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Slope Information System – An Indispensable Tool for Hong Kong Slope Safety Management

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Abstract: The paper describes the different types of information in the computerised Slope Information System (SIS) which contains pertinent information on some 54,000 man-made registered slopes in the Hong Kong Government Slope Catalogue. The SIS stores over 11 million slope data in some 30 information layers, including slope geometry, slope conditions, maintenance responsibility, past landslide incidents, previous ground investigation, drains and water pipes, geology and district information and slope photographs. Since its launch in 1999, the SIS has become a principal source of slope information for professionals, academics, slope owners and their agents in the planning and management of maintenance and upgrading works for their slopes. Slope information in the SIS is now readily available to public users through the INTERNET in the Hong Kong Slope Safety Website (http://hkss.ced.gov.hk), and to government users through dedicated work-stations in the Civil Engineering Building and the Government INTRANET. The provision of free and easy access to comprehensive slope information to the public is a principal element of the Hong Kong Slope Management System. The SIS has become the key player in the GEO public information services to the community.

1 INTRODUCTION

Hong Kong has a mountainous terrain with dense urbanization to accommodate a population of some 7 million. Many developments and infrastructures have to be carved into the steep hillsides with varying extent of site formation works forming large number of man-made slopes and retaining walls. Many of these slopes and walls were constructed in the early days with limited geotechnical considerations. Some major slopes failures have occurred in the past and resulted in high casualties. Notable landslides in the 1970's included the Po Shan Road failure with 67 people died and the Sau Mau Ping landslide on the same day with 71 fatalities, and another landslide in Sau Mau Ping in 1976 leading to the death of 18 residents. In 1977, the Government set up the Geotechnical Engineering Office (GEO) (previously named the Geotechnical Control Office) to regulate the whole process of investigation, design, construction, monitoring and maintenance of slopes (collectively to include slopes and retaining walls). To know the size of the problem of the old slopes that existed before 1977, consultants were engaged in 1977/1978 to prepare a register of sizeable man-made slopes in the urban areas and along major roads in the New Territories. A total of some 10 000 slopes were registered. The information in the 1977/78 register had been used in the planning of development, upgrading of sub-standard slopes and slope maintenance. In 1994, the Government embarked on a 4-year HK$110 million project - Systematic Identification and Registration of Slopes in the Territory (SIRST), to update and expand on the 1977/78 Slope Catalogue to cover Hong Kong, Kowloon and the New Territories. Under SIRST, some 54,000 sizeable man-made slopes have been registered and a computerised Slope Information System (SIS) has been developed to contain the information of these slopes. The SIS is a Geographical Information System (GIS) which allows spatial and textual search of slope information. It allows easy storage and fast retrieval and updating of information. Public information services on slope safety have been identified as a major component of the Hong Kong Slope Safety Management System. Since its launch in 1999, the SIS has grown to be the principal source of slope information. To ensure that the information in the SIS is comprehensive and up-to-date, a dedicated team of professional and technical staff has been deployed in the GEO to administer, maintain and update information in the SIS with updated slope data provided by various parties including government maintenance departments and geotechnical practitioners in the private sector.

2 THE SLOPE INFORMATION SYSTEM (SIS)

The SIS runs on a Windows NT platform with MicroStation Geographics as the GIS software and Oracle as the Relational Database Management Software. The SIS contains a host of slope information in some 30 information layers with over 11 million data. Information includes slope records based on field inspections, site topography, past landslides, ground investigation data, development history, slope

photographs and maintenance responsibility. Each slope is uniquely represented by a slope number (e.g. 11SW-B/C1) in the SIS and with its boundary superimposed onto a topographic map of Hong Kong. The associated slope information in textual form is recorded in tables linked to the slope identified by its slope number.

Examples on the use of the SIS are described below:

(a) The SIS can easily sort out, identify and separate slopes into various categories, e.g. fill slopes, cut slopes, retaining walls, pre-1977 and post-1977 slopes. It can also identify a group of slopes affecting a particular type of facility occurring at the toe or the crest, be it a road, a residential building, a school etc., and any changes to each of the above example group with time. This function has proved to be extremely useful in the planning, management of slope safety, identifying and grouping of features of a particular type, and allocation of resources to control and reduce landslide risk.

(b) Information on slope geometry, seepage condition, geology, slope photographs, types of affected facilities, past landslide records, signs of distress and the surrounding topography can facilitate preliminary studies, investigation and design of slope upgrading works as well as site formation works for new developments.

(c) Records of the conditions of slope cover, surface channels, seepage, proximity to facilities at the toe and the crest, responsible maintenance party etc., provide useful background information for owners and their agents in their slope maintenance work.

3 INFORMATION LAYERS

The key layers in the SIS and its applications in slope safety management are described below.

3.1 *Slope Catalogue Information Layer*

This layer contains

- a map (Figure 1) showing the slope boundary identified by its slope number together with the surrounding topography,
- a Background Information form (Figure 2) describing its location, any past document/study files in GEO relating to the slope, any Dangerous Hillside (DH) Order and Advisory Letter issued. A DH Order is a Statutory Order served by the Government to private slope owners on a slope which is considered dangerous or liable to become dangerous and investigation with necessary upgrading work is required to meet current safety standard. An Advisory Letter is a letter issued to private slope owners advising them of maintenance defects and the need for slope rectification works.
- Field Observation form (Figure 3) containing

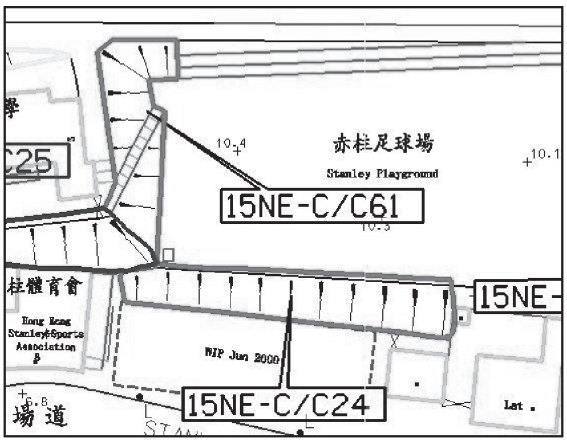

Figure 1. Feature boundary map

Feature Registration Form			
Background Information and Related Documents		**Feature Ref No :** 15NE-C/C 25	
Location	No 8-12 Stanley market Road, Stanley	**GIU Cell Ref.** 15NE12D1	
Map Sheet Ref.	15NE-12D (1 : 1000) 15NE-C (1 : 5000)	**Coordinates** Easting 839873 Northing 808942	
Aerial Photos	No. 7545 Year 1963	**Raingauge Station** St. Stephen's College **Data collected on** 14-JUN-2000 **Sift Class :** C1	
Construction History	1945 - 1963 - Constructed Pre-1963 - Constructed Post - 1998 - Modified		
Prescriptive Measure	**Works Type**	**Department**	**Completion Date**
Related Reports/Files or Documents	**File/Report** **Reference No.** DLC/BC BC SIL 26 BC STIL 75	**File/Report** **Reference No.** **Development** GCI 3/4/3260/57, GCI 3/1/763	
DH-Order	**Date of Recommendation to BD** 4-May-95 **Notice No** DH34/HK/95/C **Default Cases**	**File Reference** DH33/78/HK **Date Served by BD** 21-Aug-95 **Date of Discharge** (to be confirmed with Building Department)	
Advisory Letter	Date of Recommendation to BD 10-Jul-91 **Date Served by BD** (8-Nov-1991)	**File Reference** GCI3/4/DH31/78/HK **Date of Completion** (to be confirmed with Building Department)	
Remarks	THERE WERE TWO DH ORDERS ISSUED WHICH AFFECT TO 15NE-C/C 25		
Follow up Actions			
Maintenance Responsibility : Maintenance Type : Mix **No. of Sub-division :** 5(To be confirmed with Lands Department)			
Responsibility parties : STIL21RP Arch SD STIL33 STIL25 PM B/582			
GEOTECHNICAL ENGINEERING OFFICE - CIVIL ENGINEERING DEPARTMENT			

Figure 2. Background information form

FIELD OBSERVATION				**FEATURE Ref. No :** 15NE-C/C 25
Location No 8-12 Stanley Market Road, Stanley				
Consequence Category 1	**Toe Elevation (mPD)** 7		**Weather** Mainly Fine	
Inspected by Cheng T.T. on 15-JUN-2000		**Checked by** Chan K.Y. on 15-JUN-2000		
Previous Field Sheet Date				
SLOPE (Cut)				
Material	Soil & Rock (Decomposed volcanic)			
Max Height (m) 7	**Length (m)** 50	**Angle** 70	**Berm**	No 1 Width (m) 0.5
Slope Face Conditions & Covering	fair 0% Bare 95% Sealed 5% Vegetated Slope sealing material is shotcrete		**Condition beyond Crest & Covering**	fair 100% Sealed
Weepholes/ Horizontal Drain	Size (mm) Spacing (m) Condition Weephole 31-50 1.4-1.8 Partially blocked			Flow Condition None
Seepage	No sign of seepage			
Sign of Leaking Services	Presence of potentially leaky services but no signs of leakage			
Sign of Distress	None			
Past Instability	Inferred Multiple Minor		Confirmed	Multiple Minor
Drainage Channels	**Type**	**Size (mm)**	**Condition**	**Flow Condition**
	Berm	201-250	blocked	dry
	Crest	201-250	partially blocked	dry
	Stepped	251-300	partially blocked	dry
	Toe	101-150	blocked	dry
WALL				
No wall				
Affected Facilities	Crest facilit School		Distance (m) 1.5	
	Toe facility Residential		Distance (m) 1	
Service Conduits	None			
Observations	PART OF SLOPE SEALED BY CHUNAM			
GEOTECHNICAL ENGINEERING OFFICE - CIVIL ENGINEERING DEPARTMENT				

Figure 3. Field observation form

a record of the slope geometry, type of facility that exists at the toe and at the crest, drainage provisions, signs of distress, past instability etc. Data herein is collected based on field observations.

- Stage 1 Report (Figure 4) for old slopes that exist before 1977, i.e. the establishment of the GEO, with a sketch of the critical section, engineering judgement on the need for follow up action or urgent repair works etc.
- Score for the New Priority Classification System (NPCS) (Figure 5) is used in risk ranking of old slopes based on instability and consequence of failure (Wong 1998).

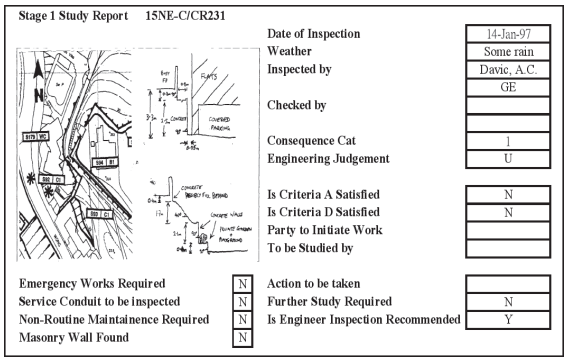

Figure 4. Stage 1 report

NPCS for Cut Feature 15NE-C/C 245		Calculation Date 20-APR-01		Background Date 08-MAR-96	
WARNING : w6 - Reinforcement is present					
	Section 1-1	Section 2-2			
Hs	6	0			
Hr	0	0			
Hcw	0	0			
Htw	0	0			
Up Slope Angle	0	0			
Slope Angle	65	0			Section 1-1
Dow Slope Angle	0	0			A 40
Surcharge	5	0			Section 2-2
Realistic Slip Surface	Y				A
Sign of Distress Reasonable					B1 0
Past Instability Confirmed : None					B2 0
Water Ingress	Slope Surface % Bare 0		% Sealed 100	% Vegetated 0	C1 0
through Surface	Crest Condition fair		% Sealed 50		
Drainage Provision for Surface Water		Few or no channels			C2 10
Water-carrying Services No potentially leaky services					C3 0
Seepage Signs of seepage					C4 5
Slope-forming Material					D 20
Material : Good 0	Uncertain A 0	Moderate 100	Uncertain B 0	Poor 0	
Lithology : Typical granite or volcanics					
Weak mass present within joint set : N		Adversely-oriented relict joints present : N			
Engineering Judgement P					E 30
Crest Facility :					
Section 1-1 Type	Road with moderate traffic				F1 1
Distance	2.5				F2 2.5
Section 2-2 Type					F1
Distance	0				F2
Toe Facility :					
Section 1-1 Type	Monastery				G1 2
Distance	1.1				G2 1.1
Section 2-2 Type					G1
Distance	0				G2
Upslope and Downslope Topography					
Section 1-1 Down Slope Angle 0		Up Slope Angle 0			J 0
Section 2-2 Down Slope Angle 0		Up Slope Angle 0			J
Consequence 1	Large volume of failure is expected : ? Occupied building may collapse or be covered : Y				K 1
Fail Scale : Full		C.S.	I.S.	T.S.	
Factor : 1	Section 1-1	24.54	105	25.77	
	Section 2-2			**Total Score :**	25.77

Figure 5. NPCS form

The information contained in the above layer is useful in understanding the background and conditions of the slope.

The NPCS score has become an invaluable tool for the GEO in the selection of old slopes for the Landslip Preventive Measures (LPM) Programme and for slope owners to establish priority ranking of their slopes in maintenance inspections and works.

3.2 *Old Slope Information Layer*

The information exists as a map layer (Figure 6) showing those man-made slopes registered in 1977/1978 including subsequent updating before the commencement of the SIRST project in 1994.

The information is a useful means of tracing the history of a slope including modification since 1977 and existence of fill materials.

3.3 *Slope Maintenance Responsibility Information Layer*

The layer has been set up as a map overlay (Figure 7) showing the individual slope boundary and the parties responsible for maintenance based on the findings of the Systematic Identification of Maintenance Responsibility of Slopes (SIMAR) project. In the case of a mixed responsibility feature, i.e. multiple parties being responsible, the demarcation lines between the parties are also illustrated on the plan.

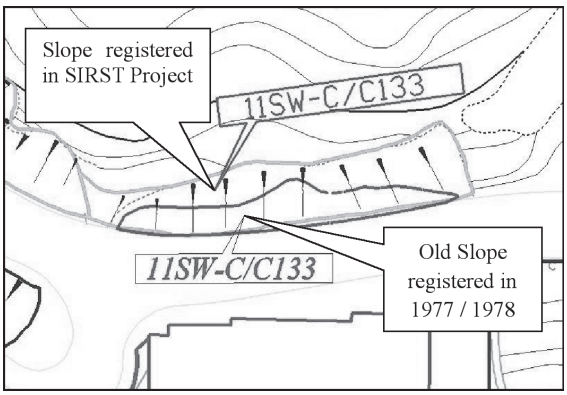

Figure 6. Old slope layer

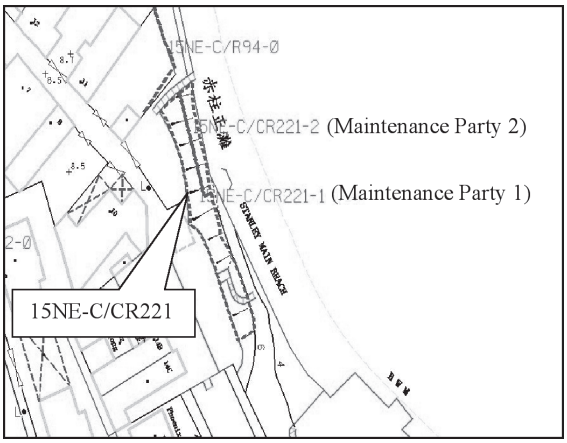

Figure 7. SIMAR layer on maintenance responsibility

It is a convenient source of information for identifying the maintenance parties and is useful to slope owners and their agents in planning their inspection and slope maintenance works.

3.4 *Landslide Incident Information Layer*

Key landslide information including location, date of occurrence, description of the failure and damage, possible causes of the failure and actions taken at the time are tabulated (Figure 8a) and the location of the landslide is shown on a map (Figure 8b).

The information is useful in upgrading and maintenance works on slopes and, in forensic study on the cause of landslides. By querying this database, it can also provide statistics on locations of clusters of past landslides, the slope types involved and the causes of the failure. It is a valuable source of information for slope design and research and investigation of landslides.

3.5 *Ground Investigation Information Layer*

The location of boreholes previously sunk are shown on a map (Figure 9a) and linked to tables (Figure 9b) showing key information, including co-ordinates of the holes, depths of the holes, date drilled and the corresponding reference of the reports available in the Geotechnical Information Unit (GIU) in which detailed borehole logs are available.

LANDSLIDE RECORDS

Incident HK97/8/13 Nothing 809570 Easting 840120
Location J/O between Tai Tam Rd and Stanley Village Road, Hong Kong

Incident Reported on : 25-Aug-97 at 08:45 from USD
Incident Inspected on : 25-Aug-97 at 14:05 Time of failure : 22-Aug-97 at

Advice Given

Cover failure scar with tarpaulin properly secured against wind.
Provide surface protection with weepholes to trimmed failure surface
Close half lane width of roundabout. Clear catchpit TT1 & the cross-road pipe.
Construct a 400 mm high up-stand wall along edge of pavement.

Should the failure feature be registered : No
Should a detail checklist be prepared :
Affected Registered Slope 15NE-A/F100

Remark

Figure 8a. Landslide incident report

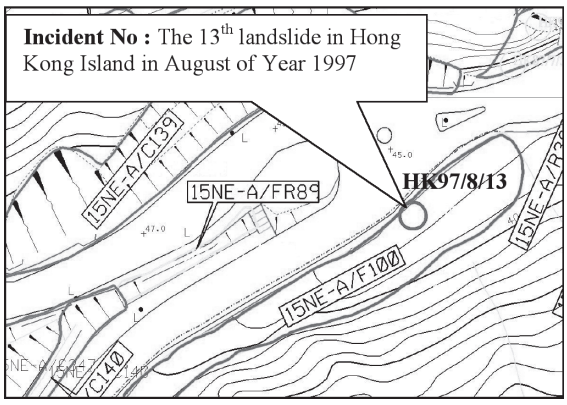

Figure 8b. Landslide incident layer

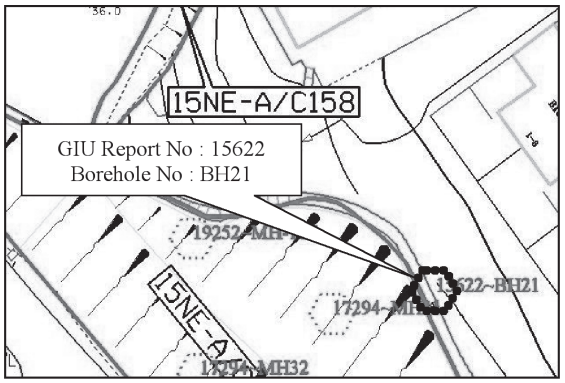

Figure 9a. Ground investigation information layer

GIU Reports

GIU Report No 15622 Works Order No 243 Contract Ref. HKHA 143/88
Author Intrusion - Prepakt (Far East) Limited
Title Ma Hang Revelopment Fieldwork Report
Date of GI 00-11-1990 Report Type GI Slope Ref. GEO Report Ref.
Remark

Station	Station Type	Incl. Angle	Easting	Northing	Works Started on	Completed on	Grd Level	Unit	Length	Lab	Rock	Perm	Piezo	Van	SPT	Highest Water Level	Date Record	Drilling Method
BH17	DH	90	839655	808066	26/9/1990	27/09/1990	39.26	mPD	13.55			N			Y			ROTARY
BH18	DH	90	839651	809079	28/9/1990	29/09/1990	40.32	mPD	13.19			N			Y			ROTARY
BH19	DH	90	839627	808098	2/10/1990	3/10/1990	41.83	mPD	14			N			Y	3	2/10/90	ROTARY
BH20	DH	90	839611	809123	5/10/1990	6/10/1990	43.71	mPD	16.9			N			Y			ROTARY
BH21	DH	90	839599	809146	8/10/1990	9/10/1990	45.42	mPD	16.4			N			Y			ROTARY

Figure 9b. Ground investigation report

Practitioners who are planning and designing for slope upgrading works or new development can access this database to obtain the sub-soil information, and if necessary, plan additional boreholes on the basis of the existing information.

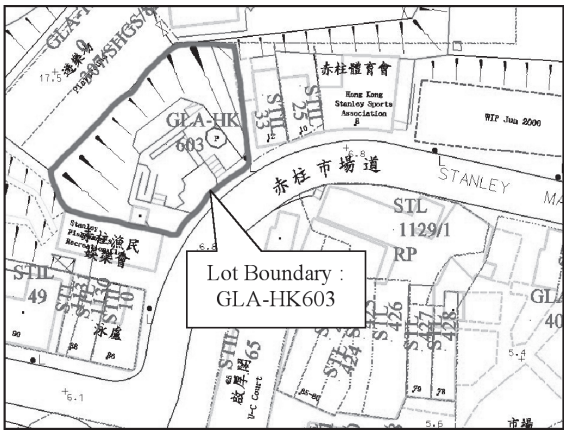

Figure 10. Lot boundary

3.6 *Lot boundary Information Layer*

The lot number and boundary are shown on a map (Figure 10). This layer can give indicative information to slope owners when planning for site access and determining the extent of their maintenance works.

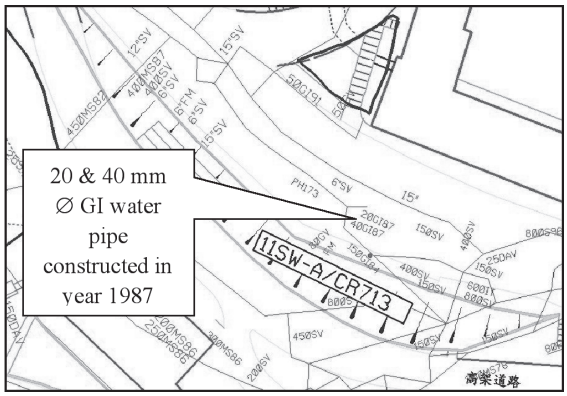

Figure 11. Drains and Water Pipe Alignment

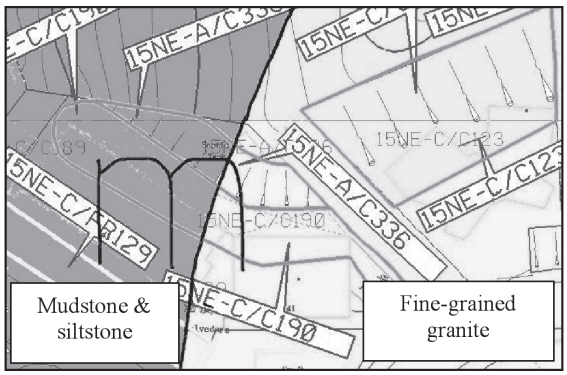

Figure 12. Geology layer

3.7 *Water Bearing Service Information Layer*

The alignments of drains, sewers and water pipes are shown on a topographic map (Figure 11) linked to tables showing the pipe diameters, depths below ground and record of past pipe inspection.

Geotechnical practitioners, in carrying out desk study for design of upgrading works, site formation for new development and maintenance works, can review the need for provisions to guard against leaking services affecting slopes.

3.8 *Geology Information Layer*

A geological map (Figure 12) is displayed in the background of a topographic map with slope boundaries shown. The map provides handy geological information for desk study.

3.9 *Natural Terrain Landslip Inventory (NTLI)*

This layer shows the locations of past landslides in natural terrain (Figure 13) and individual landslide is identified by a NTLI Registration Number (e.g. 10NWD0145).

The information is useful in assessing the natural terrain landslide risk when planning new developments close to natural hillside.

3.10 *District Information System (DIS) Layer*

The layer has a map (Figure 14) showing the slopes linked to tabulated records of DH Order, Advisory Letter and past development files dealt with by the geotechnical control arm of the GEO.

This layer provides background information for the desk studies during the planning stage of new development.

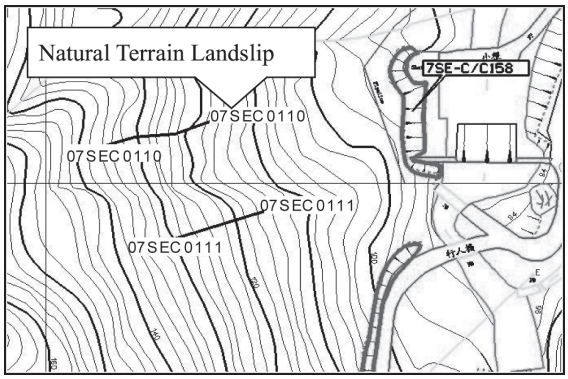

Figure 13. Natural terrain landslip inventory

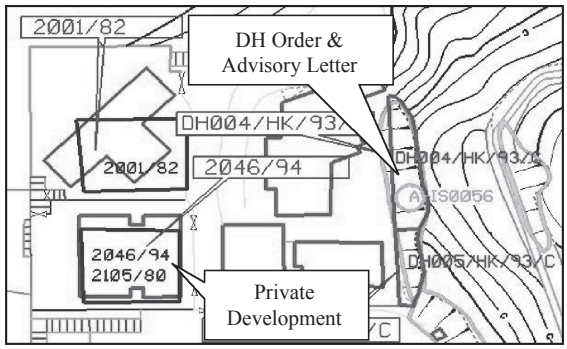

Figure 14. District information layer

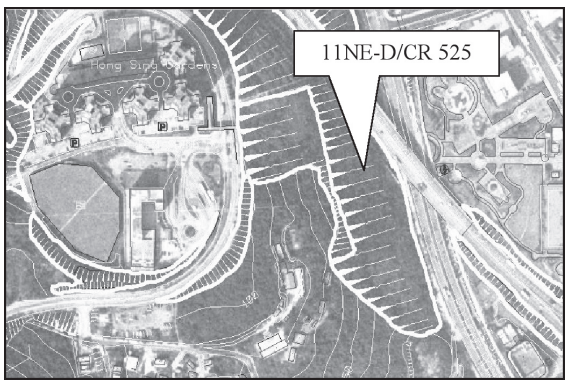

Figure 15. Aerial photo superimposed with topographic map

3.11 *Aerial Photo Information Layer*

The slope boundary map (Figure 15) is superimposed onto aerial photos. The layer is useful in the management of slope registration in confirming slope boundaries, reviewing the topography and identifying missing slopes that have not been registered. It helps users to understand more about the site topography without going out to site.

4 DISSEMINATION OF INFORMATION

There are three versions of the SIS for disseminating slope information to different groups of users. The bulk of the data is stored in the Main SIS Server which is connected via an optic fibre backbone to 14 workstations in the Civil Engineering Building for use by GEO staff, consultants and individuals from the public. The Main SIS is also used for further development to enhance system performance, functionality and dissemination of information.

An Intranet SIS is connected through the Government Office Automation Network to other Government departments. The types of information published on the Intranet have been selected to meet the requirements of other government users. This version of the SIS has been set up since June 2000.

Since March 1999, an Internet SIS has been set up in the Hong Kong Slope Safety Website (http://hkss.ced.gov.hk) for use by the general public at their homes or in their offices. As with the Intranet version, only key slope information is disseminated. The public could obtain more detailed information, if they so wish, from the workstation designated for public users on the 7th Floor of the Civil Engineering Building.

5 FUTURE DEVELOPMENTS

Further enhancement of the SIS being planned are briefly described below.

(a) To enhance system performance, the suitability of the latest hardware technology and new releases on the functional software and new software available in the market is regularly being reviewed. One improvement being considered is storage and retrieval of graphical data in Oracle spatial data format to enable free exchange between different GIS platforms. Such format could greatly improve the speed of graphical data retrieval and display.

(b) With the increasing popularity of Pocket PC, investigation is made to enable access from Pocket PC to the SIS through the Internet. This is particularly useful during attendance of landslide situations when immediate access to slope information from the incident site will greatly assist the inspecting engineer in making a quick judgement on emergency actions.

(c) On an ongoing basis, additional information layers are being added to the SIS to meet new users' requirements.

6 CONCLUSIONS

Since the launch of the SIS in 1999, some 30 information layers with over 11 million data have been set up in the SIS. Additional layers will be progressively developed and uploaded to the System. Access to this wealth of slope information can be made at ease with a click of the fingertip through workstations in the Civil Engineering Building, through the Government Intranet and the Hong Kong Slope Safety Website (http://hkss.ced.gov.hk) on the Internet. The SIS has now become the principal source of slope information for slope owners and their agents, consultants, academics and government staff in the planning and management of slope maintenance and upgrading works. It is also an indispensable tool for the management of slope safety in Hong Kong.

Users' needs for slope information are dynamic and various means of improving the SIS both in its performance and functionality are being planned and implemented as part of government's efforts to enhance public information services to the community.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge past and present members of the SIS team who have contributed their best in the development, setting up and maintenance of the SIS. They would also like to thank all data owners including officers from government departments and consultants who have maintained a continuous supply of data to ensure that the slope information in the SIS is comprehensive and up-to-date. This paper is published with the permission of the Director of Civil Engineering of the Government of the Hong Kong Special Administrative Region.

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