Building a Statewide Inventory of Landslides in Arizona

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Introduction

Arizona has landslides - lots of landslides. But how many? What types? Where are they?

The very limited, fragmented and incomplete data regarding the nature and extent of landslide hazards within Arizona makes assessing landslide risks difficult. To address this knowledge and data gap, the Arizona Geological Survey (AZGS) has begun conducting the first comprehensive landslide inventory in Arizona.

Task 1: Design and build a GIS database capable of accommodating diverse landslide data from many sources, utilizing a comprehensive metadata structure that is versatile, easily updated as new mapping or data become available, and compatible with the US Geoscience Information Network (USGIN).

Task 2: Compile all documented landslides from available maps and reports, map archives, and published journal articles.

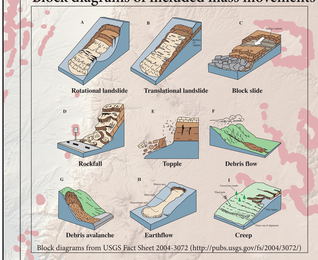
Task 3: Work with our partner agency, the Arizona Division of Emergency and Military Affairs, (DEMA) and with our stakeholders to identify and prioritize areas requiring new mapping of known but previously undocumented landslides.

Task 4: Incorporate the new landslide information into the 2018 State of Arizona Hazard Mitigation Plan, and provide assistance for incorporating the data into local and tribal hazard mitigation plans.

Task 5: Get the word out - reach out to public and civil authorities with map tools identifying landslides.

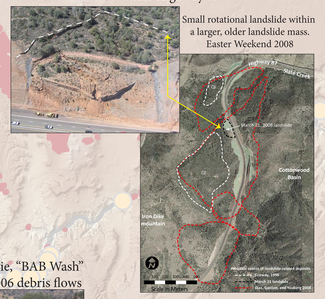
Classes of Mass Movements ("Landslides") Included in the Database

Block diagrams of included mass movements



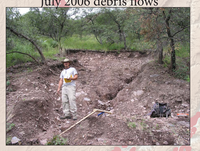
Block diagrams from USGS Fact Sheet 2004-3072 (http://pubs.usgs.gov/fs/2004/3072/)

State Highway 87



Small rotational landslide within a larger, older landslide mass. Easter Weekend 2008

Shallow translational landslide
Coronado National Memorial
July 2006 debris flows



Ft Bowie, "BAB Wash"
July 2006 debris flows

Rockfall in the Verde Valley

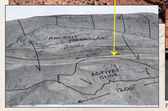
Head Scarp
Black Canyon City
Landslide, Rotational

Sabino Canyon near Tucson

Another July 2006 debris flow in Sabino Canyon

Februrary 2013
Bitterspring Landslide

Re-initiation of smaller landslide within larger ancient slide. South of Page, AZ



Photos and map from AZ Dept of Transportation

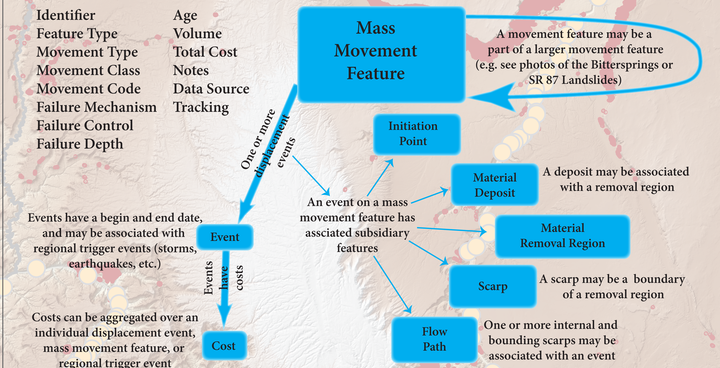
July 2006 debris flow in Ocho Grande

August 2003 post-Aspen Fire debris flow in Ocho Grande

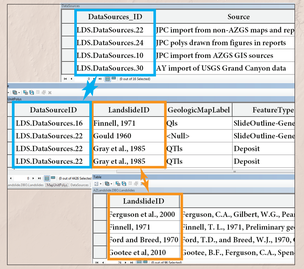
Conceptual Idea and Database Design

Properties of Mass Movement ("Landslide") Feature

Identifier
Feature Type
Movement Type
Movement Class
Movement Code
Failure Mechanism
Failure Control
Failure Depth
Age
Volume
Total Cost
Notes
Data Source
Tracking



The source of each data element is tracked using Foreign keys. The DataSources table tracks provenance (how and who brought the data element into the database) and the LandslideID table tracks citation(s).

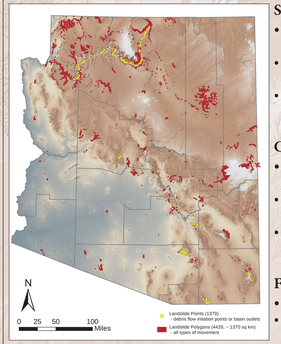


DataSources_ID	Source
LDS.DataSources.22	IPC import from non-AZGS maps and rep
LDS.DataSources.24	IPC polys drawn from figures in reports
LDS.DataSources.10	IPC import from AZGS GIS sources
LDS.DataSources.30	AY import of USGS Grand Canyon data

DataSourceID	LandslideID	GeologicMapLabel	FeatureType
LDS.DataSources.16	Finnell, 1971	Qls	SlideOutline-Gene
LDS.DataSources.22	Gould 1960	<Null>	SlideOutline-Gene
LDS.DataSources.22	Gray et al., 1985	QTls	Deposit
LDS.DataSources.22	Gray et al., 1985	QTls	Deposit

LandslideID
ergusson et al., 2000
innell, 1971
ord and Breed, 1970
oootee et al, 2010

Status and Challenges of the State Landslide Inventory



Status:
- Most (~98%) identified and known landslide masses have been added to the database
- Landslide units must be found manually (scrutinize scanned map)
- Many (~80%) identified debris flows have been added to the database

Challenges:
- Data deficient areas (e.g. sparesly populated areas, Native American Reservations)
- Designing a database that works well with broad data types and information
- Finding and obtaining data held by other agencies and stakeholders

Funding Sources:
- 75% by FEMA's Pre-Disaster Mitigation Grant Program
- Designing a database that works well with broad 25% by the AZGS in partnership with DEMA

Acknowledgements:
- The development and design of this database was influenced by the experience and efforts of other states who have lead the way, particularly OR, WA, NC, VA, and KY
- Support and efforts by Jessica Good, Michael Conway, Steve Richard and Gary Hudman (AZGS), and Susan Wood and Thomas "Duke" Jones (DEMA)

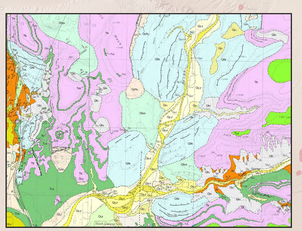
Data Sources

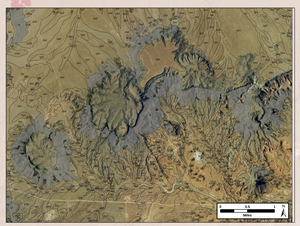
Georeferenced scans of pre-GIS, non-AZGS geologic maps

- Scans of older geologic maps georeferenced in ArcMap
- Landslide units must be found manually (scrutinize scanned map)
- Draw in landslide boundaries according to map, refine as needed using basemaps and imagery
- Errors in original map and georectification must be addressed
- Often coarse in scale, primary focus on bedrock mapping
- May be compiled/superceded by more accurate GIS-based mapping

AZGS geologic maps

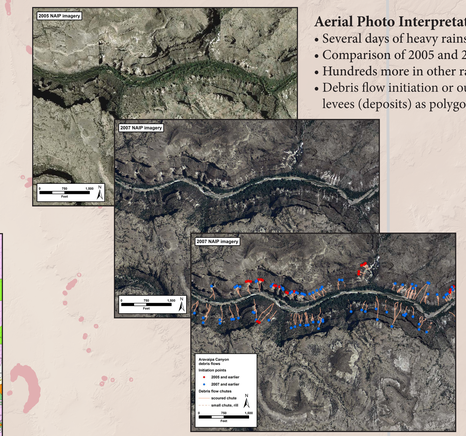
- Scans of older AZGS geologic maps have the same issues as other scanned maps
- Many AZGS maps have GIS data available and the database format is familiar to current database architecture
- Select landslide units from existing GIS database and import into new landslide database
- Attribute imported polygons with available data
- Mapped polygons often general landslide unit, no specific age data or information about mechanics of failure
- Some scarp linework exists and has been imported





Import from existing GIS data

- Many USGS and other agency maps and data available in GIS formats
- Database format may be dated and require import tools to make readable in current versions of ArcMap
- Spatial accuracy is good, much better than scanned maps although projections should be double-checked
- Select landslide units from database using attribute selection tools, no manual scrutiny of all map polys
- Attribute imported polygons with available data
- Mapped polygons often general landslide unit, no specific age data or information about mechanics of failure
- Some scarp linework exists and has been imported



Aerial Photo Interpretation - Aravaipa Canyon, AZ

- Several days of heavy rains in southern AZ in July, 2006 resulted in many new debris flows in steep terrains
- Comparison of 2005 and 2007 imagery yielded over 400 debris flows in the canyon
- Hundreds more in other ranges throughout southern AZ attributable to same time period
- Debris flow initiation or outlet points mapped as point features, flow paths as line features, and snouts and levees (deposits) as polygon features depending on scale and method of observation

Other AZGS studies and institutional knowledge

- Most of the debris flows in this database are derived from other AZGS studies, many of which are associated with post-wildfire assessments (e.g. AZGS OFR 08-08 or DI-44)
- Additional debris flows are derived from informal reports and surveys of debris-flow events (e.g. 1983 debris flows in the Picacho Mtns from dissipating tropical storm Octave or the 2010 Orange Peel debris flow in the Four Peaks from a monsoon storm)

Orange Peel debris flow near Roosevelt Lake

Google Earth landslide mapping

- Many large landslide complexes were spotted in Google Earth through a combination of aerial photo interpretation and panning/tilting the 3D surface
- Rough approximation of unmapped landslide features
- Best for larger features that show up in the DEM
- Great for adding landslide features in similar terrain/geology outside nearby mapped geologic quadrangles
- Possible to draw landslide extent in Google Earth and accurately import to ArcMap using import tools
- Historical imagery tool is useful for locating recent debris flows and rockfalls