CHAPTER 1 – INTRODUCTION

BACKGROUND

Synthetic aperture radar (SAR) technology, in combination with interferometry, has the ability to measure topography or ground movement. The technique is called Interferometric Synthetic Aperture Radar (InSAR), and in the context of its use in measuring relative ground movement, it is often referred to as Differential InSAR, or DInSAR. When SAR is mounted on a satellite, InSAR provides a convenient means of measuring ground movement, often without the deployment of field personnel or the expense of aircraft. Wherever vertical differential movement occurs due to subsidence, slides, settling, or creep, InSAR can often estimate the differential movement to sub-centimeter accuracy. Several radar satellites are commercially available to collect InSAR data on corridors of interest. For some locations, historical data dating back to 1992 is also available which provides a unique ability to perform historical reviews of ground movement when other data sources do not exist.

OBJECTIVES

The Federal Lands Highways (FLH) of the Federal Highway Administration (FHWA) is interested in evaluating InSAR technology to monitor slide movements that may impact road networks. A previous study by the FLH used InSAR to evaluate two landslide areas in Badlands National Park in South Dakota.(1) The FLH has initiated the current project to establish and demonstrate reliable, cost effective procedures to measure ground movement using InSAR in support of federal highways projects. This project demonstrates the effectiveness of InSAR in monitoring ground movement, and includes a comparison to conventional survey techniques. In addition, this project recommends guidelines for the coordinated use of InSAR with other FLH data collections, including photogrammetry, field surveys, boreholes and slope inclinometers.

STUDY METHODOLOGY

To execute the objectives of this project, three sites with a known history of slope instability were chosen for piloting the application of InSAR, including the Cimarron slide at Owl Creek (CO), the Prosser slide near Benton City (WA) and several unstable slopes in Mesa Verde National Park (CO). InSAR has the unique ability to measure both present and prior ground movement and consequently, the study involved collection and analysis of InSAR data from both the past and present. As stated in the original FLH solicitation, InSAR analysis was to be conducted over the following time periods, referenced to the start of the project in September 2003.

1. For a period beginning from the previous one to five years and ending within the previous year (to demonstrate the use of historical data),
2. Then for a period of time beginning at the end of the previous period and ending at a point in time following the award of this contract (to demonstrate the use of combining historical data with newly collected data),
3. Then for a period of time beginning at the end of the previous period and ending at a later point within the contract time where both InSAR and geotechnical data would be

collected simultaneously (to demonstrate the correlation of the InSAR and geotechnical data.)

The study methodology could be followed as outlined above to the extent that SAR data were available at the sites chosen for the project, and geotechnical data were collected for the correlation. However, as outlined in this document, there were several deviations made to the original study methodology to accommodate the availability of SAR images, the limited coherence of the SAR data over the desired monitoring intervals, the coordination of SAR imagery with slide events, and the availability of geotechnical data.

The collection of geotechnical data at the sites was not within the scope of this project. Instead, it was required to coordinate and direct the collection of these data, which would be funded by the participating transportation agencies if funding became available.

There are several sources of SAR data available for this study, including ERS-1/2, JERS, ENVISAT and RADARSAT-1. There are limited useful datasets available from ENVISAT and RADARSAT-1 prior to 2003 at the sites chosen for this study, and thus the main source of historical SAR data is ERS-1 and ERS-2. For all newly acquired data collected during the timeframe of this study, RADARSAT-1 was chosen as the main source of SAR data; this satellite has data which is generally more expensive than ERS-1/2 and ENVISAT however, the satellite has higher resolution imaging capabilities that are more conducive to imaging slopes.

The general methodology of the InSAR analysis was;

- Select and procure SAR data based on meteorological data and satellite baseline (see further the sections on the Factors Affecting InSAR Results and Slope Movement Monitoring in Chapter 2).
- Extract/acquire digital elevation model (DEM) for use with the analysis.
- Perform InSAR analysis, which includes:
    - SAR image processing;
    - Image geo-referencing (to DEM and other site data);
    - Image pair registration;
    - Coherence measurement;
    - Interferogram production;
    - Phase unwrapping;
    - Phase conversion to deformation; and
    - Map product generation.
- Perform deformation analysis.
- Perform geotechnical analysis and correlation of InSAR deformation movement to in-situ data collections.

REPORT ORGANIZATION

This report is organized as follows:

- Chapter 2 presents an overview of SAR and InSAR, including their application to slope monitoring and issues that must be considered when performing the monitoring.

- Chapter 3 presents an overview of the three sites selected for this study and provides background on the slope stability problems being experienced at the sites.
- Chapter 4 describes the InSAR processing that was conducted for each site, including the scenes selected, the processing and analysis performed and the interpretation of the data.
- Chapter 5 presents overall recommendations for the application of InSAR with federal highways projects and the coordinated use of the data with other data collections (surveys, photogrammetry, slope inclinometers, etc.).