High-Resolution DEM Development of the Kajakai Dam and Reservoir, Helmand and Uruzugan Provinces, Afghanistan

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INTRODUCTION

More than 25 years of conflict has largely destroyed the Afghanistan natural resources organizations and their capacity to function for "public good" and to contribute to the economy of the country. Facilities, laboratories, and field equipment, have largely disappeared. The earth sciences infrastructure must be completely recreated beginning with the organizations, mission, structure, culture, and revitalizing and retraining of the remaining technical staff. The rebuilding of this infrastructure is critical to the short and long term planning for and management of natural resources such as minerals, energy, water, agriculture, and geospatial infrastructure.

The USGS, in cooperation with the U.S. Agency for International Development (USAID), is conducting natural resource assessments in support of reconstruction efforts in Afghanistan. The natural resource assessments include scientific investigations mapping coal, oil, natural gas, mineral, and hydrologic resources, as well as evaluating earthquake hazard risk. Each of these applications requires remote sensing data and analysis at a variety of spatial and spectral resolutions. In conducting these assessments, the USGS project team has integrated the full suite of available sensors ranging from government operated LANDSAT-7 and ASTER to QuickBird, and SPOT-5 commercial imagery data sets.

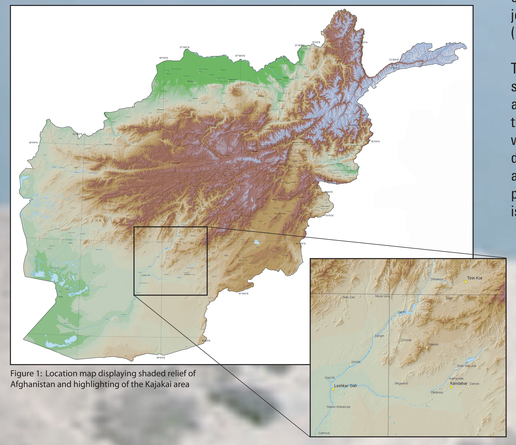

Figure 1: Location map displaying shaded relief of Afghanistan and highlighting of the Kajakai area

Figure 3: 3-D visualization of the Kajakai Dam using pansharpened 1m Quickbird imagery draped on the 5m SPOT DEM

DEM DEVELOPMENT

One component of the overall USGS initiative is the development of digital elevation models (DEMs) of the Helmand River and Kajakai Dam located in the south-western Afghan provinces of Helmand and Uruzgan (Figure 1). Accurate, high resolution DEMs are required to determine the number and location of thousands of households that will have to be relocated with the installation of the new Kajakai Dam spillway gates and a projected increase in the current reservoir level (Figure 2).

The DEMs will also be used in developing stage-storage curves of the reservoir to determine storage volume available. This information will allow the determination of the most efficient balance of water demands between irrigation, power production and flood control. The information will also be used in the analysis of the dam's ability to pass large floods and potential dam overtopping issues with the gates installed.

METHODOLOGY

Acquisition and processing of 2.5m resolution panchromatic SPOT-5 stereo imagery enables the development of digital elevation models (DEMs) with a horizontal resolution of 5m using stereo-autocorrelation techniques and GPS ground control measurements. DEMs are integrated with pan-sharpened Quickbird imagery in delineating the reservoir elevation scenarios, individual households, and critical land-use/land-cover data which will be provided to decision makers in considering the costs and benefits for the Kajakai Dam capacity increase (Figure 3).

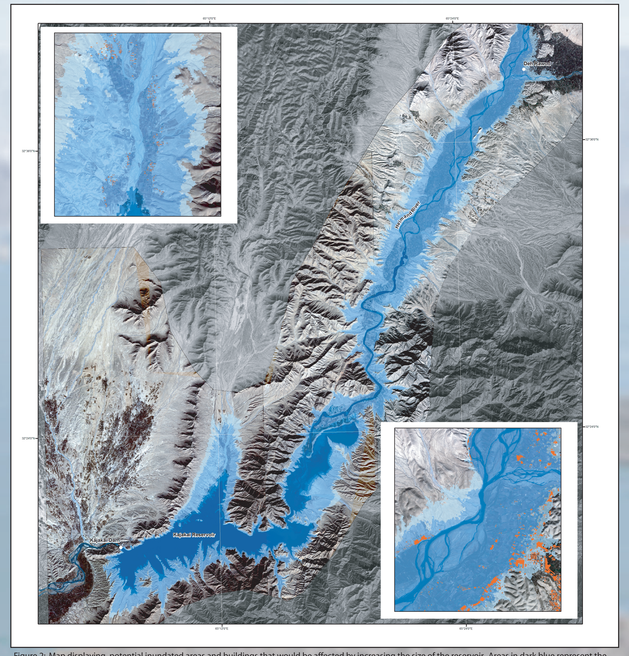

Figure 2: Map displaying potential inundated areas and buildings that would be affected by increasing the size of the reservoir. Areas in dark blue represent the current lake level, while the shade of blue in the middle represents elevations between the current lake level and 1040m, and the lightest shade symbolizes elevations between 1040 - 1060m.

SPOT-5 HRG	Image Resolution	Acquisition Date	Acquisition Time (Local)	Incidence Angle	Sun Azimuth	Sun Elevation
Image #1	2.5 meters	2/26/2006	11:03:02 AM	9.718	152.19	44.39
Image #2	2.5 meters	2/27/2006	11:13:47 AM	-23.783	146.13	42.66

Table 1

Image Acquisition

Two SPOT-5 HRG 2.5m resolution panchromatic satellite images were used in the production the Kajakai DEM. The two images were collected in across-track stereo viewing mode and consequently were acquired on two different days from two different orbital passes. While acquired on different days the SPOT acquisition was ideal for stereo extraction as the images were acquired only day apart and have no clouds or other atmospheric interference. Table 1 documents the image characteristic of the SPOT stereo pair.

Sensor Geometry Modeling

The satellite images were loaded into PCI Geomatica's OrthoEngine module (version 9.1.7) for the sensor geometry modeling, stereo matching, and elevation extraction staged of the DEM development. To enhance the sensor geometry model, a set of 35 Global Positioning System (GPS) ground control points (GCPs) were surveyed by AED specialists to be used for image sensor geometry modeling. The surveyed GCPs were acquired mainly along the Helmand River valley and the Kajakai Dam site (Figure 4).

Figure 4: Army Corps of Engineers staff collected ground control points for the study area.

Stereo-Autocorrelation and Elevation Extraction

Once the sensor geometry is modeled utilizing the orbital characteristic of the satellite sensor and the GCPs stereo autocorrelation and elevation extraction is initiated. The geometric properties of each image and the GCPs are used to correlate each pixel in the first satellite image with its matching pixel in the second satellite image. The software algorithm then calculates an elevation based on the sensor geometry, GCPs and measured parallax or difference of each pixel set. To improve stereo-matching correlation and elevation extraction accuracy, elevation values were matched for a sub-sampled 5m by 5m image. As a result, the extracted DEM has a resolution of 5m.

Post-Processing

The raw DEM contains artifacts from the stereo-autocorrelation process which may result in "pits and spikes" in the extracted DEM elevation values. A progressive morphological filter was used in a post-processing step to remove erroneous elevation values and improve the quality of the DEM. The result is that only elevation values that exceed the user-defined parameters are replaced; all other values remain unchanged and the overall output quality is improved without degrading the high resolution fidelity of the DEM. The final post-processed DEM is shown in Figure 5.

Accuracy Reporting

A set of elevation independent test points was compared to the final post-processed DEM to provide an understanding of the vertical accuracy of the final product. The test point elevations were derived from Soviet Topographic maps at 1:50,000 scale and are estimated to be accurate to with 1m vertical. Two measures of accuracy were conducted. The first was a measure of the accuracy of points below 1100m elevation. The second was the entire set of 56 test points for an overall measure of vertical accuracy. Vertical accuracy is reported as both Root Mean Squared Error (RMSEZ) of the test points measured and also stated at the 95% confidence interval.

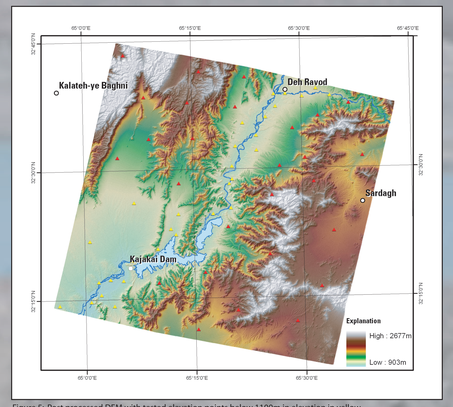

Figure 5: Post processed DEM with tested elevation points below 1100m in elevation in yellow and above 1100m in red.

Accuracy Reporting (continued)

The 95th percentile indicates that 95% of the errors in the dataset will have absolute values of equal or lesser value and 5 percent of the values will be of larger value.

The RMSEZ values below 1100m were calculated based on 29 test points and was found to be ± 5.91m. For vertical accuracy reporting requirements, the tested fundamental vertical accuracy at 95% confidence level in open terrain below 1100m elevation (using RMSEz x 1.9600) is calculated to be ±11.58m.

The root mean squared error of the elevation (RMSEZ) values calculated based on 56 overall test points and was found to be ± 10.03m. For vertical accuracy reporting requirements, the tested fundamental vertical accuracy at 95% confidence level in open terrain (using RMSEz x 1.9600) is calculated to be ±19.65m.

Additional Infomation

Visit our website for more information on research of the development, quantitative analysis, and applications of digital elevation models and remotely sensed imagery.

http://geology.er.usgs.gov/eespteam/terrainmodeling