DIGITAL MAPPING TECHNIQUES 2018

The following was presented at DMT'18
(May 20-23, 2018 - University of Kentucky,
Lexington, KY)

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See Presentations and Proceedings
from the DMT Meetings (1997-2018)

http://ngmdb.usgs.gov/info/dmt/

3D geological modeling and management system for Singapore

By Jian Chu [a]*, Xiaohua Pan [a], Kiefer Chiam [b], and Defu Wu [b]

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This presentation describes the procedure for the establishment of a 3D geological modeling and management system for Singapore based on borehole data collected by the Building and Construction Authority (BCA) of Singapore and the 3D geological model and geotechnical models that have been built so far. More than 60,000 borehole data with geotechnical testing data are available to be used for this project. The first step was to screen all the data. This involved in removing errors and duplicates from the database as well as identifying and adjusting missing data in the database using the SubsurfaceViewer software. Geological consistency was also checked by comparing among adjacent boreholes. The second step was to construct fence diagrams zone by zone. Different zones were connected using common boundaries. Finally, 3D geological models were constructed using all the fence diagrams and the digital elevation model. Some sections of the models are shown in the presentation. For critical areas where changes in geological formations are involved, the use of extra data and extra fence diagrams to reduce the uncertainties in the geological model is also illustrated in the presentation. The plan for future online access of the 3D geological model and the services that the model could offer is also outlined in the presentation.

Digital Map Technique 2018, Lexington, KY

3D geological modeling and management system (GeM2S) for Singapore

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Nanyang Technological University, Singapore

Kiefer Chiam and Defu Wu
Building Control Authority, Singapore

May 22, 2018

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Outline

- Introduction
  - Background of the project
  - Geology of Singapore
- The Geodata Modelling and Management System (GeM2S) – in the making
- Future plan

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Objective

- To **establish a geodata modelling and management system (GeM2S)** to transform 60,000 borehole data and geotechnical testing data to 3D geological and geotechnical models for future underground developments in Singapore.
- The key deliverables are the 3D geological model, geotechnical models and a web-based design tool for future underground projects.
- The models are to be verified by a tunnelling project by the Land Transport Authority (LTA) and apply it to the master plan by the Urban Utility Board (URA).
- It will be BIM ready and form part of the Digital City program

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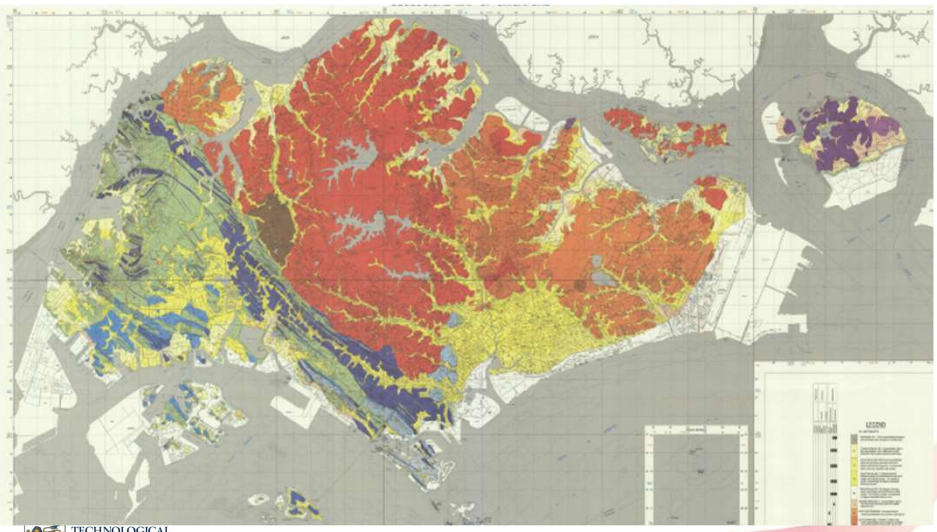
2D Geological Map of Singapore



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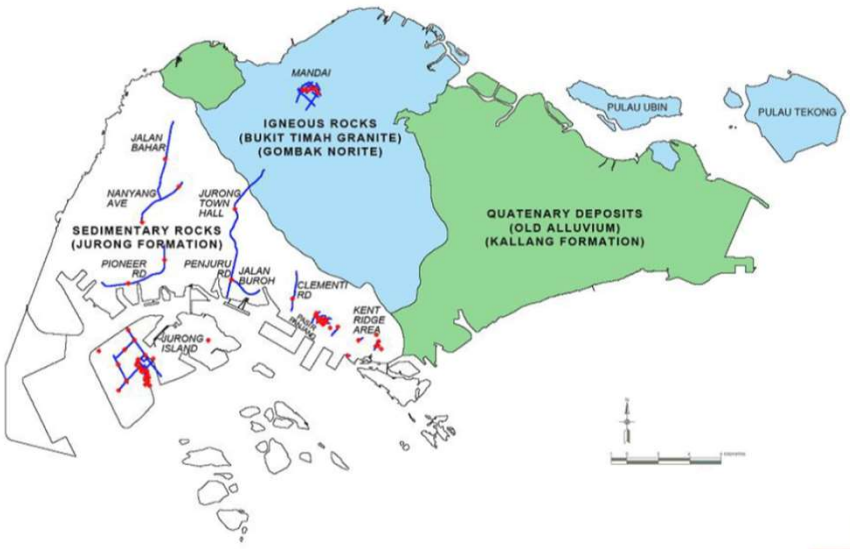

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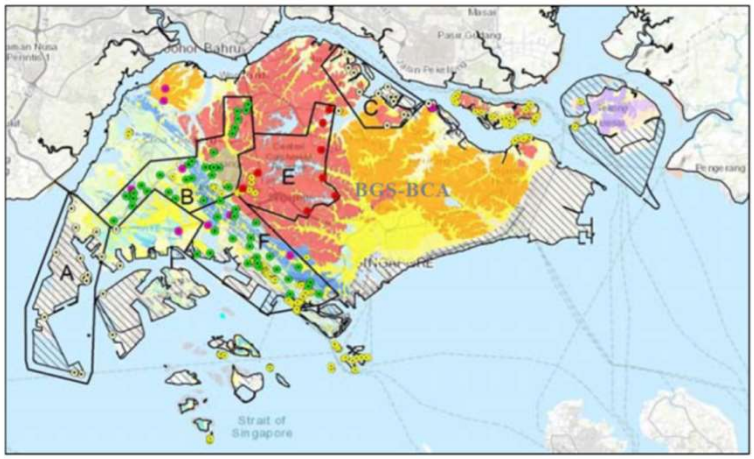
Updating of Bedrock Geology



Some 100 new boreholes (c. 13,400 m of new core), with new 2D seismic data in five study areas; and new outcrop study from some 300 locations (⊙).....

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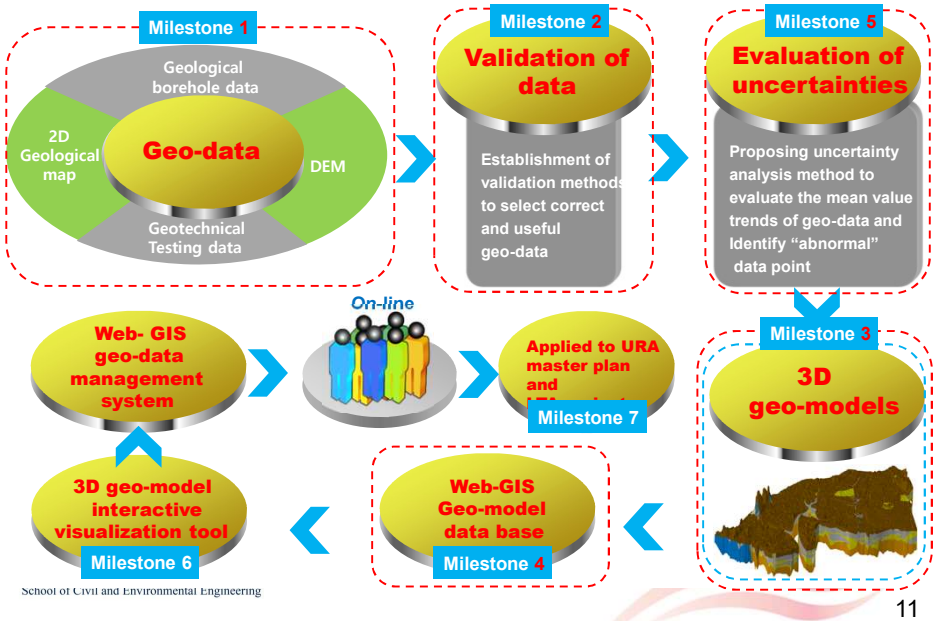
Project Milestones



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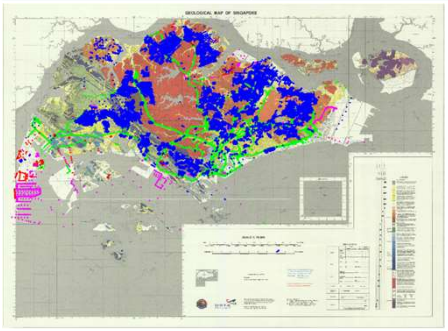
M1: Processing of Borehole Data

1) Compiling digital BH data (.ags) into access database

Total No of BH	BH data in .ags	BH data in pdf files
59,275	48,828	10,447



- BH data from LTA
- BH data from HDB
- BH data fromBCA, MPA, URA and private sectors
- BH data from JTC

48,828 digital BH data in .ags (SG) digital data transfer format include:
Site specific information: geology, core, fracture, ground water condition, etc.
In-situ testing data: geophysical, permeability, SPT, PMT, etc.
Lab testing data: physical, chemical, compressibility, consolidation, stiffness, strength, etc.

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M2: Validation of Geological and Geotechnical Data

1) Geological data

1st Step: Using SubsurfaceViewer to identify and adjust missing data

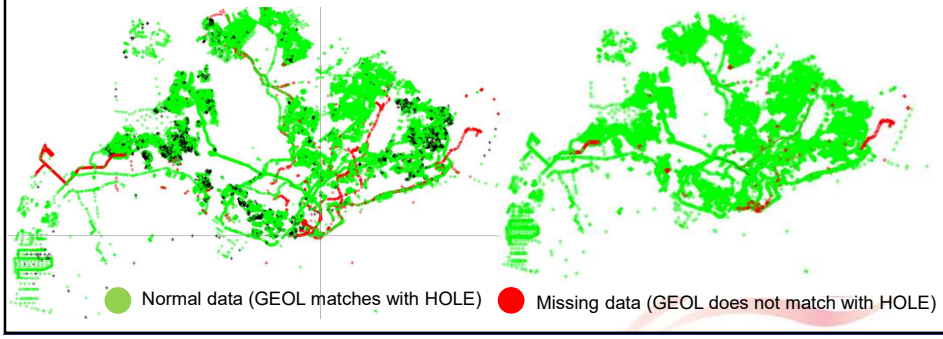
1_HOLE

GUID	HOLE_ID	HOLE_TYPE	HOLE_NATE	HOLE_NATN	HOLE_GL	HOLE_FDEP	HOLE_STAR	HOLE_REM	HOLE_ENDD	HOLT_BACD	HOLE_CREW
HDB-1970-10B	24453	CP	33935	33880	103.35	21.95	4/10/1970		14/4/1970	14/4/1970	
HDB-1970-10B	24454	CP	33866	33859	103.41	19.81	4/5/1970		4/9/1970	4/9/1970	
HDB-1970-10B	24455	CP	33788	33857	103.44	17.37	4/1/1970		4/4/1970	4/4/1970	
HDB-1970-10B	24456	CP	33853	33965	103.48	21.34	17/4/1970		21/4/1970	21/4/1970	
HDB-1970-10B	24457	CP	33930	33950	103.5	15.85	23/4/1970		27/4/1970	27/4/1970	

HDB-1970-10B_24453

3_GEOL

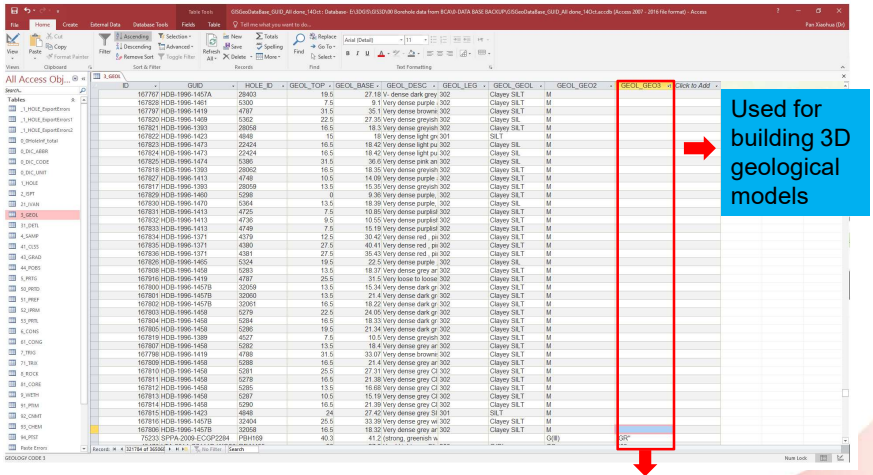
GUID	HOLE_ID	GEOL_TOP	GEOL_BASE	GEOL_DESC	GEOL_LEG	GEOL_GEOL	GEOL_GEO2	GEOL_GEO3
HDB-1970-10B	24453	5.79	7.92	Dense greenish cemented SAND	401	SAND	S	K
HDB-1970-10B	24453	7.92	8.84	Dense greenish cemented fine SAND with yellowish brown mottles	401	SAND	S	K
HDB-1970-10B	24453	8.84	11.28	Dense yellow cemented SAND	401	SAND	S	K
HDB-1970-10B	24453	11.28	16.15	Dense grey cemented fine SAND	401	SAND	S	K
HDB-1970-10B	24453	16.15	18.9	Dense yellowish grey cemented fine SAND	401	SAND	S	K



M2: Validation of Geological and Geotechnical Data

1) Geological data

2nd Step: Translate Geological Code 1&2 to Code 3



Used for building 3D geological models

GEOL 3 (Lithostratigraphical classification)
398,854 Total in GEOL table
321,784 (81%) Unclassified in SI Report

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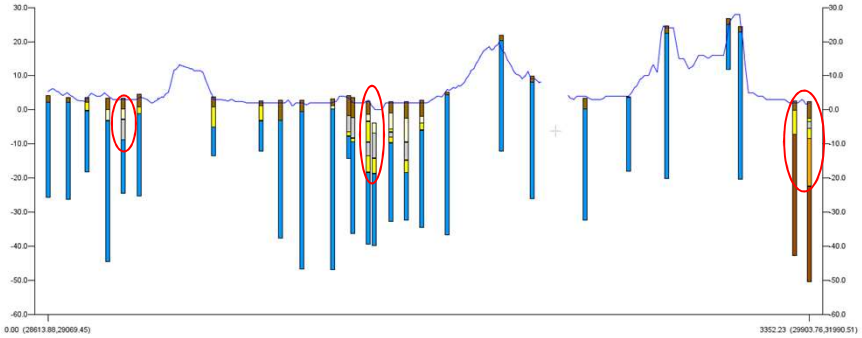
M2: Validation of Geological and Geotechnical Data

1) Geological data

3rd Step: Check inconsistency in geological data

Comparing adjacent boreholes with each other



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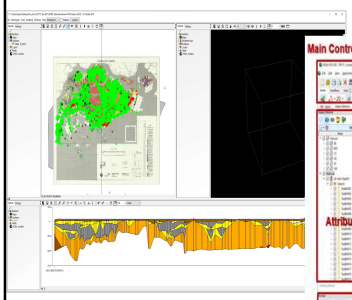
M3: Establishment of 3D Geo-models

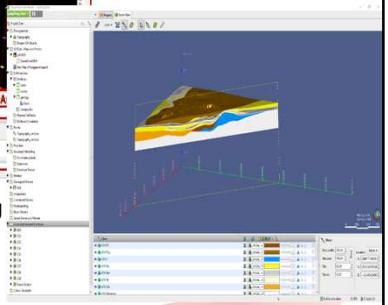
1. Software used:

SubsurfaceViewer 6_MX SKUA GoCAD 15.5 Leapfrog Geo 4.0.1



Shallow
3D geological modelling

Deep
3D geological modelling



3D geotechnical modelling

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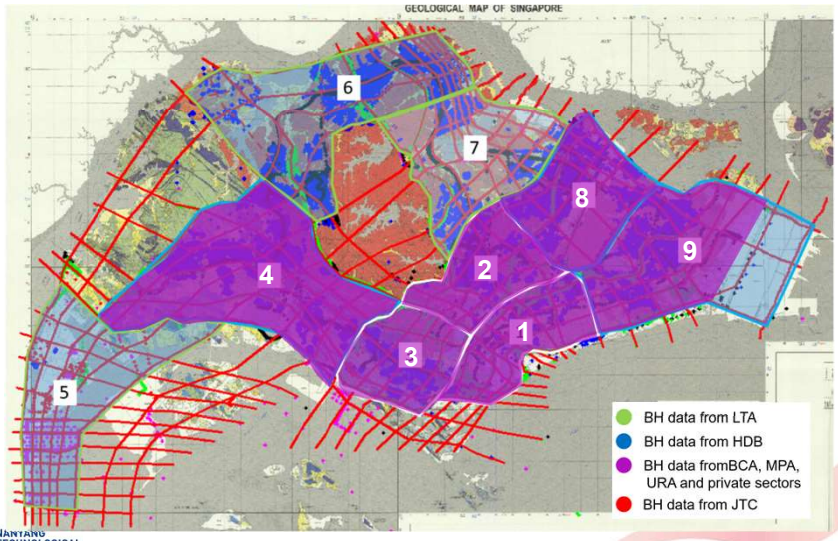
M3: Establishment of 3D Geo-models

2 Geological modelling-Nine sub-zones



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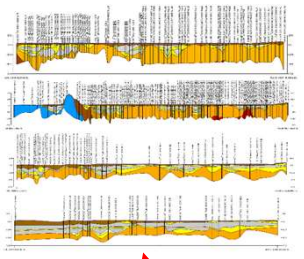
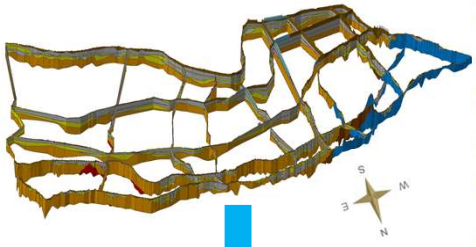
M3: Establishment of 3D Geo-models

2 Geological modelling-zone 1

Cross-sections (15)

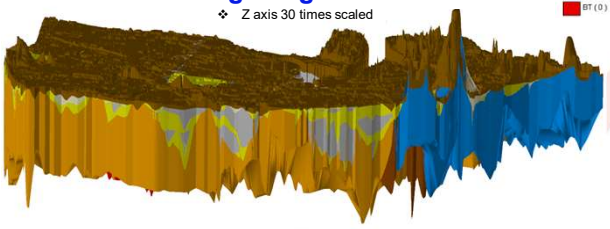


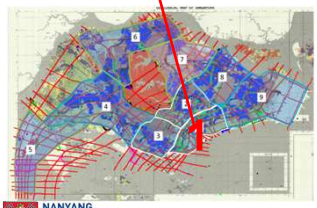
Fence diagrams



3D geological model

- Z axis 30 times scaled





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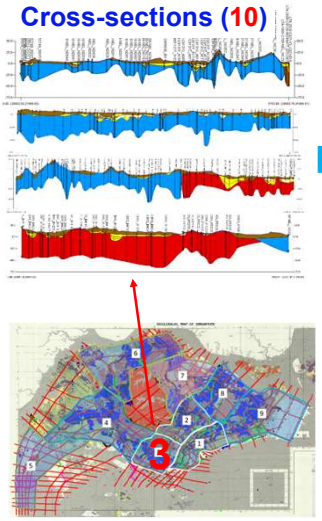
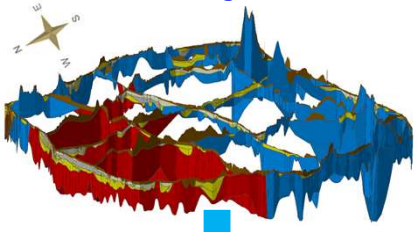
M3: Establishment of 3D Geo-models

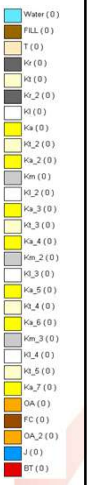
2 Geological modelling-zone 3

Cross-sections (10)



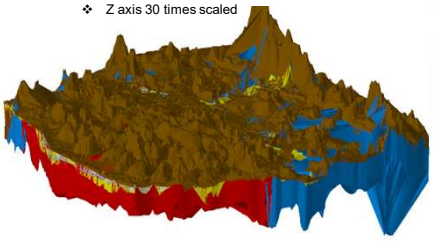
Fence diagrams





3D geological model

- Z axis 30 times scaled



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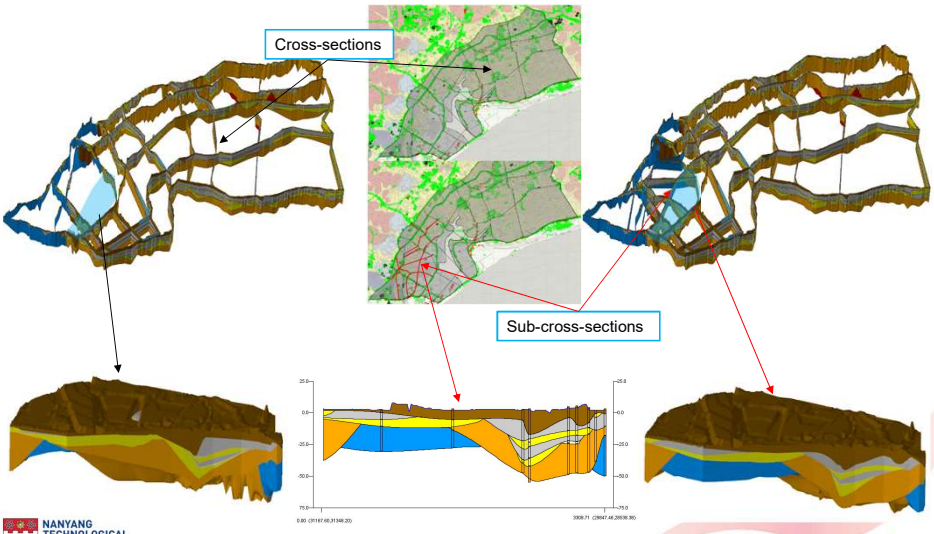
M3: Establishment of 3D Geo-models

2 Geological modelling-quality control method

Fence diagrams quality control (Adding sub-cross-sections)



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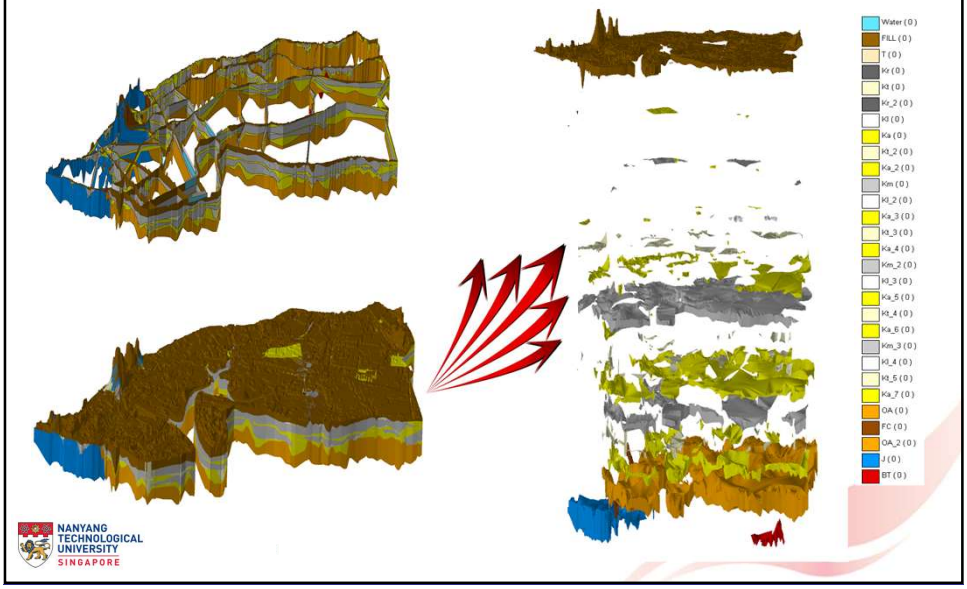
M3: Establishment of 3D Geo-models

2 Geological modelling-quality control methods

3) 3rd method: Layer boundary quality control (Based on boreholes and geological map)



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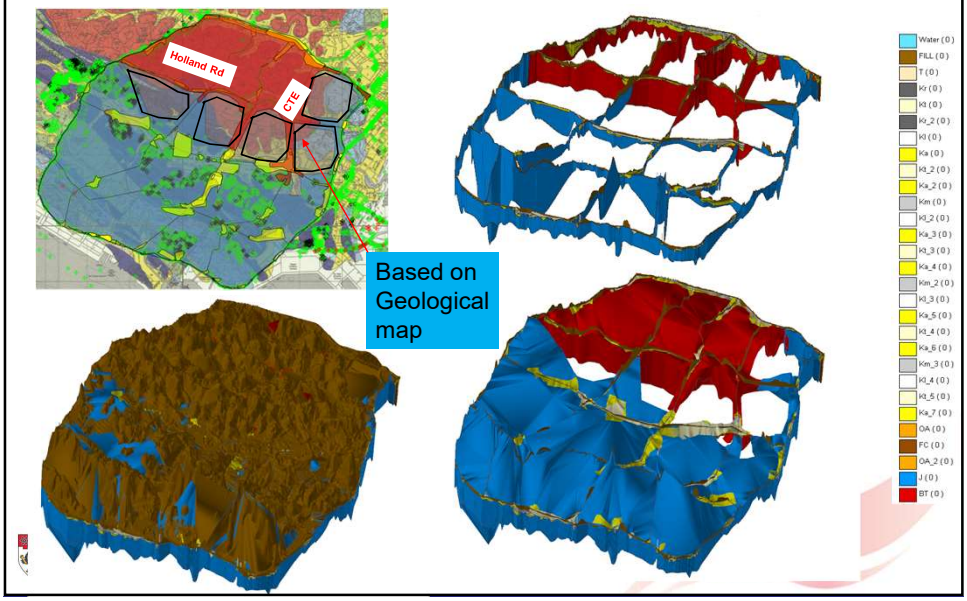
M3: Establishment of 3D Geo-models

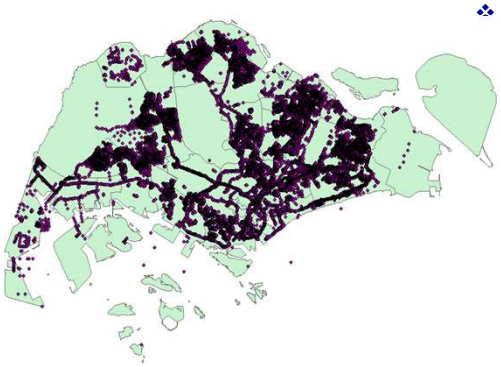
2 Geological modelling-quality control methods

3) 3rd method: Layer boundary quality control (Based on boreholes and geological map)



M3: Establishment of 3D Geo-models

SPT Geotechnical modelling-BH selection criteria



- **Geotechnical Data in hand**
  - 43,054 boreholes all over Singapore
  - 416,366 rows of SPT data
  - Other types of geotechnical data are given as attachments
- **Error form**
  - Duplicated Hole ID
  - Conflicted BH information
  - Over lapping segments
  - Conflicted soil data for re-bored BH
- **Selection criteria**
  - If soil data is conflicted in re-bored BH, use the new one
  - Contradicting BH data is filtered by majority of the nearby BH

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M3: Establishment of 3D Geo-models

SPT Geotechnical modelling - BH data processing

- **Models with two levels of details are to be produced regarding the SPT N value**
  - **Coarse model – for the whole Singapore**
  - **Fine model – take sample boreholes and form smaller models all over Singapore**
- **Coarse model - five categories**
  - **N <12, N 12-25, N 25-50, N 50-100, and N >100 (very hard layer)**
- **Fine model - ten categories**

For sandy soil

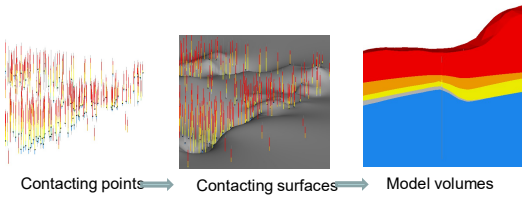
N-value	Consistency	Category (tentatively)
<4	Very Loose	S1
4-10	Loose	S2
10-30	Medium Loose	S3
30-50	Dense	S4
>50	Very Dense	S5

For clayey soil

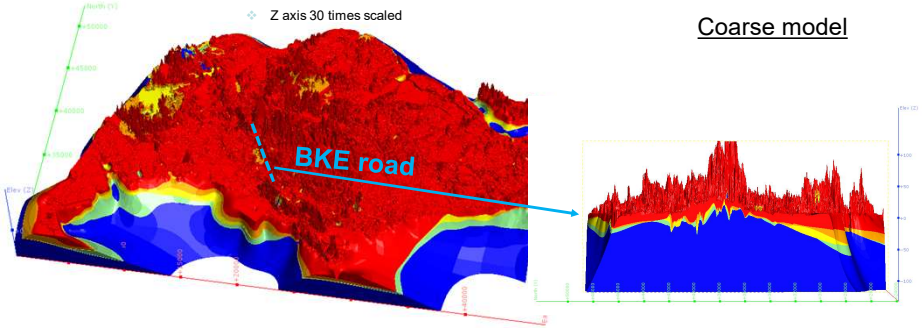
N-value	Consistency	Category (tentatively)
<4	Very Soft to Soft	C1
4-8	Firm	C2
8-15	Stiff	C3
15-30	Very Stiff	C4
>30	Hard	C5

M3: Establishment of 3D Geo-models

3 SPT Geotechnical modelling- Coarse Model



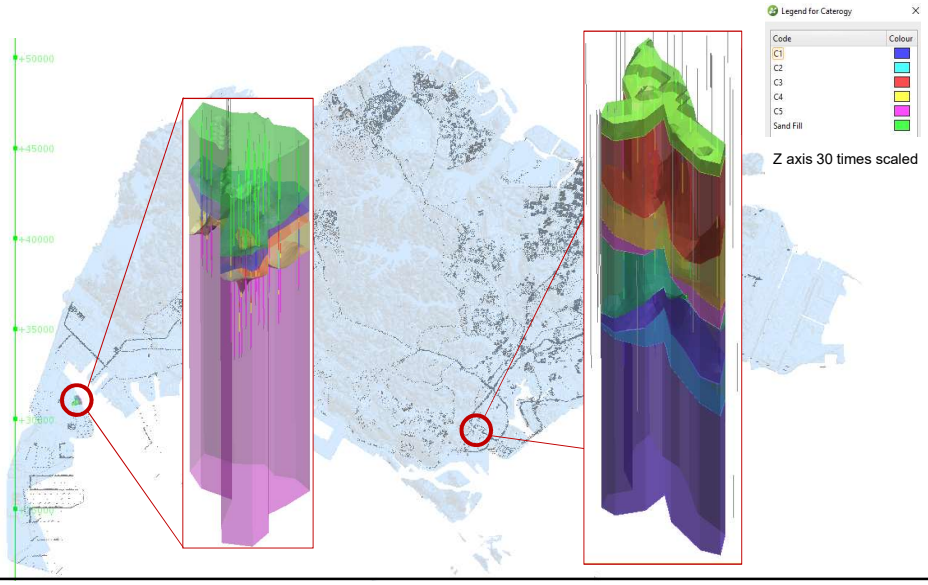
Legend
- SPT N <12
- SPT N 12-25
- SPT N 25-50
- SPT N 50-100
- SPT N >=100



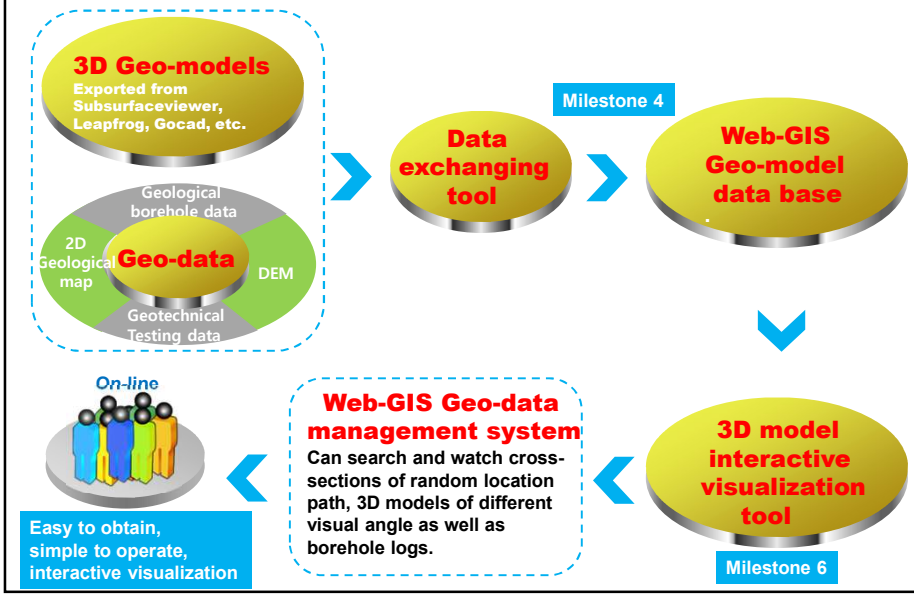
Coarse model

M3: Establishment of 3D Geo-models

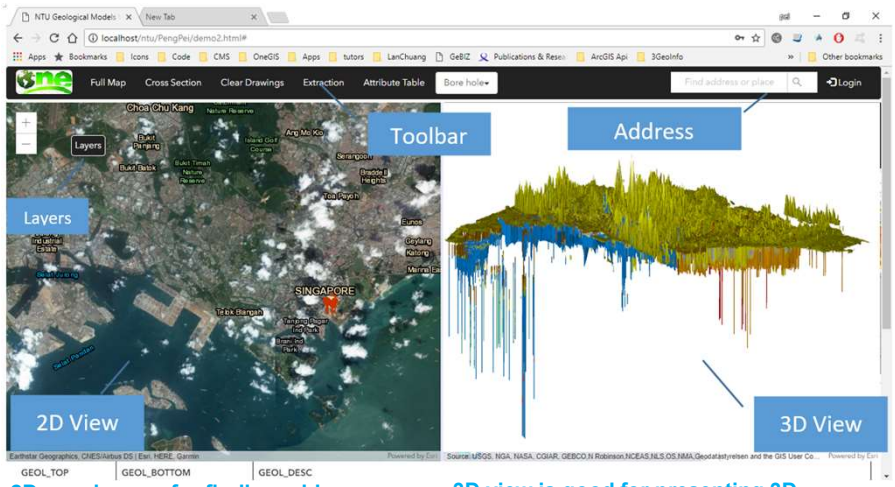
3 SPT Geotechnical modelling- Fine Model



M4: Moving on from GeM2S to online 3D models



Web-based 3D Geo-models



2D map is easy for finding address, boreholes and drawing cross-section line

3D view is good for presenting 3D models, boreholes as well as BIM models

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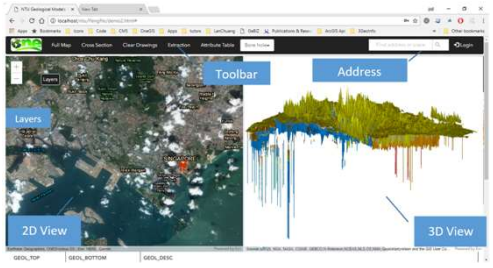
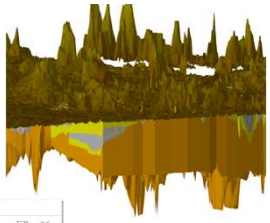
System operation interface

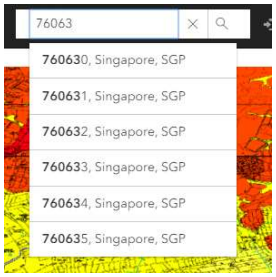
The visible content of 2D and 3D view are synchronized. When visible extent in 2D view is changed, such as zoom in/out and pan, the 3D view will automatically change to same visible extend

Web-based 3D Geo-models

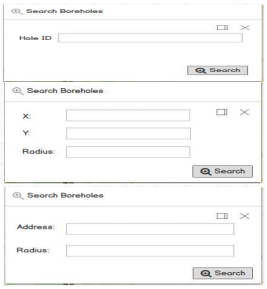


3D model extraction allows user to specify an area to extract and display on 3D view by drawing a geometry on 2D view using rectangle, circle and free polygon.

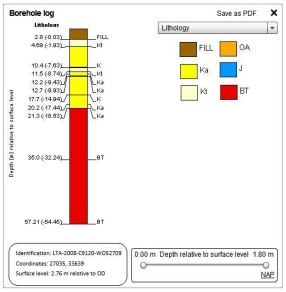




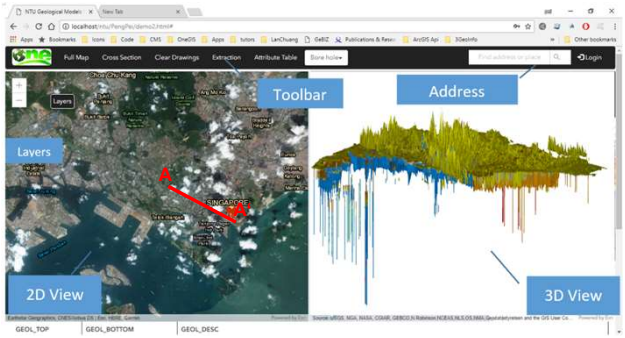
Address Search widget allows user to search address by inputting road name, land mark name and postal code

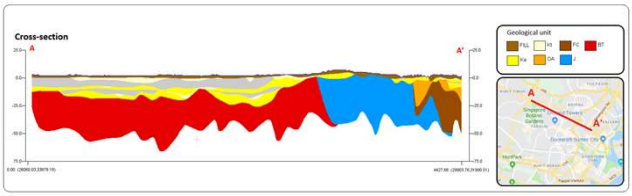


Borehole query widget allows user to search boreholes by inputting BH ID, location and radius, address and radius.



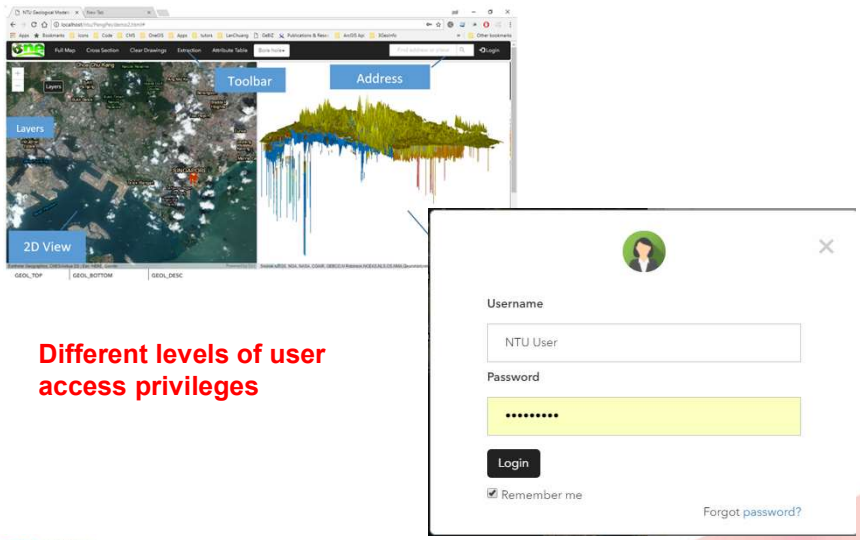
Web-based 3D Geo-models





Query random cross-sections
allows user to get the cross section profile by drawing horizontal polyline on the 2D View

Web-based 3D Geo-models – Access



Different levels of user access privileges

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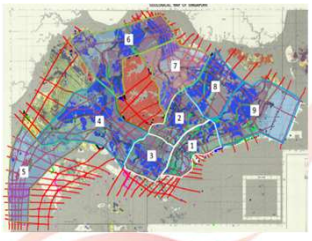
In Conclusion

- **In the past 18 months we have established**
  - The 3D geological models of 9 sub-zones;
  - The 3D SPT model and other geotechnical models are ongoing;
  - A working procedure for the Web-based GeM2S system
- **Coming up:**
  1. Complete the 3D geological model;
  2. Complete the 3D geotechnical models;
  3. Setup the online access platform;
  4. Verify the system using a tunnelling project;
  5. Merge it with Digital City Program.



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