Geoprocessing in landslide risk assessment and mapping

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• Causes for landslides

• Risk = Probability of Hazard * Consequences

• ArcGIS for modelling and map production (Model Builder, Spatial Analyst, Data driven pages) in a 3 year project in Gota river valley, Sweden
Occured landsides in Sweden

Småröd 2006, societal cost > 500 Mkr
Trigger: (improper) dumping of filling / earth masses

Geotechnical engineering - is the branch of civil engineering concerned with the engineering (technical) behavior of earth materials. Geotechnical engineering uses principles of soil mechanics and rock mechanics to investigate subsurface conditions and materials.

From http://gis.swedgeo.se/skred/ (~800, compare Norway >10,000)

Surte 1950, 1 dead, 300 homeless, 30 damaged houses

Tuve 1977, 9 dead, 300 injured
Causes for landslides

- Soil geology and topography/geometry (slope) are two important parameters for assessment of the **preconditions** for landslide. Landslide **risk mapping/analysis** (probability of a hazard and consequences) is a more extensive task.

Landslides is indeed a 3D problem…

- Topography/geometry (land and in river)
- Geology, stratigraphy (for silt and clay)
- Hydrology

- Soli mechanics - driving and resisting forces (which may change due to buildings/construction on land, change of the river’s water level)

- Erosion – changed flow in the river will affect the topography/geometry in the long term…

- Precipitation/rain fall - can increase groundwater level and pore pressure in the soil (silt/clay)
Terrain model (land and in river)
Risk = probability of Hazard occurrence * Consequences (vulnerability of exposed elements)

Landslide mapping of Göta river valley (some 200 km shoreline) with regard to climate changes. 3 year project. 40 reports incl. maps annex A3 1:10,000. Finished 31 March 2012.

Geotechnical evaluation and assessment based on field investigations (boreholes) and slope stability calculations

60 of 100MSEK (~ 14 million $)

Data from Statistics Sweden, National Land Survey, National Road Adm., Communities, County Adm. etc.

MSEK per 100m-square, i.e. a "cost" per each square

Life/population
Land values
Transport infrastructure
Energy/water/sewage
Env. hazard activities
Business, nature, culture
Risk model adopted to ArcGIS Model Builder

Unmanageable (very time consuming) to do (once) without modelling it. There were constant changes in input data ‡ must be able to run the model through again and again (approx. over 100 times)
Drawing of lines between the five probability classes is a qualified geotechnical engineering assessment – cannot be entirely automated! (however "Spatial Join" is used)
The geotechnical engineer's web-based viewer, some 100 layers/themes, a lot of symbology…
Creation of consequence classes (Raster Calculator † Raster2polygon)

Spatial Analyst Raster calculator (Map Algebra) – an invaluable tool!

GRIDCODE
- 0
- 1 - 6
- 7 - 35
- 36 - 150
- 151 - 600
- > 600 MKR  (~ 100 million $)
Spatial Analyst ZONAL statistics: the sum of costs under a defined ("known") landslide area

Over 90% of consequence cost (in this area) is related to:
life cost, transport infrastructure and land values
INTERSECT, one of many ArcGIS Tools which was used

Dim output
IF ([sklasstext] = "S5") AND ([kklasstext] = "k2" OR [kklasstext] = "k3" OR [kklasstext] = "k4" OR [kklasstext] = "k5") OR ([sklasstext] = "S4") AND ([kklasstext] = "k3" OR [kklasstext] = "k4" OR [kklasstext] = "k5") THEN
output = "HÖG"
ELSEIF ...
...
Data Driven Pages ArcGIS 10

Very useful for creating PDF map series (e.g. 1:4000, 1:10,000, etc.)

- Generate a large number of pdf’s referenced to a fixed grid
- Apply dynamic text such as Page Number, Date, values in an attribute field etc.

[Can autogenerate grids]
[Grid may be rotated, have a set overlap etc]
Final map products

Conclusions:
- Without ArcGIS the implementation of the landslide risk assessment/mapping (particularly modelling but also map production) would – in practice - have been impossible!
- Lots of ArcGIS Tools were used (web editing, Spatial join, Clip/Merge/Dissolve, Raster calculator, Zonal statistics, Intersect, hillshading, 3D profiles, Data driven pages etc) and implemented in Model Builder
- The cost to lower the risk in all red and some orange areas is estimated to 6000 MSEK ~ 1 billion $...
3D visualization, some examples

- Hillshade, ArcScene
- Executable 3D-pdf (made in FME)
- Executable 3D model (coming soon on gis.swedgeo.se)

+ WebGIS map applications
  - Metadata and WMS for INSPIRE