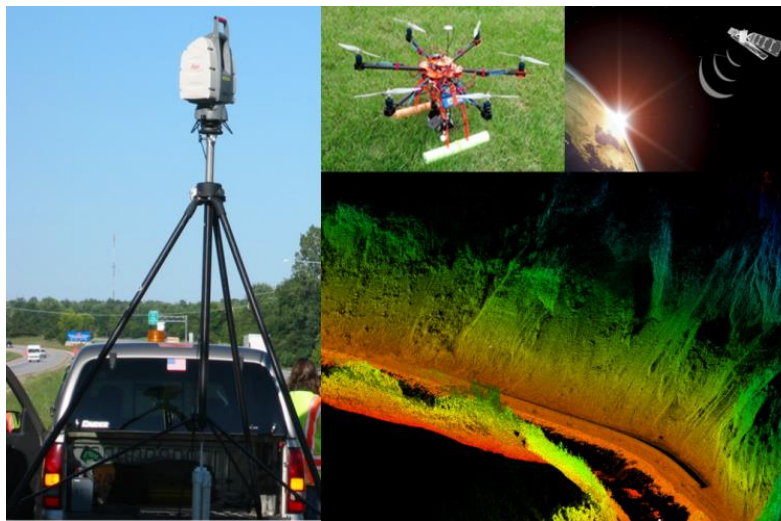


Deliverable 5-A&B: A Review and Demonstration of the Geotechnical Asset Management Decisions Support System (GAMDSS)

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1. EXECUTIVE SUMMARY

Geotechnical Asset Management Decisions Support System (GAMDSS) is a web based geospatial mapping tool designed to assist program managers. By combining remote sensing data with analyzed results, site variables, hazard information, and other ancillary data managers can explore the confluence of factors in a target region. GAMDSS support both raster and vector data which allow a great deal of flexibility in what the DSS can display. Both formats have built in capability to display legends which allow for quick visual interpretation of large volumes of data while popups allow vector data to express detailed information for any given feature. As a web based technology, the GAMDSS can be accessed anywhere a suitable internet connection is available, including mobile devices such as cellphones or tablets connected to the cellular network (3G/4G). A web based administration tool also allows authorized users to remotely upload new data, making it available to users immediately. A demonstration of the GAMDSS can be viewed at http://geodjango.mtri.org/SGAM_DSS/.

2. INTRODUCTION

GAMDSS is a mobile friendly web application solution for sharing geotechnical asset management information with users. It is built on a variety of primarily open source or freely available technologies and represents a complete solution including client and server software. Key features include a remote layer management system that allows authorized users to upload and manage projects and layers, support for high resolution raster imagery using Web Mapping Services (WMS), vector support using Google's KML standard, vector feature info popups, and legends for both raster and vector layers. The server software can be easily installed on any Linux machine running Apache webserver and the client web application can be viewed on virtually any device with a modern web browser and internet connection, opening the possibility to access asset management information in the field.

3. SERVER SOFTWARE

The GAMDSS server is the suite of software that receives web requests, processes the data, and returns a response. This software suite consists of Apache, PostgreSQL, Django, and GeoServer, all of which are open source and widely used by the online community. Apache considered the world's most used web server and has been around since 1995. PostgreSQL is an object-relational database management system based on the SQL standard. Django is a Python based web framework that simplifies the integration of a database with a web application.

While Django is a fully featured web framework that can handle entire websites, the GAMDSS uses a subset of its features to implement a web interface rather than the client application itself. In this context, Django acts as the middleman between Apache and PostgreSQL, interpreting web requests passed to it from Apache and handling the database queries to formulate a response. Django also includes an online administration tool that allows authorized users to manage the contents of the GAMDSS database. This is particularly useful as it enables users to manage projects and remotely upload new layers, which are then available to clients upon refresh of the client website.

Django administration Log out

Home > Layers > Layers > Layer object

Change layer History

Project:	Caliente <input style="font-size: 0.8em; vertical-align: middle;" type="button" value="+"/>	Category:	Risk <input style="font-size: 0.8em; vertical-align: middle;" type="button" value="v"/>
Which project the layer belongs to'			
Title:	<input type="text" value="Velocity_1992-2010_SqueeSAR"/>		
Filepath:	Currently: /usr/local/project/SGAM_Server/data/Caliente/hazard/Velocity_2003-2010_SqueeSAR_Caliente.kmz <input type="checkbox"/> Clear Change: <input type="button" value="Choose File"/> No file chosen		
Timestamp:	Date: <input type="text" value="2015-11-06"/> Today <input type="button" value="calendar"/> Time: <input type="text" value="05:27:26"/> Now <input type="button" value="clock"/>		

Figure 1: The server administration page allows authorized users to upload and configure project layers remotely.

Separate from the PostgreSQL and Django interface, the GAMDSS also employs GeoServer, an open source server for sharing geospatial data. Specifically, GeoServer implements a Web Mapping Service (WMS), which allows the GAMDSS client access to high resolution raster imagery that can be efficiently transmitted through an internet connection. Achieving optimal performance is a two part process. First the high resolution datasets must be modified to incorporate overviews. Overviews are reduced resolution copies of the original high resolution image that are stored in a single file. The second part is known as tiling and is part of the GeoServer software. Tiling enables the WMS client to send parts of an image, rather than the entire image. These individual tiles are compressed as JPG images further reducing the cost of transmitting high resolution imagery. Overviews further improve performance as the GeoServer tiling operation can select the lowest resolution overview that makes sense for the zoom level of the user. When viewing imagery from a high zoom level, transmitting a high resolution tile would be futile since the image will be downsampled for display anyways. With these features, GeoServer can avoid ever sending the full high resolution imagery at once: broad overviews of the image can be viewed with low resolution overviews, while zooming in to examine details can be handled with small subsets of the native high resolution image. For the GAMDSS, this means the client application can incorporate high resolution orthophotos or other datasets such as SAR derived slope for broad regions while maintaining good performance.

4. CLIENT SOFTWARE

The GAMDSS client is a web application built using a combination of HTML, JavaScript, and Sencha ExtJS 4.2.1. HTML and JavaScript are both standard languages used in the design and

implementation of web applications. ExtJS is a JavaScript application framework and is used by the GAMDSS to build the Graphical User Interface (GUI) as well as the communication with the server software.

The client application also includes several JavaScript libraries to provide geospatial mapping functionality. Google Maps API V3 provides the generic mapping functionality which the remaining client functionality is built from. GeoXML3, an open source KML parsing library, enables the client application to read and display KML files. KML files, another google standard, can incorporate both raster and vector components such as point features, line features, polygon features, and ground overlays. Since GeoXML3 is open source, it was modified to provide additional functionality to support the display of custom legend overlays using ExtJS, enabling content creators greater flexibility when determining how to present information in the GAMDSS.

Several plugin libraries for Google Maps were integrated as well, including the Marker Spiderfier and Marker Clustering plugins. The clustering plugin aggregates markers that appear close to one another at the current mapping zoom level, improving performance by minimizing the actual number of markers rendered by the application. This change allows for thousands of points to be displayed without an unbearable loss of application responsiveness. The marker spiderfier plugin allows markers that are in close proximity to be individually selected by ‘spidering’ them. In practice this means that point features that are on top of each other will move into a spiral formation when clicked, allowing each individual feature to be examined rather than only the feature on top of the pile.

5. USER INTERFACE

The GAMDSS user interface is dominated primarily by the map view minimize the loss of screen space to controls. The single control panel on the right side of the screen initially contains little information except for a dropdown that allows the user to select a project study area and can be collapsed to allow unrestricted view of the map. Once the user has selected the study area of their choice, the Hazard, Site Variable, and Ancillary subsections are populated with any layers assigned to the project. Each layer can be individually toggled on or off to control its display allowing users to view information in any combination they choose. Layers can be vector or raster layers and will render appropriately.

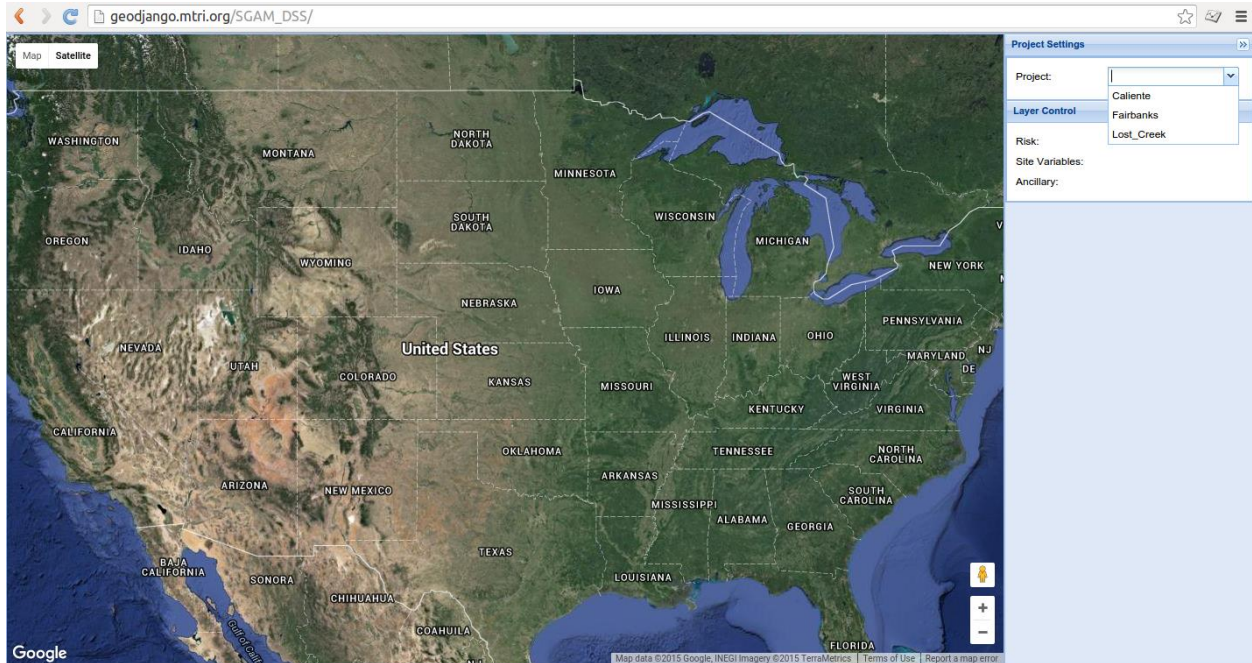


Figure 2: The GAMDSS defaults to an overview of continental US, and allows users to select the project area they are interested in.

The client also supports legends for both raster and vector layers, which will appear when the layer they pertain to is toggled on (visible). Each legend appears in a separate floating window for each layer which can be rearranged or minimized by the user to allow them to customize their display. The mapping window has also been modified to allow further zoom levels than Google Maps normally allows, so high resolution raster layers can be viewed with maximum detail. Since Google Maps does not provide imagery at extreme zoom levels, the background map will change to a Latitude/Longitude grid to try and maintain the user's ability to navigate the world.



Figure 3: GAMDSS allows users to zoom in closer than normally allowed by Google Maps for closer inspection of data.

6. NEVADA CASE STUDY

Successful implementation of the GAMDSS can be illustrated through the Nevada case study. In this example, the user is interested in observing spatial and temporal variables that reveal potential slope hazard along a 30-mile stretch of railroad corridor. The study site is prone to rockfalls, sometimes impacting the railroad track itself, and poses a danger to railroad personnel safety and to economic sustainability of the railroad company.

Using the GAMDSS, the user is able to zoom in to the study site and view input map variables partitioned into three categories: hazard, site variables, and ancillary. The ‘hazard’ category includes processed products derived from field- or remote sensing-based data and assist in the analysis of potential slope hazard and future risk. ‘Site variables’ category includes raw (unprocessed) data that may be beneficial to view with respect to slope hazard.



Figure 4: GAMDSS set up of Nevada case study, which is named 'Caliente' after the nearby town of Caliente, Nevada. Input map variables are separated into three categories: hazard, site variables, and ancillary.

The slope stability investigation of the Nevada case study can begin with an observation of site variables and characteristics. Site variables such as slope inclination can be displayed, as shown in the image below (Figure 5).

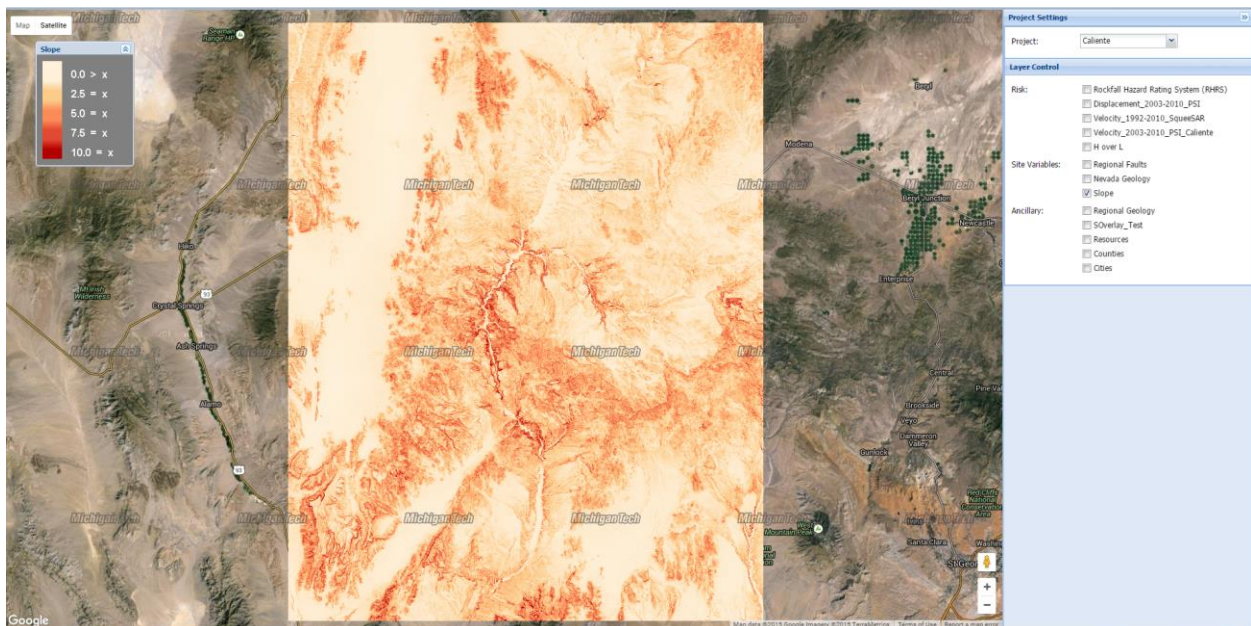


Figure 5: Regional slope inclination (in degrees).

Multiple site variables may be checked simultaneously, such as regional geology and regional faults. Additional pertinent information about regional geology can be displayed by clicking on

the map. As shown in the image below (Figure 6), the rose-colored geologic layers are younger rhyolitic volcanic rocks. Additional information on the selected geologic unit include unit area, unit perimeter, USGS geologic formation abbreviation (Tt3), etc.



Figure 6: Both regional geology and regional faults displayed in the GAMDSS. Additional information displayed when the user clicks on the geologic map.

The GAMDSS is capable of displaying large datasets that assist in the analysis of slope instability. The image below (Figure 7) shows ground velocity at the pixel-scale (25 meters) derived from satellite radar data provided by the European Space Agency (ENVISAT satellite) using the Interferometric Synthetic Aperture Radar (InSAR) stacking technique. Each point displays the velocity as a vector with magnitudes ranging between negative (downward - red) and positive (upward - blue) 20 mm/year and the direction at 23° from nadir. Each point contains a wealth of information, including average velocity, total displacement, and incremental displacement recorded at each image acquisition in the InSAR processing stack. The velocity dataset includes over 16,000 points.

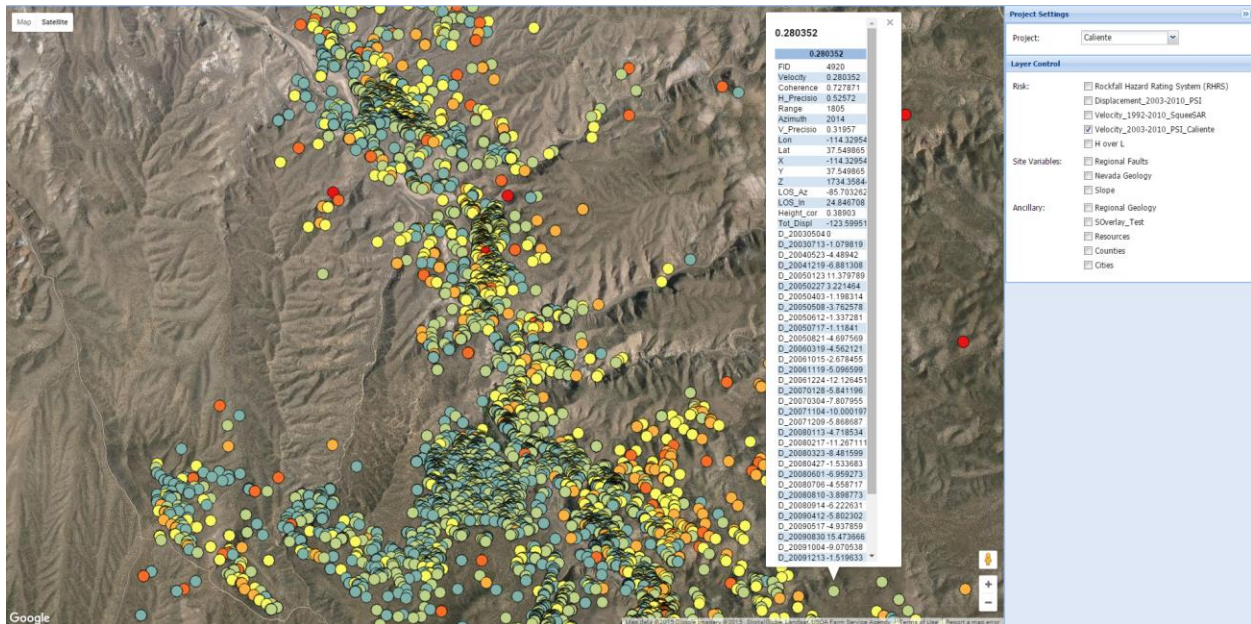


Figure 7: Ground velocity (mm/year) data displayed across the Nevada study area. Velocities range from -20 mm/year (red) to +20 mm/year (blue). Each point contains a wealth of information. 36 ENVISAT images (from the European Space Agency) were processed.

Ground velocity measures the average point velocity over the study period, which in this case is 2003 to 2010. Another way to view the same dataset is to display the cumulative ground displacement (mm) at each point, as shown in the image below (Figure 8). The vector rules stated above still apply. Viewing the dataset with displacement values allows the user to identify regions of relatively high displacement which are shown as clusters of yellow-orange-red points along slopes.

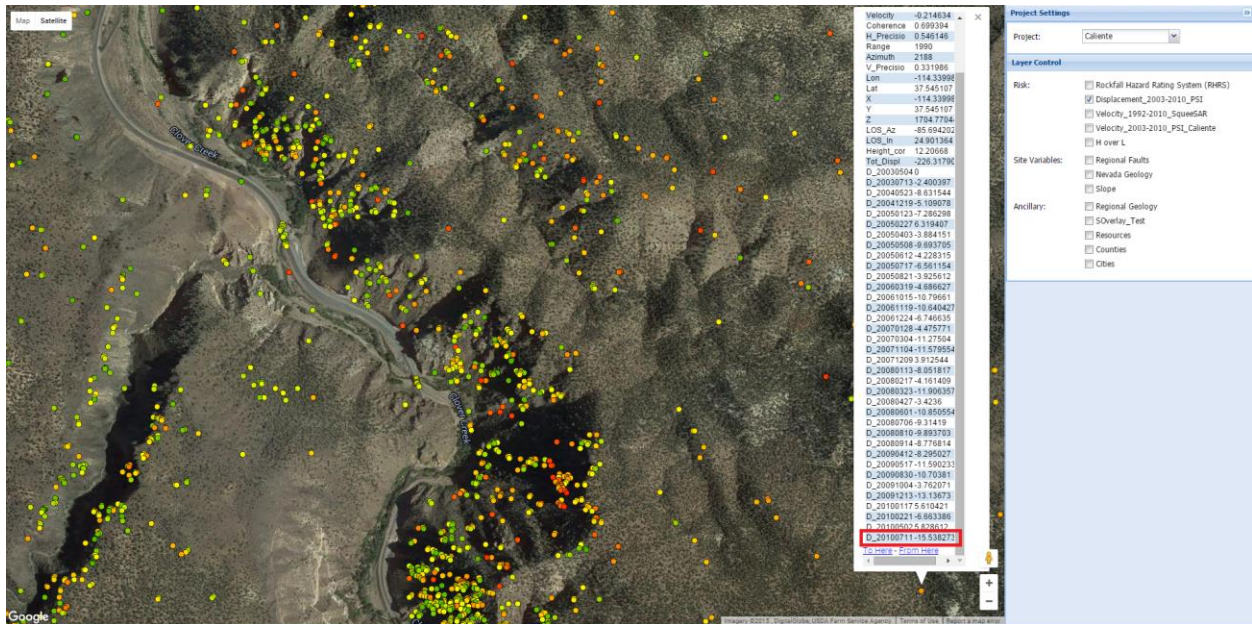


Figure 8: Cumulative ground displacement (mm) ranging from 0 mm (green) to 1.5 m (red) with negative values indicating downward motion. Cumulative ground displacement values may be displayed by clicking a point and scrolling to the last value in the attributes table (red box). The point selected here has undergone a downward displacement of 15.5 mm between 2003 and 2010.

Finally, the user may view site-specific field notes in map view. The image below (Figure 9) shows the results of the Rockfall Hazard Rating System (RHRS), a procedure that ranks potential slope hazard by assigning an RHRS hazard score based on 10 site characteristics as input metrics. If a slope's RHRS score greater than 400, then the slope is assigned a 'high' hazard rating (red); if RHRS score is between 350 and 400 the slope is a 'medium' hazard (yellow) and below 350 the slope is of 'low' hazard (green). The image below shows the RHRS score (452) as well as the 10 site characteristics used to calculate the RHRS score.

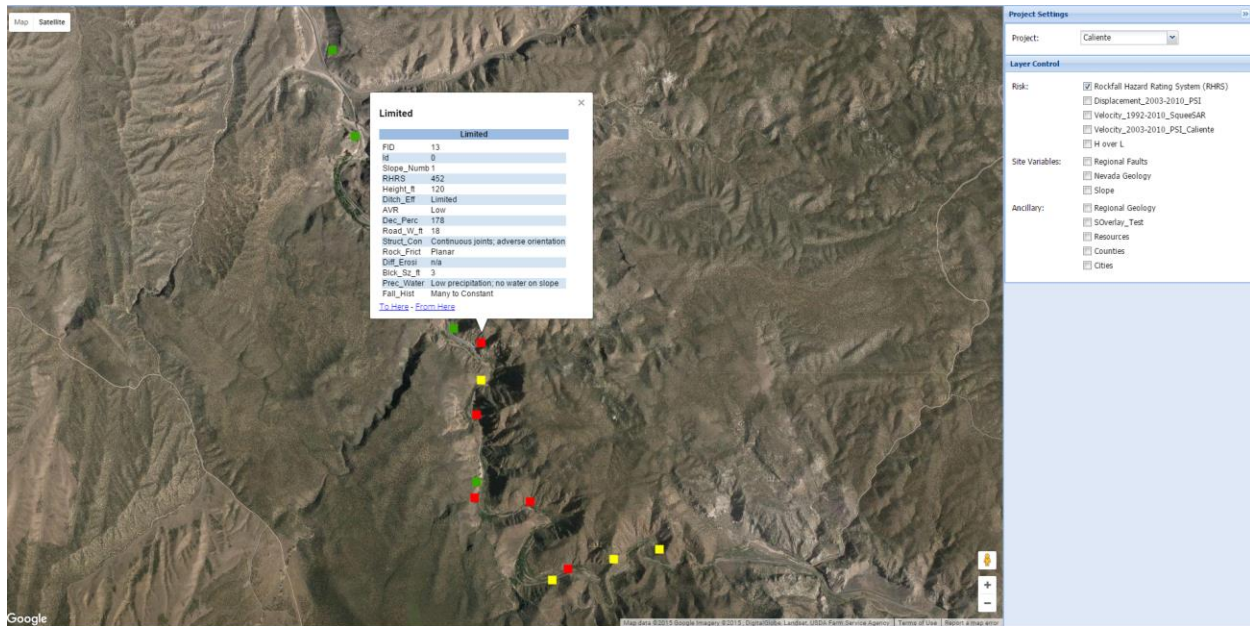


Figure 9: RHRs results for 14 slopes across the Nevada study site. RHRs > 400 (red), 350 < RHRs < 400 (yellow), and RHRs < 350 (green).

The GAMDSS allows the user to fully investigate the Nevada study site by displaying hazard and site characteristic variables. The ability to observe data in this fashion allows for a pre-field work screening of slope instability, granting the user a preventative edge compared to the traditional reactive approach of awaiting disaster and then mitigating the problem slopes.

On a broader scale, globally or nationally available datasets can also be used and incorporated into the DSS platform, to assess the areas considered most critical at such a larger scale. Digital elevation models (DEMs), which describe the terrain geometry and topography, are globally available at a ~ 30 m pixel resolution, and nationally (in the US) at a 10 m pixel (or smaller) resolution. Slope, as shown previously, is one of the variables that can be derived from such DEMs, being a very relevant variable that correlates highly with slope instability, i.e., the higher the slope the less stable the terrain tends to be. This however only shows areas that are unstable, and where landslides may initiate. Assessing the mobility (i.e., how far it can travel) of a landslide is equally important as it would show areas and potential transportation infrastructure that would be exposed to the impact of landslides that may originate at a certain distance from the assets.

Several authors have proposed to use the ratio of the vertical (H) to horizontal (L) distance traveled by the landslide mass, as an index of the landslide mobility (Hsü, 1975; Corominas, 1994; Finlay et al., 1999; and Hunter and Fell, 2003). Taking a given H/L ratio as a measure of the expected landslide propagation characteristics, and applying it to the DEM dataset, it is possible to build H/L cones that delineate areas exposed to landslides originating on particular DEM pixels, constraint by the terrain geometry given in the DEM (e.g., Jaboyedoff et al., 2005; and Jaboyedoff and Labiouse, 2011).

Counting how many times a pixel falls within the reach of a potential landslide, it is possible to delineate areas with a higher exposure. This is shown in Figures 10 through 12 for the Nevada site. First pixels with a slope above a certain threshold (35° in this case) were chosen as potential locations for future landslides. Then an H/L value of 0.5 was chosen to represent the likely propagation distance of landslides. The times each pixel was within a “landslide area” was counted (Figure 10) and the 95 and 99 (Figure 11) percentiles of the distribution were taken to show the most exposed areas. Finally, the transportation corridor within those areas was flagged as highly or intermediately exposed (Figure 12).

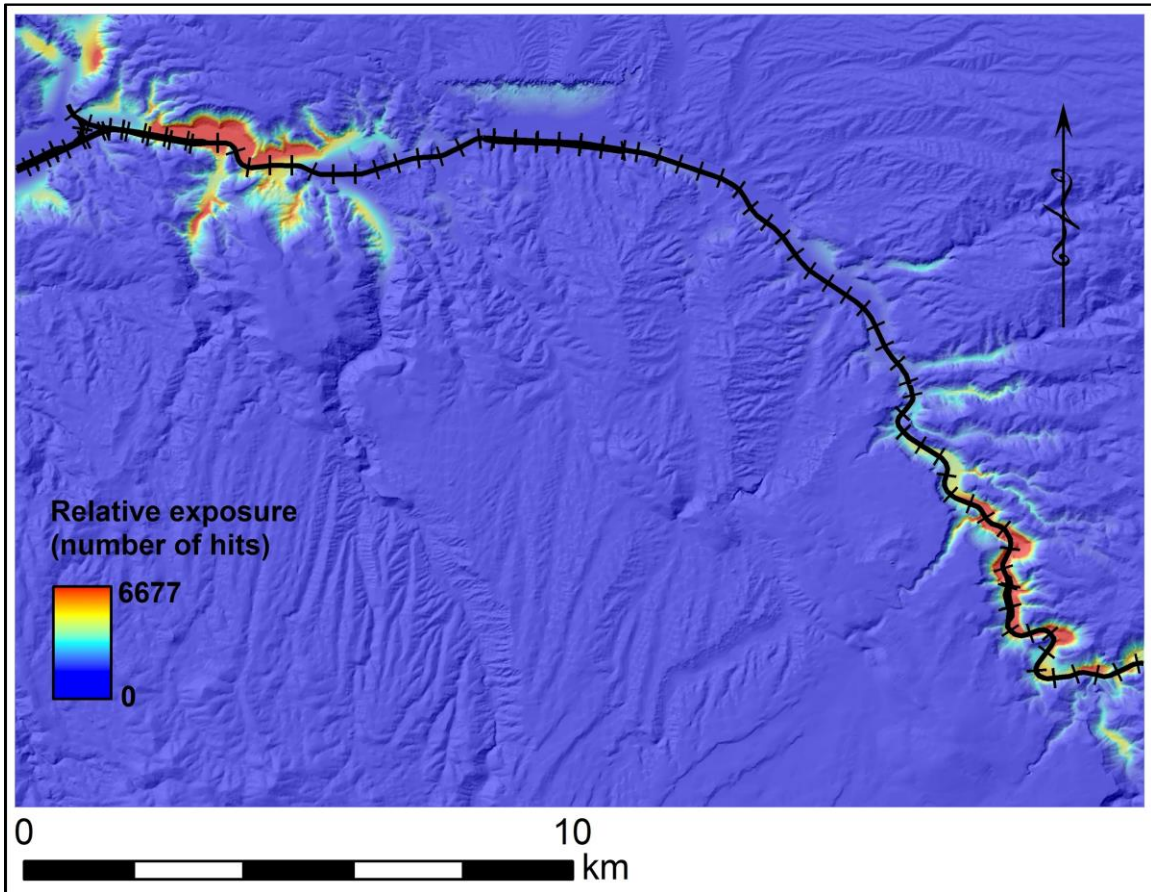


Figure 10. Plot of the relative exposure to potential landslide based on how many times a pixel falls within its reach.

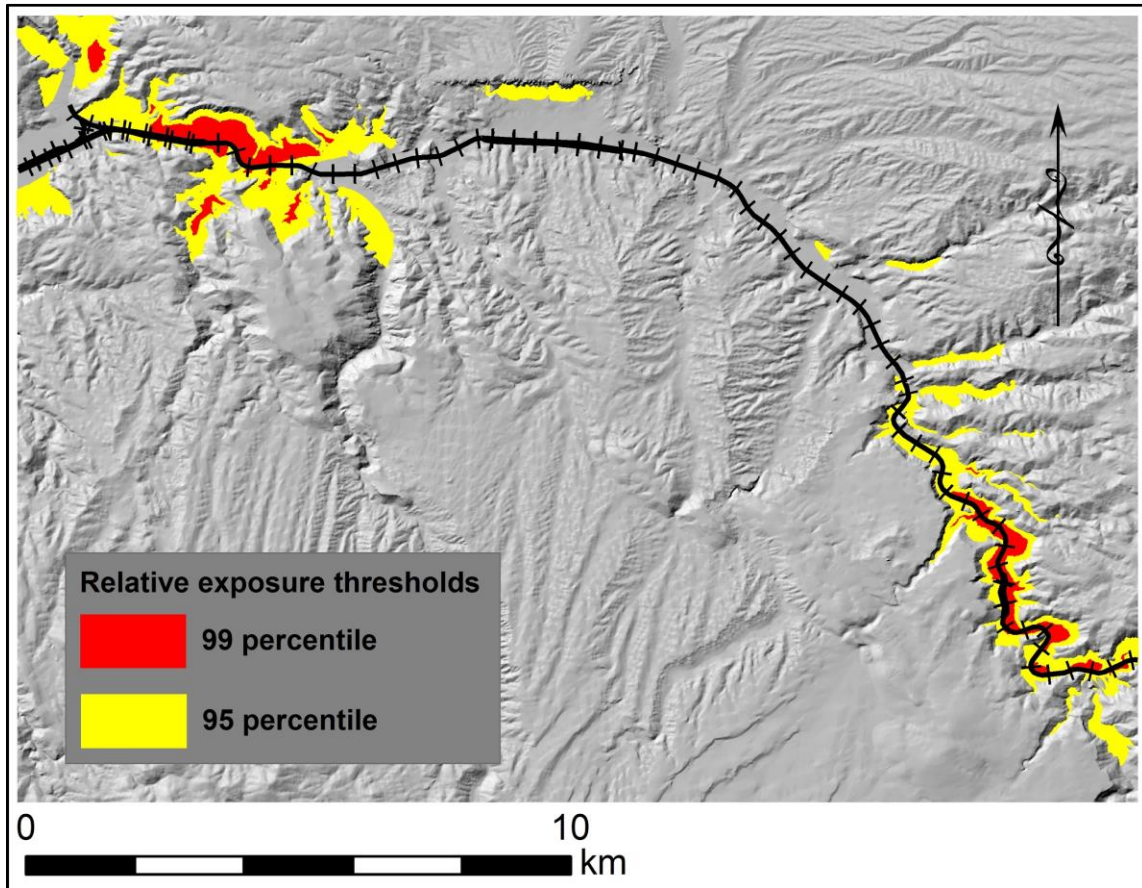


Figure 11. Plot showing the percentile of exposure to potential landslide.

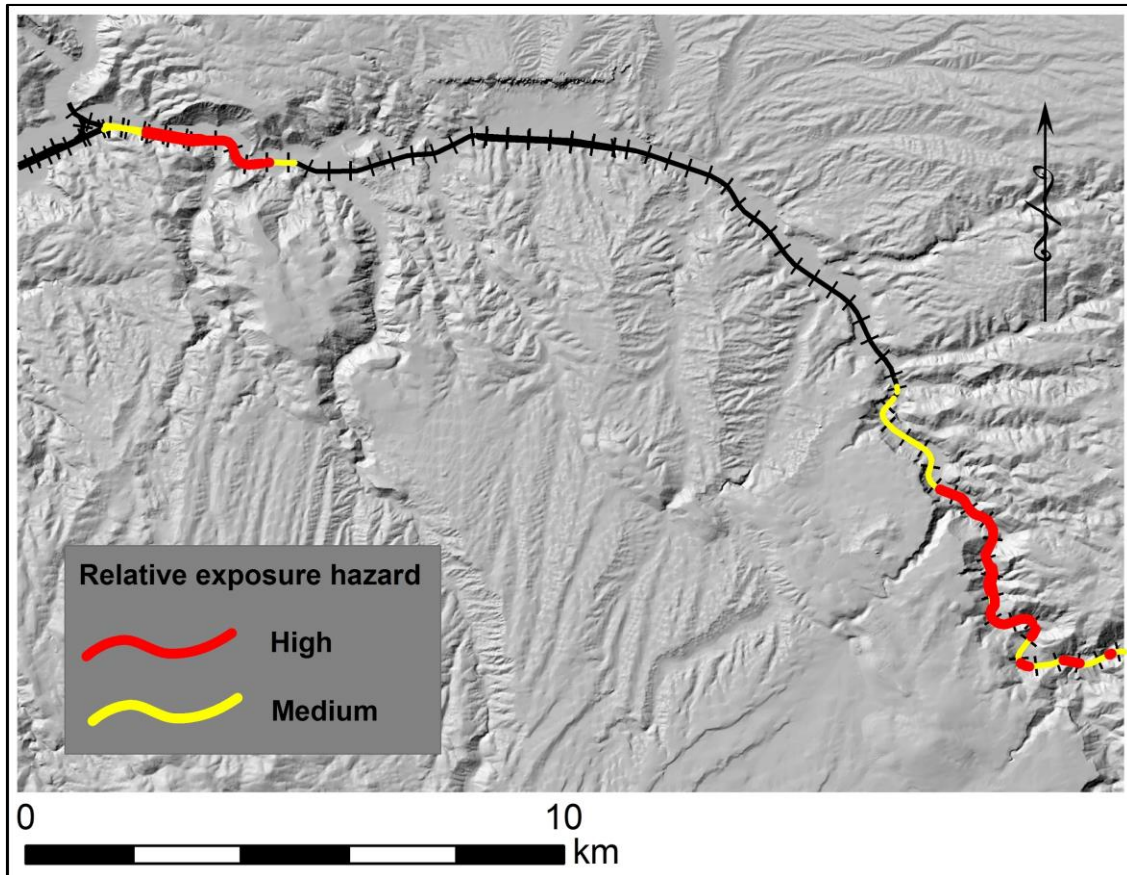


Figure 12. Areas with high and medium exposure to landslides within the transportation corridor.

7. CONCLUSION

The GAMDSS client and server applications represent a fully function solution for distributing geotechnical asset management information including hazard and site characteristic assessments as well as ancillary information about a target site. By integrating key open source or freely available softwares, the DSS is easy to use, can be managed remotely, and can be accessed on any device with a modern web browser and internet connection. The client application can display high resolution raster layers through GeoServer, as well as vector layers with Google's KML standard. The Nevada case study effectively demonstrates the capabilities of the DSS by displaying geotechnical layers such as SAR derived slope, ground displacement, and regional geometry. By making such asset management information available beyond the scientists generating the data, the GAMDSS can improve management decisions and long term project outcomes.

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