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# An Inventory of Landslides within the Sydney Basin to aid the development of a refined Susceptibility zoning

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## ABSTRACT

The University of Wollongong GIS-based Landslide Inventory is currently being expanded from its Illawarra centric coverage (664 landslides) to include the 31,000km<sup>2</sup> geological extent of the Sydney Basin and ultimately all of New South Wales (hereafter this inventory will be referred to as the NSW LI). In 1998, this inventory stood at 319 sites of instability and in 2010 it had grown to 616 landslides. The population of the Sydney Basin in 2006 was approximately 4.9 million people, representing approximately one quarter of the population of Australia. When this current phase of expansion is completed, the NSW LI will include up to 1600 landslide sites, and it will continue to expand over the next few years. The NSW LI is being redesigned following an international literature review and is being re-compiled into an ESRI ArcGIS v10 Geodatabase. This work is being undertaken in the Faculty of Engineering at the University of Wollongong with a joint Faculty of Engineering and SMART doctoral research scholarship that commenced in late 2011. In tandem with this development, additional GIS-based datasets are being compiled to facilitate the refined modelling of Landslide Susceptibility across the Sydney Basin Region.

*Keywords:* landslide, inventory, susceptibility, GIS, hazard, risk

## 1 INTRODUCTION

Landslide inventories play a crucial role in modelling landslide susceptibility and hazard zoning for land use planning since the historic landslide records are a guide towards assessing the future possibility of landsliding (Fell et al. 2008). Furthermore, the JTC-1 Landslide Risk Management guidelines emphasize that landslide inventories are a vital component of any landslide zoning programmes and essential to be included in landslide zoning reports (Fell et al. 2008). The quality and comprehensiveness of a landslide inventory directly affect the reliability of the evaluations derived from it (Galli et al. 2008). Furthermore, designing an effective and less complicated database structure in order to accomplish the required tasks should be facilitated by conducting further research in this field (Mazengarb et al. 2010). Since a national scheme for developing a landslide inventory is not available, a number of landslide inventories have been developed across Australia to serve a variety of purposes (Mazengarb et al. 2010). Also, many international organizations who conduct landslide research activities and or landslide risk management operations develop landslide inventories according to their own schemas in the absence of a universal procedure for conducting this type of work, and some of these will be referenced later in this paper. Thus, findings of the literature reviewed on other international systems have been incorporated in the re-design of the state of the art NSW LI.

This work is being undertaken by the Landslide Research Team (LRT) in the Faculty of Engineering at the University of Wollongong with a SMART doctoral scholarship that commenced in late 2011. The LRT is currently engaged in expanding and re-designing the existing Wollongong landslide inventory to cover the 31,000km<sup>2</sup> geological extent of the Sydney Basin and ultimately all of New South Wales. This NSW LI is expected to include up to 2000 landslide sites within the next few years. The database structure is being developed in MS Access 2007 to facilitate the effective storing and analysis of landslide alphanumeric data linked with the spatial database all of which is being compiled as an ArcGIS v10 geo-database.

## 2 WOLLONGONG LANDSLIDE INVENTORY

The GIS-based Landslide Inventory comprises digital landslide datasets (shapefiles in an ESRI ArcGIS Personal Geodatabase), from which maps are generated of known landslide sites as required. The Inventory comprises a relational database with over 70 fields of information for each landslide site

(Flentje and Chowdhury 2005), was first developed from 1993 and has substantially grown in capacity every year since. The Inventory currently includes 1522 landslide sites with a total of 1894 landslide 'events' (including all known occurrences and recurrences).

Field mapping and compilation work has been carried out using base maps and on the desktop GIS software at 1:4000 or larger scales, field mapping assisted with GPS and more recently high resolution differential GNSS. Aerial photograph interpretation and in recent years with sub metre resolution Airborne Laser Scan data and derived high resolution hillshade models have also been employed. Each landslide is referenced by a key Site Reference Code which does not change over time.

### **3 SYDNEY BASIN/NSW LANDSLIDE INVENTORY**

#### **3.1 Literature reviewed on the structures of the International landslide inventories**

Numerous international organizations were contacted to obtain details on their database structures of the landslide inventories and the following organisations shared their information with us.

- Mineral Resources Tasmania (MRT)
- Geoscience Australia (GA)
- United States Geological Survey (USGS)
- Oregon Department of Geology and Mineral Industries (DOGAMI)
- California Geological Survey
- National Building Research Organisation of Sri Lanka
- Geotechnical Engineering Office (GEO), Hong Kong
- Italian National Institute for Environmental Protection and Research
- British Geological Survey

#### **3.2 Refined NSW Landslide Inventory**

The landslide alphanumeric, text and graphical data is stored in a fully relational MS Access database to facilitate data viewing and updating. In addition, landslide affected areas will be digitized in ArcGIS v10 and linked with the landslide alphanumeric database.

According to the JTC-1 landslide zoning guidelines, a landslide inventory should include the information on location, classification, volume, travel distance and date of occurrence (Fell et al. 2008). Also, with the increasing level of sophistication of the landslide inventory, more information should be documented (Fell et al. 2008). Thus, to comply with these standards, several landslide inventory tables were developed with a number of fields to facilitate the storing of data for each landslide record.

##### **3.2.1 Data Tables**

The non-spatial database compiled in MS Access 2007, is composed of seven main tables taking part in the relational diagram. These tables are developed to document the information under several titles namely, Landslide Summary (Table 1), Landslide Location (Table 2), Landslide Geo-Data, Landslide Identification, Risk Assessment, Field Visits and Photographs. In addition, borehole data table is also linked to the landslide identification table to facilitate accessing borehole information of relevant sites. The tables that are not in the relational diagram are designed to provide values/descriptions for fields in the relational tables. The column related to field description or value is linked to respective combo boxes in the MS Access form and dropdown lists of access spreadsheets. There are ten supporting tables namely, AGS Risk, Instability, Potential Damage to Economic Activities, Potential Damage to Land, Potential Damage to Structures and Services, Potential Loss of Human Lives, Rate, Site Status, Slope and Trigger.

##### **3.2.2 Relational Diagram**

The Landslide Summary table (Table 1) is the central table for all the relationships in the database. Landslide Summary ID, a unique number assigned to each landslide event, is the primary key for this

table which links the information in the three related Landslide Geo-data, Landslide Identification and Risk assessment tables (Figure 1). Each landslide location is assigned a unique Site Reference Code (SRC) which acts as the Primary Key for the entire database. The data field "Recurrence" is used to denote whether the movement is a first time or a reactivation of an earlier landslide event. Both first time occurring landslides as well as recurring landslides are considered as individual landslide events and a unique Landslide Summary ID is assigned to each of these events. A recurrence may be recorded under the same SRC as an earlier event if spatially similar to the earlier event, or as a new SRC if sufficiently spatially different to the previous event. A field is also allocated for each landslide event to record whether it is located within another landslide. If so, landslide summary ID of the encompassing landslide (Parent landslide) can be added to the Parent Landslide ID field.

*Table 1: Landslide Summary*

Attribute	Name	Description	Data type
SRC	Site reference code	Unique numeric site reference number, including the decimal point i.e. 222.2	Number(Double)
Recurrence	Recurrence	First time or recurrence of movement	Integer(Long)
LS_Sum_ID	Landslide summary ID	Unique progressive number assigned to each landslide event (First time landslides and recurrences)	Number(Double)
Creation_Date	Creation Date	Date of record creation	Date/Time
Revision_date	Revision Date	Date of record revision	Date/Time
Confidence	Confidence	Confidence of interpretation of the landslide	Text
Failure_Date	Date of failure	Date and time of the landslide	Date/Time
Trigger	Trigger	Cause of land sliding	Text
Primary_Instability	Primary Instability type	Type of the Primary instability	Text
Secondary_Instability	Secondary Instability type	Type of the secondary instability	Text
Parent_LS	Parent Landslide	Landslide summary ID of the parent landslide If a parent landslide exists. Else, 0	Integer(Long)
Slope	Ground Slope	Local area average ground slope	Integer
Movement_Type	Type of the movement	Slope movement classification (Cruden and Varnes (1996) full landslide classification)	Text
Movement_Rate	Rate of movement	Rate of movement of sliding mass	Integer(Long)
Activity	Activity	Landslide activity	Text

*Table 2: Landslide Location*

Attribute	Name	Description	Data type
SRC	Site reference code	Unique numeric site reference number, including the decimal point i.e. 222.2	Number(Double)
Easting	Easting	GDA1994 Easting grid position to centre of landslide	Integer(Long)
Northing	Northing	GDA1994 Easting grid position to centre of landslide	Integer(Long)
Head_Elevation	Head Elevation	Elevation of the landslide crown	Integer(Long)
Toe_Elevation	Toe Elevation	Elevation of the landslide toe	Integer(Long)
Suburb	Suburb	Suburb as shown in Gregory's street Directory	Text
City	City	City	Text
State	State	State	Text
Street_Name	Street Name	Physical street name	Text
Landowner	Landowner	Organization or individual responsible for land management of site	Text
Comments	Comments	Comments	Text

In addition, Landslide Location table (Table 2) is linked to four main tables namely, Landslide Summary, Landslide Geo-data, Landslide Identification and Risk assessment via the SRC. This relational structure facilitates viewing, updating and analysing of all the recorded landslide information (i.e. recurrence) corresponding to landslide locations.

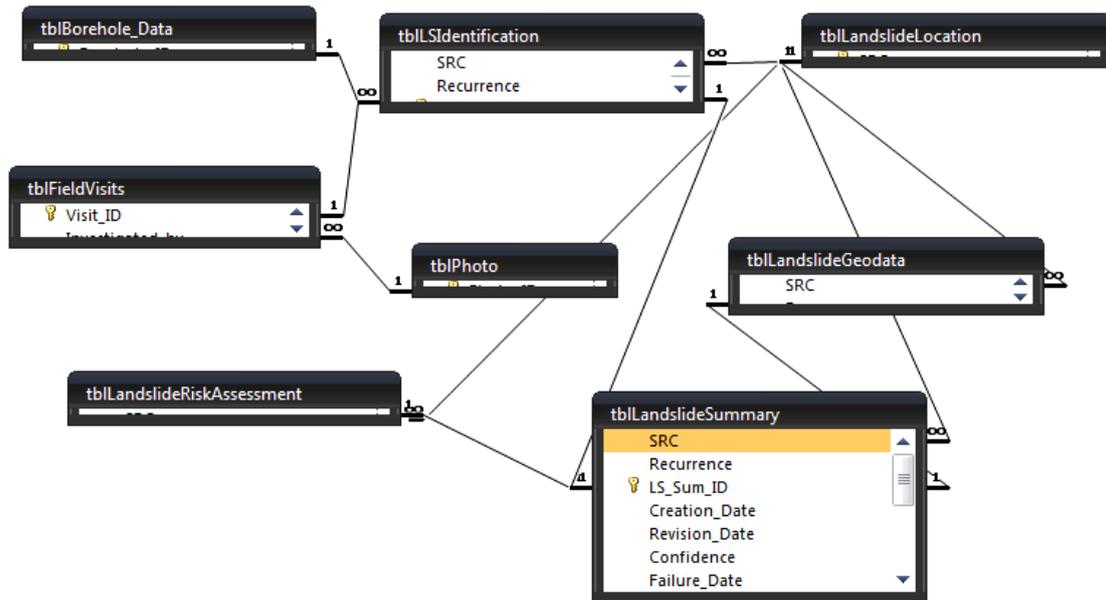


Figure 1. Simplified Relationships of the Landslide Inventory

Figure 2. Landslide information form

Figure 3. Landslide Recurrence details form

### 3.2.3 User Interface

A user interface for viewing, updating and analyzing data is developed within MS Access. For this purpose, several forms linked to the data tables are used. Users are able to add/edit records, view details on landslide events (Figure 2) and landslide recurrences at site locations (Figure 3).

#### 4 SYDNEY BASIN WIDE LANDSLIDE SUSCEPTIBILITY MODELLING

The Landslide Inventory described above is the fundamental dataset required upon which Susceptibility modelling can be based and developed. To undertake the zoning work we use knowledge-based methods including Data Mining techniques within a GIS framework. This work is ongoing at larger scales for a large portion of the Illawarra Escarpment within the Wollongong Local Government Area (LGA) where considerable data have been obtained and the landslide inventory development is comprehensive. Increasingly more reliable modelling, analysis and synthesis is being done at the present time. For the entire 31,000km<sup>2</sup> geological extent of the Sydney Basin region, where the available data are relatively small scale and the process of developing the landslide inventory is in the early stages, preliminary studies which are described as 'proof of concept' have been completed (Fientje et al, 2007 and 2011) as shown in Figure 4.

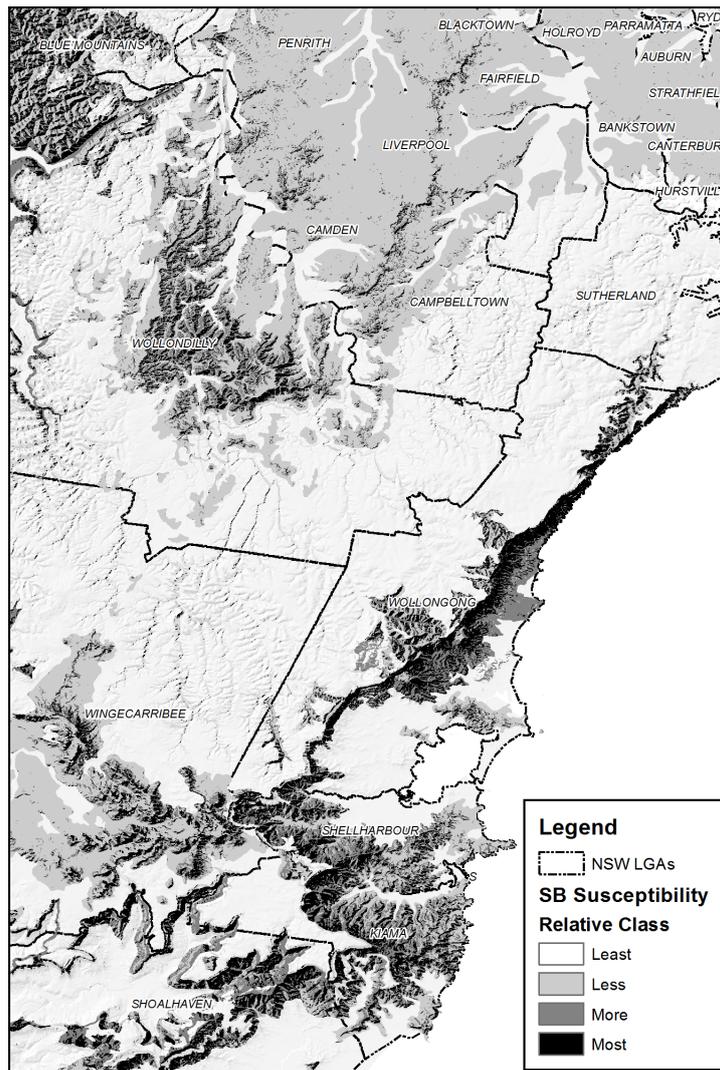


Figure 4. Southwestern Sydney Basin Proof of Concept Landslide Susceptibility Zoning

All the while, input data is being refined and improved, in particular with the advent of Airborne Laser Scan derived Digital Elevation Models (DEM) and the ongoing development and populating of Landslide Inventories. Higher resolution geological mapping data is now available, as is the relevant portion of a year 2000 Global Digital Elevation Model v2 dataset from NASA and METI at 30m pixel resolution (ASTER GDEM v10, 2011). In tandem with refined input data, computing capabilities are also rapidly evolving and this is enabling ever growing terrain modelling capacity. With higher resolution input data for the Sydney Basin project, including the afore mentioned and more rigorous Landslide Inventory, modelling outcomes are likely to be suitable for use at Local Government Planning levels.

One important aspect of the SMART doctoral research relates to the scale at which the susceptibility modelling will be undertaken. The Wollongong project is being undertaken using a 10m pixel resolution, whilst the Sydney Basin work to date has been completed using a 25m pixel resolution. The question remains, "What is the optimum pixel resolution for this work?" In due course, this SMART research will report on these findings.

## 5 CONCLUSION

Landslide Inventories play a major role in landslide risk management zoning programmes for decision making and should be carried out thoroughly. Currently, many national/international organizations manage landslide inventories and the structure or schema of the inventories used depends on the specific business requirements, funds available and the level of technology being used. Due to the unavailability of national/international standards on developing a landslide inventory, it has been worthwhile to search existing examples worldwide and incorporate the findings to develop a current state of the art schema. A great deal of attention has been given to design this database comprehensively by allowing the user to compile available records in detail across a range of categories. However, efforts were taken to balance detail versus an over complicated database structure. We aim to achieve a not too cumbersome, state-of-the-art database structure to facilitate appropriate data storage and analysis. A relational GIS geo-database was considered essential. Furthermore, this landslide inventory is designed in order to facilitate its growth for the next 5 to 10 or more years. The proof of concept susceptibility modelling has already been completed and higher resolution datasets are already being assembled. The missing piece of the puzzle that remains outstanding is this populated Landslide Inventory, and that is now well on the way.

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