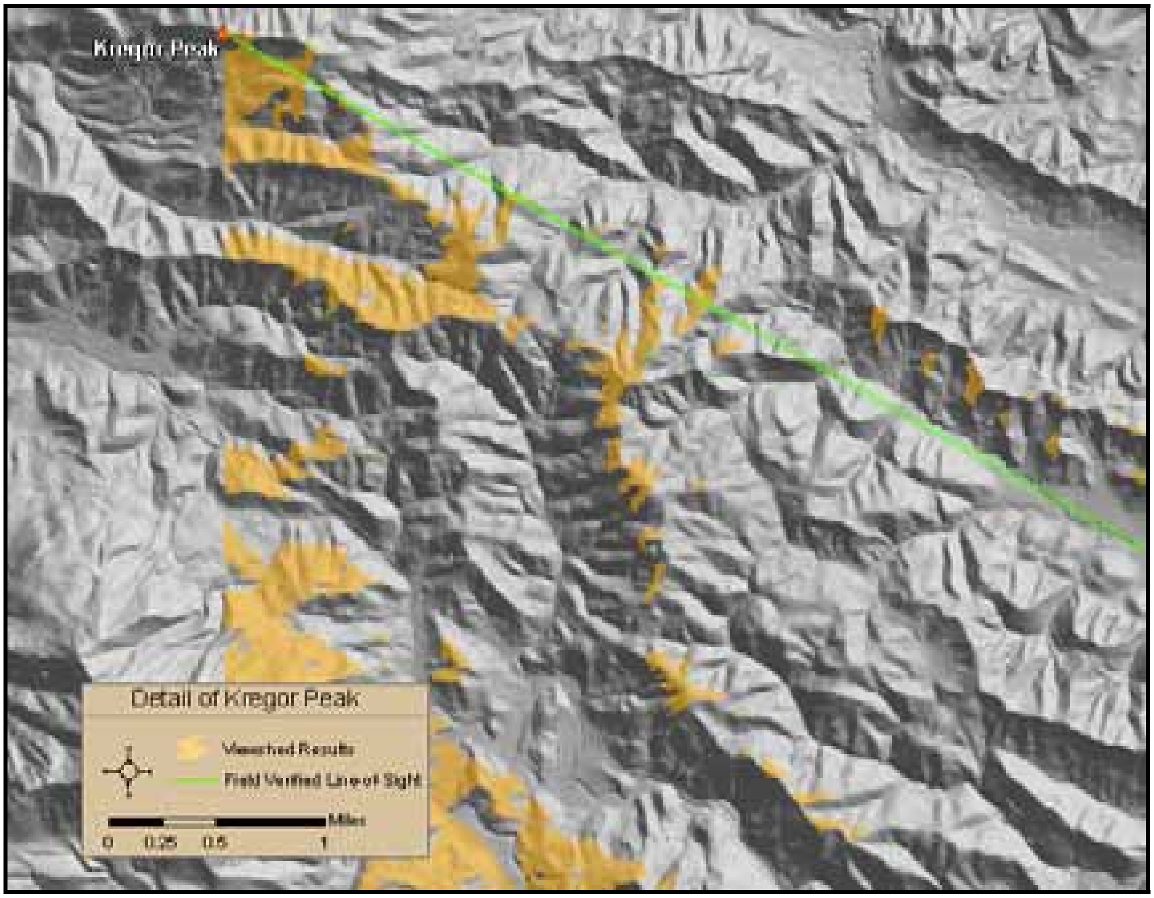

Figure 3. Detail of Kregor Peak Area showing hillshade, viewshed results (orange), and Line-of-Sight as observed from Byron Airport.

The observation point for this study is an existing communication tower on nearby Kregor Peak. The characteristics of the tower location and height (OFFSETA) are stored as parameters in the attribute table. Additional parameters stored in the attribute table include vertical (VERT1, VERT2) and horizontal (AZIMUTH1, AZIMUTH2) angles to scan/look, height to elevate observed locations (OFFSETB), as well as a scanning radius (RADIUS1, RADIUS2). These additional parameters help refine the observer characteristics, and can minimize processing time when analyzing large datasets. Due diligence should be practiced to ensure parameter field properties are properly defined. This project utilized the numeric 'Double' type. If a field is not present, a default is applied.

Attributes of Kregor_Pk

FID	Shape*	NAME	SPOT	OFFSETA	OFFSETB	AZIMUTH1	AZIMUTH2	VERT1	VERT2	RADIUS1	RADIUS2
0	Point	Kregor Peak	0	20	5	90	180	90	-90	1	105600

Record 1 Show: All Selected Records (0 out of 1 Selected) Options

Figure 4. Analysis parameters stored in observation point attribute table (units in feet and degrees).

Early in the planning process, GPS point locations were captured at Byron Airport. These points represent the eastern and western most locations with line-of-sight visibility to the communication tower on Kregor Peak. As the project progressed, and the viewshed analysis was completed, these points served to validate the analysis.

The availability of additional reference data helped plan and visualize the location of the new communication tower at Byron Airport. High-resolution ortho-imagery acquired in 2004, allowed for the adherence to strict policies with respect to tower locations in relation to hangers and runways. Additionally the use of a Hillshade and USGS topographic quadrangle, made for a visually appealing, familiar and easily interpreted map.

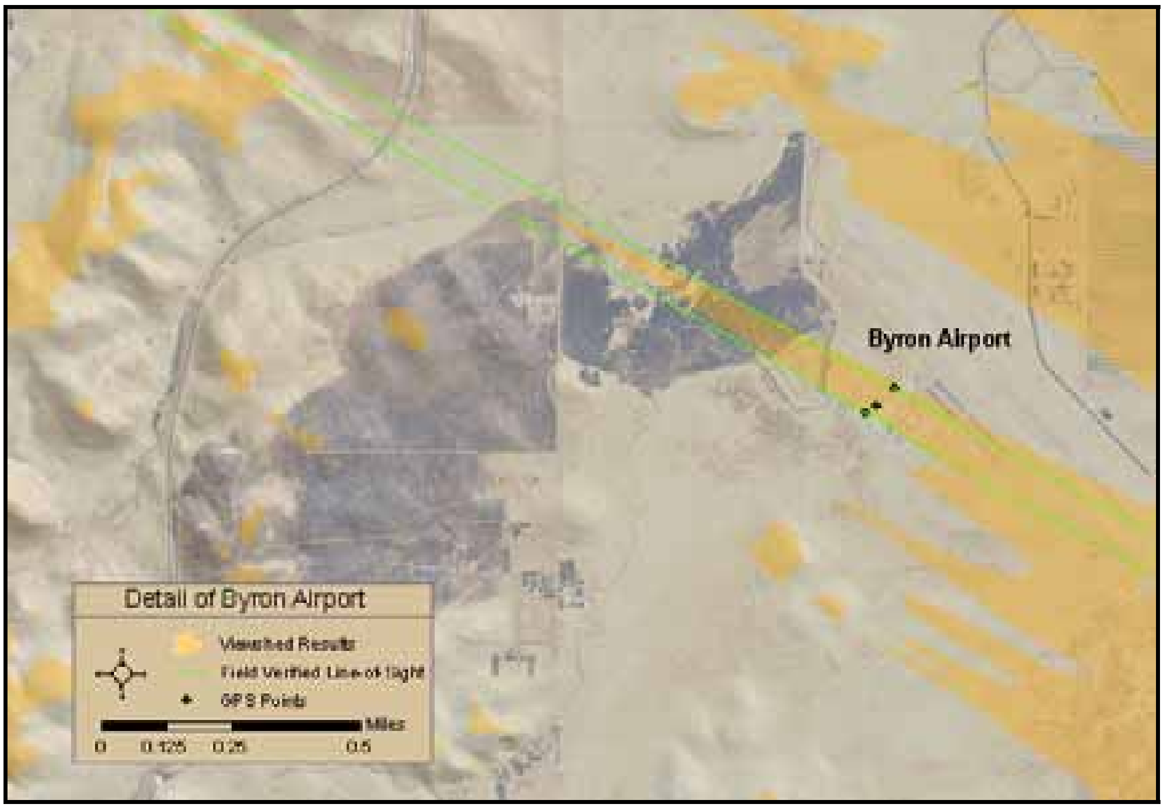

Figure 5. Detail of Byron Airport. Notice the correlation of the GPS data points (collected prior to any GIS analysis) with the results of the viewshed analysis.

Conclusion

It should be noted that many complex factors are associated with the sighting of communication equipment. The type of signal and its associated wavelength play a major roll in the locating of towers. GIS provides a starting point to help determine options and feasibility. A microwave provider will conduct their own survey of the area for final location and installation, but having an understanding of what the options are can save time and money.

The planning phase of the project is nearing completion. Two major microwave providers have each conducted their own traditional survey to determine access from Kregor Peak to Byron Airport, both surveys have confirmed our findings. Bids have come in under initial estimates.

This project has fueled the imagination of managers within the Public Works Department. Specifically, the Flood Control District is considering a similar analysis for the selection of perspective sites of rain gauges, and their associated data transmission equipment.

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