Annual Report of E-learning Project: Site Investigation Simulation Program Part I: User Interface and Generating 3-D site models

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1 Introduction

A good understanding of in-situ underground conditions is crucial to the success of construction. Site investigation is, therefore, always conducted prior to all constructions in order to better understand the engineering underground conditions. The cost of construction, as well as the risk during and after the construction, can be significantly reduced if a proper site investigation plan is carried out.

The task of carrying out a site investigation is to understand the underground conditions subject to the construction goal and the budget. This is a complicated multi-objective optimization problem which needs to be solved. Hence, the site investigation is usually planed by experienced engineers.

Due to the high costs of carrying out a real site investigation plan for learning purposes, apprentices or unexperienced engineers encounter obstacles to develop such a skill. That is also the main difficulty in the university courses. Thanks to the computer technology, this situation is now possible to be improved by taking advantage of computer simulations. Just like a pilot sitting in front of a programmed simulating machine learning how to fly a jet, a geotechnical student can also sit in front of a computer and learn how to conduct a site investigation. The main task of this project is to design a computer simulation program, which integrates real engineering site models and geological conditions. By using that simulation program, the user shall experience and learn how to carry out a better site investigation subject to a limit budget and a construction type.

In order to get closer to a real site condition procedure, three-dimensional site models are generated and the program is designed to be interactive and visually close to the real condition. By playing with this program, the user will evolve good understanding of the site investigation and related problems. In addition, a good sense of how to conduct a proper site investigation plan shall be developed.

This project consists of two parts (as addressed in later sections). The *Project Part I*, as described in the following sections, has be successfully carried out. It is financially supported by the University of Innsbruck.
(E-learning Project; Project No: 2010.164; Project Period: 01-Jan-2010 ÷ 31-Oct-2010.)

2 The Target User

All students who study in the field of Geotechnical and Tunnel Engineering can benefit from this program. For example, students who take part in courses of Bodenmechanik und Grundbau (VL and UE), AK Grundbau (VL) and AK Bodenmechanik (SE) can use this program to practice their skills in conducting a site investigation. Thus, about 150 students will profit from this program in each semester.

Students from other scientific fields, for example engineering geology, engineering construction, construction management, etc. may also use this program for their own interests.

3 Project Part I

This project consists of two parts, Project Part I and II. Project Part I has been successfully completed.

The main task of the first part is to create the interface of the simulation program and the three-dimensional (3-D) geological models. The 3-D geological models provide information of soil layers and corresponding physical and mechanical properties, e.g. soil type and the SPT-N value, respectively. In the simulation program, the 3-D geological models, the button functions, the output figures are all written in separate subroutines so that the program can be easily maintained. This also makes the integration of new modules (which will be developed in the Project Part II) easier. The geological models and the program interface are explained in detail in the following subsections.

3.1 User Interface

This program is designed to be very user-friendly, as shown in Fig.1. All functions are implemented into button groups and edit-boxes and the same function group is marked by the same color. All information the user needs are given before or after each click of the button.

The 3-D site is shown in the middle of the program interface. The visual design makes it close to the real conditions. Site investigation have to be carried out by conducting in-situ tests on the designated site, marked with orange color.

3.1.1 For teaching and training

This program is designed for the purpose of training as well as teaching. Therefore, there is one version for the instructors/teachers, and the other version for the learners. A random mechanism is integrated in the 3-D

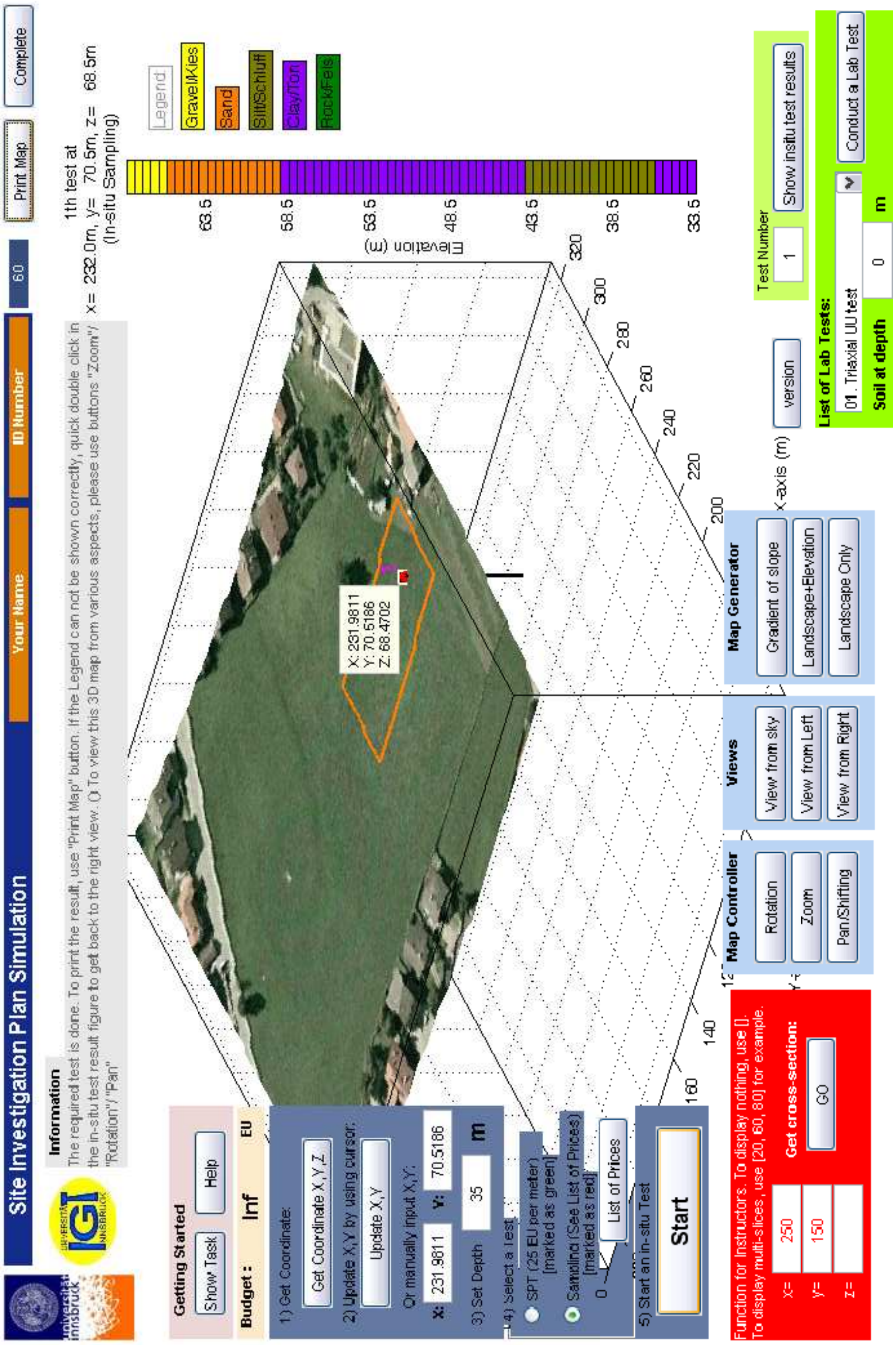

Figure 1: The user interface of the site investigation simulation program at the beginning of the program.

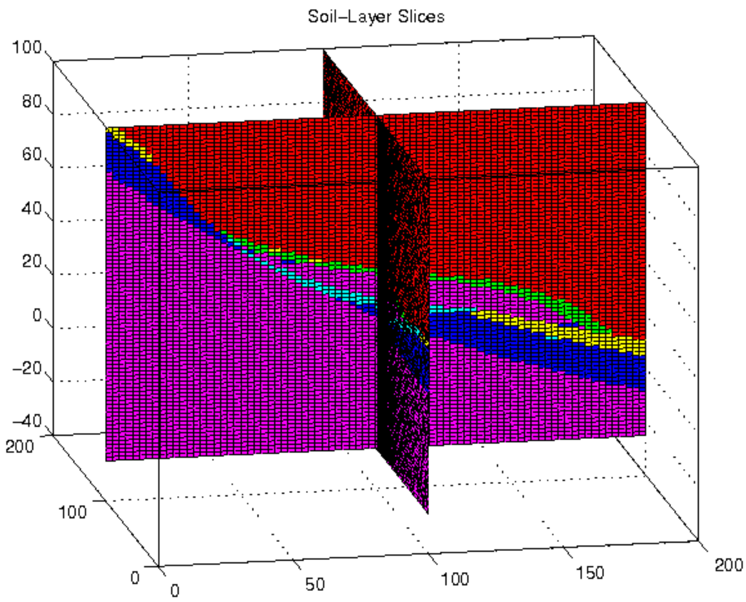

Figure 2: An example showing the intersection of the 3-D site model.

model subroutine so that the user always gets a different size and location of the construction site along with a different geological model in each case of site investigation. In addition all 3-D models are realized based on real cases and real soil profiles. Each task is challenging and the user is expected to experience the simulated sophistication of underground conditions. This is something the students hardly experience just by reading a book or by attaining a site investigation course. The students are encouraged to play with this simulation program as many times as they want until they have developed 'an engineering feeling' for carrying out site investigations.

It is worth mentioning that, for the purpose of teaching, two additional functions are provided in the teaching version of the program:

- **Case re-generation function:** For each simulated site investigation case, a case code is generate so that the instructor can re-generate each site investigation case for teaching and discussion purpose. This enables the interaction between the teacher and the student. At starting of the program, the instructor/teacher can type in the case code to re-generate a certain case, although the cases are randomly generated for the user. The teacher can also get a random case with infinite budget for demonstrating purpose.

- **Intersection inspection function:** In reality, it usually costs a fortune in order to look into the ground and know what is in there. For learning purpose, looking into the ground is necessary. Our 3-D model provides the means to check the underground conditions. A intersection can be generated at any location in our site models by input the x, y, or z coordinate(s), as shown in Fig.2

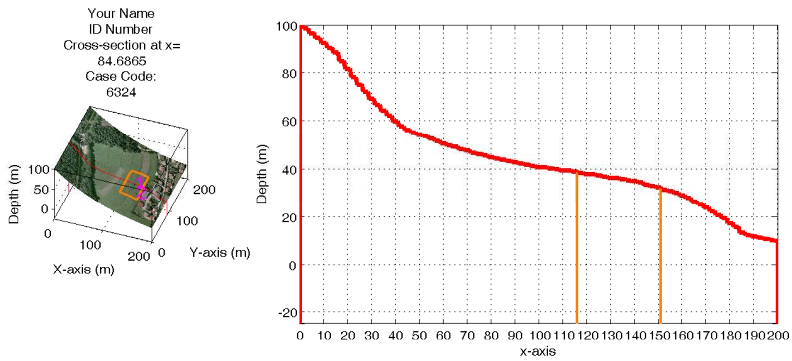

Figure 3: An example of the task, drawing the best guess of underground geology.

3.1.2 Information Block

The information Block is a marked area in the program interface (Fig.1). All the information students need will pop-up at right moment or at the click on each button. It is placed on the very top of the interface so that it easily attracts the users attention.

3.1.3 Task and Help

At the very beginning, two buttons 'Task' and 'Help' can provide help. They are located on the upper-left side of the user interface (Fig.1). By clicking at each button, a new window appears to provide more information. The user can at every stage click on the two buttons to get help.

- **The Task Button:** By clicking on the 'Task' button, the task for the user shows up in a new dialog window. The user has to carry out a site investigation for a given designated scenario subject to a limited budget. With all the information at hand, the user has to plot the 'best guess' of a soil profile, which is given after one finishes the site investigation, as shown in Fig.3

- **The Help Button:** By clicking on the 'help' button, the information for the program is provided in a new dialog window.

3.1.4 Outputs of the site investigation

At the beginning of the program, a directory in the user's name is created. That personal directory is generated in order to save all the outputs for the user when the program starts. In the directory, the following data are saved:

- **Datalog:** Datalog records the user's identity, the case code (this is a number which can be used for re-generating the same case in a teaching version of the program), the starting time, all the information of conducted tests (including location, depth, test type, and time), budget, and the task.

- **Test results:** Each in-situ test is automatically saved as a JPG file in the personal directory. It's relative location in the 3-D construction site is also printed in the same JPG file to make comparison easier

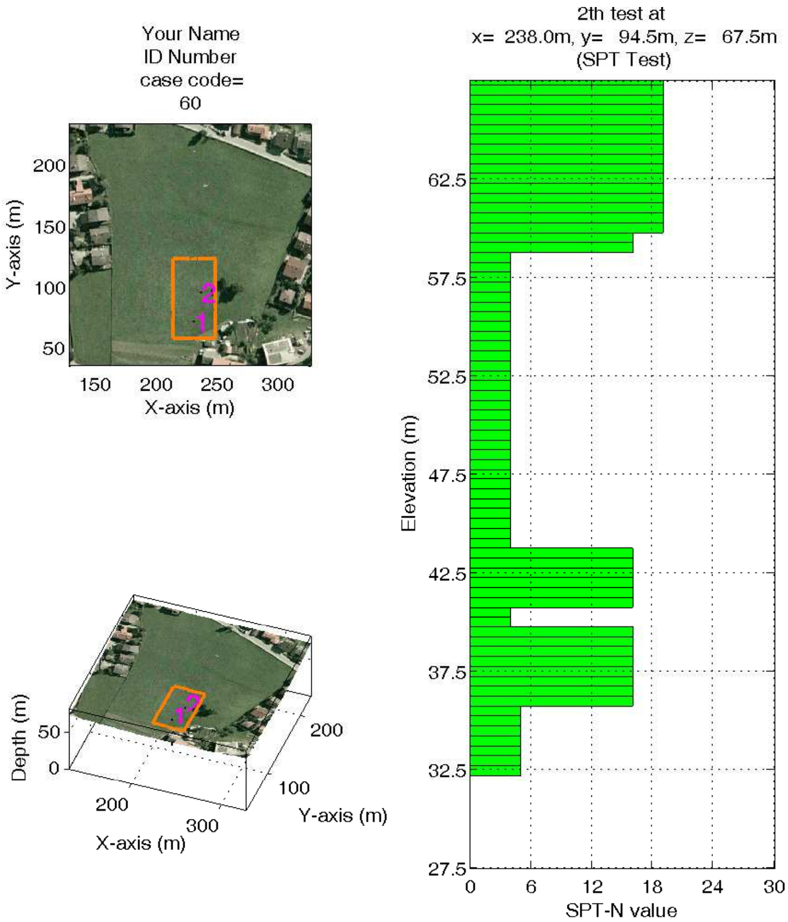

Figure 4: An example of the output file after the execution of a SPT.

- **Task:** At the end of the site investigation, the user receives a randomly generated vertical intersection, on which one has to draw the underground soil layers in the construction site. This intersection is saved as JPG at the end of the site investigation (See Fig.3).
- **Site maps:** The site map is automatically printed out at the end of the site investigation. This provides the user a large clear map, on which the conducted tests are marked.

3.1.5 Conducting an in-situ test

In engineering practice, in-situ tests are carried out in order to understand the underground geological and mechanical characteristics at the construction site. Among all in-situ tests, the Soil Sampling and the Standard Penetration Test (SPT) are very often used. The SPT provides rough information of the strength and the stiffness of the soil, denoted by the N value (as shown in Fig.4). The Soil Sampling will provide detailed information (e.g. soil types, color, thickness of soil layers, etc.) for underground soils (as shown in Fig.5). The retrieved samples are also needed for further laboratory tests, which are necessary for characterizing the physical as well as the mechanical properties of soils or rocks. It is noted that integrating the

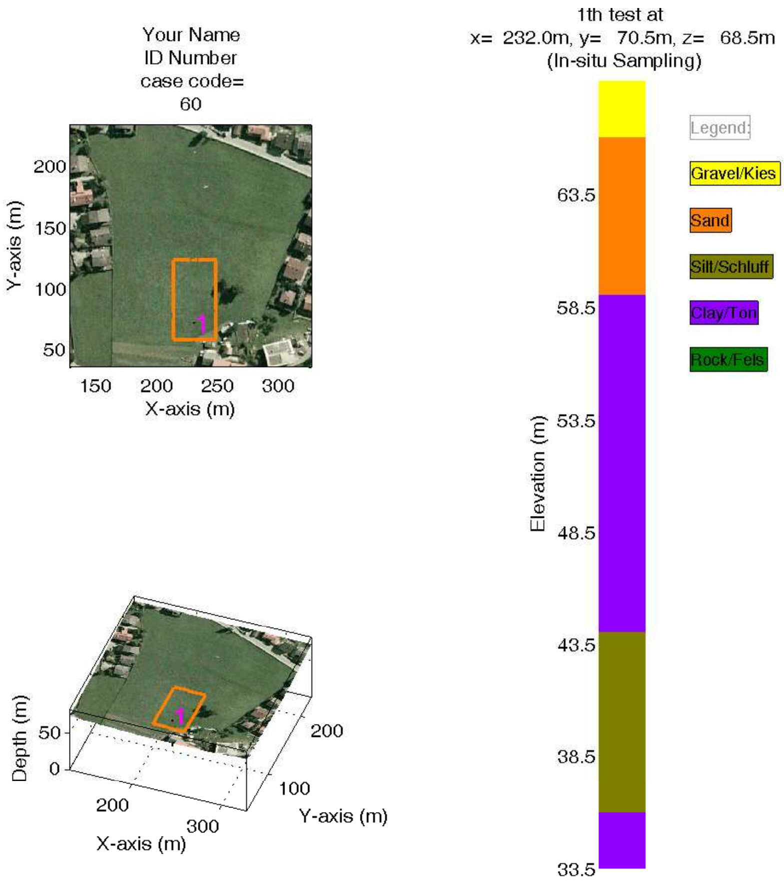

Figure 5: An example of the output file after the execution of a Soil Sampling.

lab tests into the program is in the scope of the Project Part II.

To conduct an in-situ test, the user needs to provide the following information:

- **The location:** Where to conduct an in-situ test? The x and y coordinates shall be updated by function buttons, 'Get Coordinates X,Y,Z' and 'Update X,Y', or can be entered manually.
- **The depth:** How deep shall an in-situ test be executed? A depth shall be entered.
- **The in-situ test type:** Which test shall be executed? An in-situ test shall be selected by clicking at it.

After providing the information above, a click on the 'Start' button shall offer the confirmation before execution. The test will be carried out only if the confirmation is made. The test results are saved in JPG format in the users' directory. On the simulation interface, the user can also regenerate the executed in-situ tests by input test number into the edit-box below the test result.

3.1.6 Interacting with the 3-D site

In order to interact with the 3-D construction site, three button groups are provided:

- The 'Map Controller' button group: Three buttons are provided in this group to rotate, zoom and shift the 3-D map, see Fig.6.
- The 'Views' button group: Three buttons provide three default aspects/views from Top, left side and right side of the map.
- The 'Map Generator' button group: In this button group, three buttons provide the means to view the landscape, the elevation, and the gradient of the slope.

3.1.7 Showing results

Each test result is shown on the right side of the program interface (Fig.1) and is saved in the users' directory after each execution of an in-situ test. For a SPT, the output is a bar chart of SPT-N values plotted against elevation. For a sampling test, the soil type is shown in different colors along the elevation. It is noted that the outputs are close to a real test report, as well as the color and chart type agree to the up-to-date regulations (DIN).

3.1.8 How to get this program, how to start it?

This program is written using GUI in Matlab. GUI is short for graphical user interface, on which the site investigation simulation program is built on. The program codes are encrypted into p-files and will be uploaded to our website. Learners can download the p-files from our website and run it in Matlab by typing in the command line 'Site_ investigation_ plan_ simulation'. All students who are enrolled can use Matlab at UIBK computer

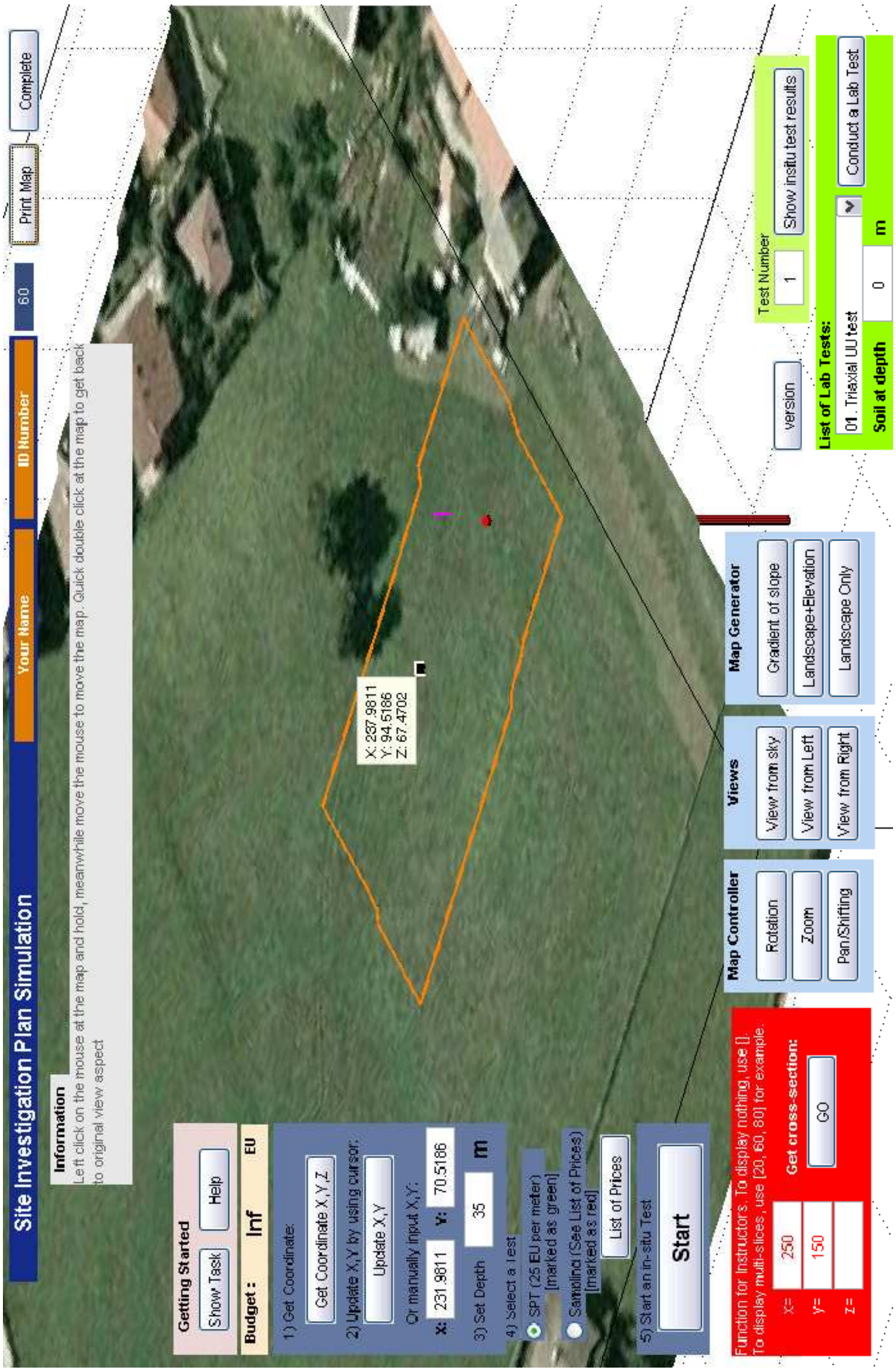

Figure 6: An example of using zoom and shift function.

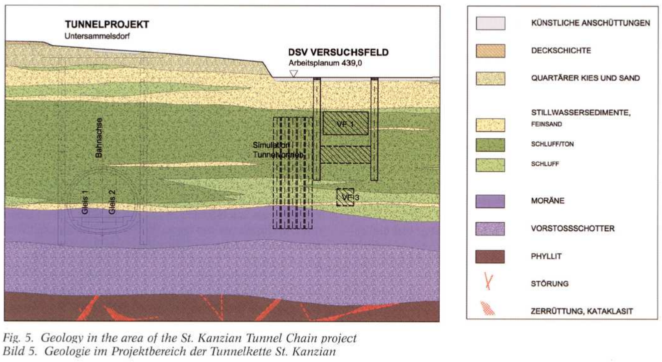

Figure 7: Case of a complicated geological condition. (Source: Geomachanics and Tunnelling 3(2010) No.2.)

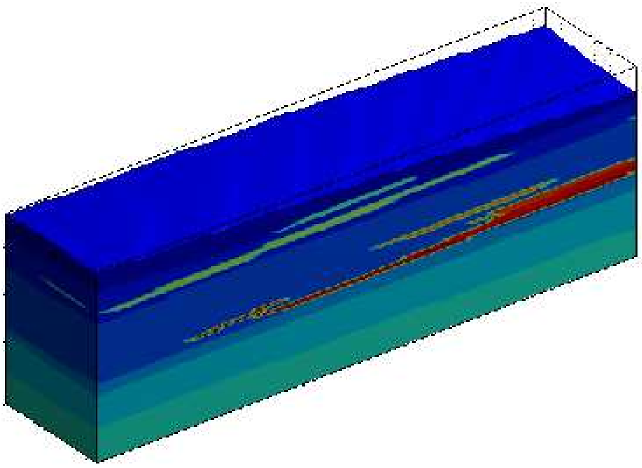

Figure 8: The digitalized 3-D geological site model for the case of site with complicated soil layers.

centers or from their own computers at home using a free access to activate a Matlab license through the VPN tunnel. This will make learning possible everywhere in the world.

3.2 Three-dimensional models

This program includes four typical geological conditions: *Slope failure*, *River course* and *Glacial geology* are provided by the geologist Mag. Daniela Engl. The 3-D model 'Site with complicated soil layers' is referenced from a journal paper.

3.2.1 Site with complicated soil layers

The latter is documented in the journal paper (Fig.7), *Geomachanics and Tunnelling 3(2010) No.2*. A tunnel has been planed to be located in such a site. With a little bit more imagination, the 2-D model is modified to simulate a real underground condition, which is often sophisticated and engineers have to carefully examine the site before further construction plans will be made. The digitalized 3 dimensional site model is shown in Fig.8.

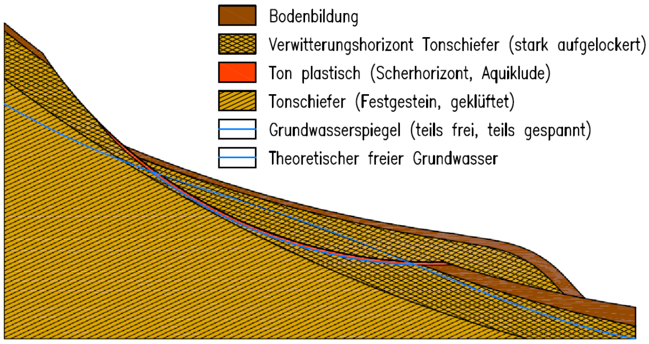

Figure 9: Case of a slope failure, provided by the geologist Mag. Daniela Engl

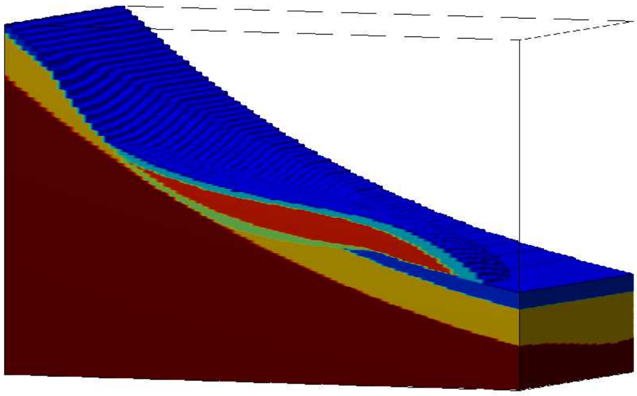

Figure 10: The digitalized 3-D geological site model for the case of slope failure.

3.2.2 Slope failure

A typical slope failure site, which student may be familiar with, yet, they will still encounter the difficulties to conduct a proper site investigation. The case of slope failure and the corresponding digitalized 3-D model are shown in Fig.9 and Fig.10.

3.2.3 River course problem

The river course changes with time (Fig.11). Old river beds can be filled with other materials and form new land. In engineering practice, it is important to understand this natural transition and detect this geological difference in case of construction. The generated 3 model is shown in Fig.12

3.2.4 Glacial geology

After glacial had occurred at a certain area, special geological conditions may be formed. Many anomalies occur in the underground (Fig.13), which can be confusing enough, even for an experienced engineer. The generated 3 model is shown in Fig.14

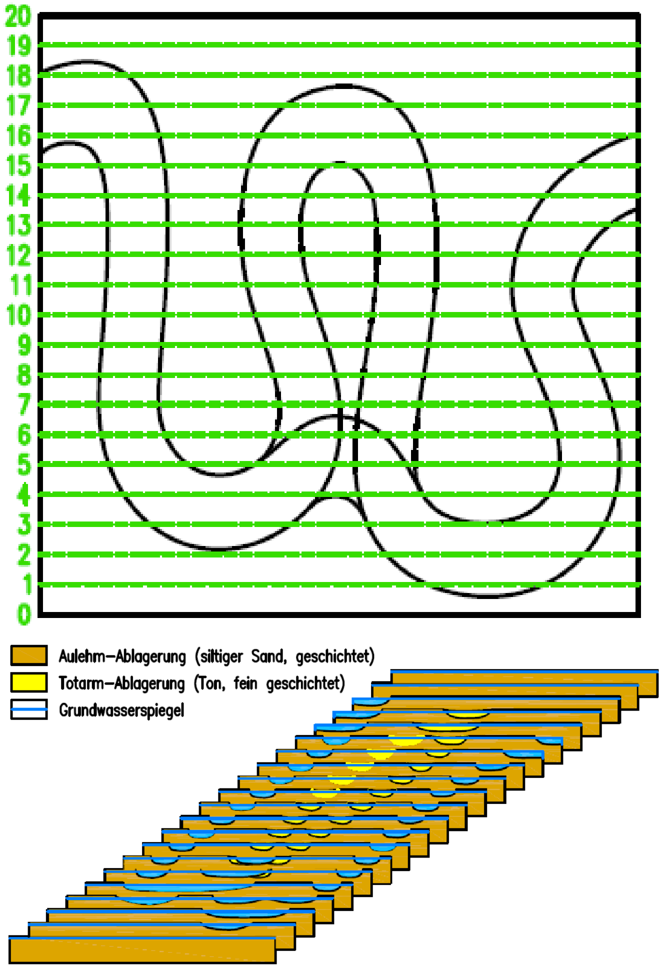

Figure 11: The change of a river course, provided by the geologist Mag. Daniela Engl

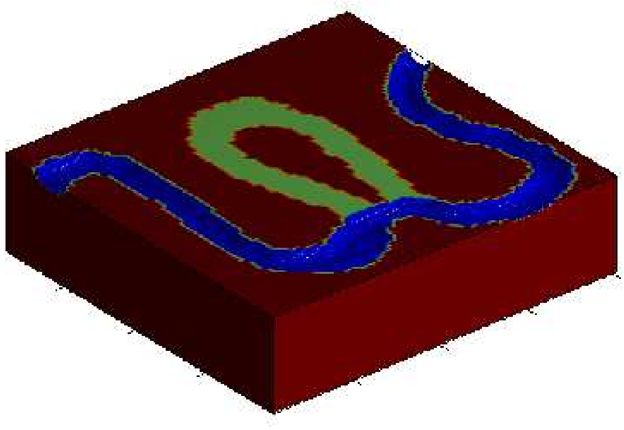

Figure 12: The digitalized 3-D geological site model for the case of river course.

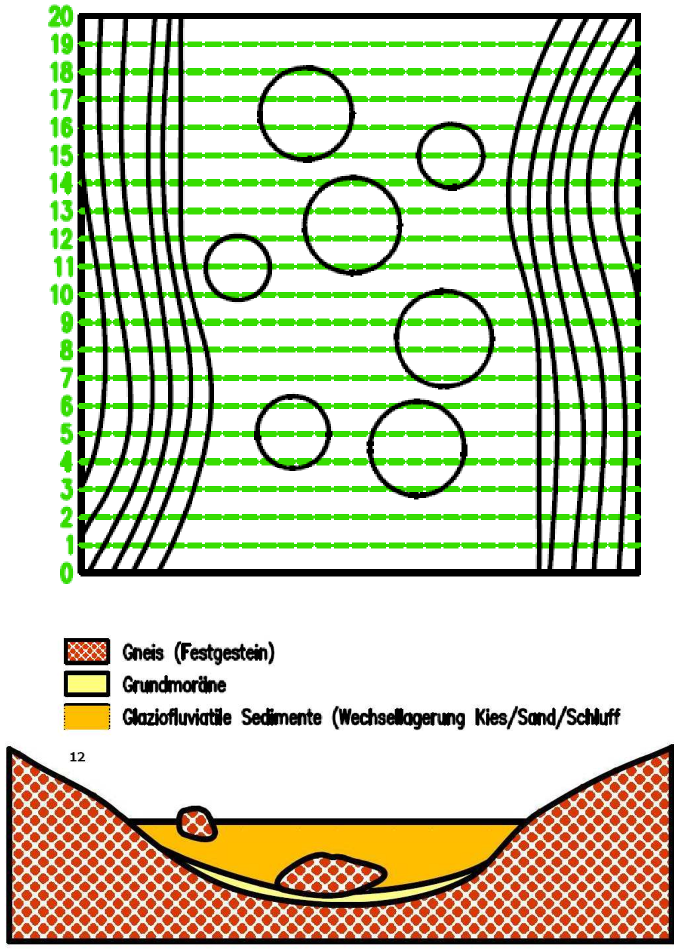

Figure 13: The case of glacial, provided by the geologist Mag. Daniela Engl

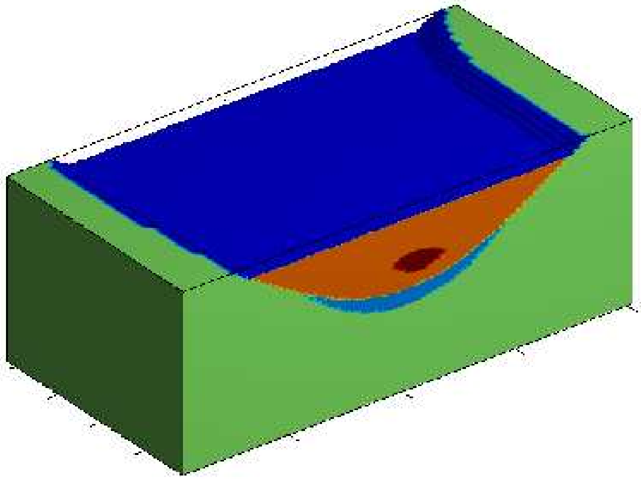

Figure 14: The digitalized 3-D geological site model for the case of glacial.

4 Project Part II

4.1 Introduction

As mentioned earlier, the laboratory tests are crucial in order to understand the mechanical properties of soils. Thus, it is definitely necessary to implement this function into the site investigation simulation program in order to make the program a powerful tool for teaching and learning purpose. The main task of Project Part II is, therefore, to create a database by digitalizing lab tests results of soil samples and make conducting a lab test with corresponding output results possible.

In the laboratory, mechanical tests such as the direct shear test, the CU-, CD- and UU- triaxial test, the oedemeter test, etc. are often used to predict the soil behavior during and after construction. They are used to predict potential natural disasters (e.g. landslide, soil liquefaction). In fact, some important physical properties also need to be carried out in the lab (e.g. the Plasticity Index, liquid limit, plasticity limit, grain size distribution, permeability and etc.). Soil samples are retrieved at field and sent to the lab. The physical or mechanical test results are then used in the design phase, construction phase and, later, in the maintenance of the structure.

4.2 Carry-out the Project

In order to fulfill our task for Project Part II, we will need to collect lab test results of soil parameters used in design and construction. The main sources are the literature and our own lab test results. Then, the collected data will be digitalized into our database. To simulate the test results, we also need proper numerical models in order to re-produce the test results from the digitalized database. The numerical models will be programmed into subroutines and, later on, will be integrated into the user interface. To create a sufficient database for lab tests, data collection will always be part of the work so that the database will be continuously extended during Part II of this project.

4.3 Benefits for the User

In Project Part II, the student will be expected to learn the following important tasks:

- To decide which lab test should be used in which condition: In engineering practice, depending on construction type and the geological conditions, different lab tests are required. This program will be good for training users until they become experts for site investigations.
- To manage the budget: The budget is always limited and, very often, not much. Therefore, using the limited budget in a smart way to get valuable information from all the tests becomes an important task. That needs practice!

4.4 Connecting Project Part I and II

In the Project Part I, the real 3-D dimensional models were created and implemented into the user interface. The user can carry out a site investigation through conducting in-situ tests. The site investigation simulation program in Project Part I is written in modules (subroutines). That makes the program flexible to be extended to a more powerful tool for learning. The Project Part II will be written in subroutines and be implemented into the site investigation simulation program developed in Project Part I.