

Software for the assessment of primary flood defences

# D-SOIL MODEL

WTI2017



Functional Design

# Functional Design D-Soil Model

WTI-2017

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1230088-026



**Titel**

Functional Design D-Soil Model

|   |                |                      |                 |
|---|----------------|----------------------|-----------------|
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**Trefwoorden**

Stochastic subsoil schematization, soil profile, soil properties, macro stability, piping, flow slide

**Summary**

This document contains the requirements and functional design for the application D-Soil Model, which will be a part of the WTI 2017 software. The application supports the (stochastic) subsoil schematizations for the failure mechanisms Macro stability and Piping. A subsoil schematization for soil segment consists of 1D and/or 2D soil profiles, profile properties, layer properties and soil material properties.

**Samenvatting**

Dit document bevat de eisen en het functioneel ontwerp voor de applicatie D-Soil Model welke deel uit maakt van de WTI-2017 software. De applicatie ondersteunt de (stochastische) schematisering van de ondergrond voor de faalmechanismen Macro stabiliteit en Piping. Per ondergrondsegment bestaat deze schematisering uit 1D en/of 2D profielen, profieleigenschappen, laag eigenschappen en materiaaleigenschappen.

| Versie | Datum    | Auteur             | Paraaf  | Review          | Paraaf   | Goedkeuring           | Paraaf  |
|--------|----------|--------------------|---|-----------------|--|-----------------------|---|
| 01     | dec 2015 | Irene van der Zwan |   | Kin Sun Lam     |  | Joost Icke            |   |
| 02     | jun 2016 | Irene van der Zwan |   | Kin Sun Lam     |  | Joost Icke            |   |
|        |          |                    |   | Hans van Putten |  |                       |   |
| 03     | aug 2016 | Irene van der Zwan |   | Wim van Balen   |  | Jan Aart van Twillert |   |
|        |          |                    |   | Hans van Putten |  |                       |   |
| 04     | dec 2016 | Irene van der Zwan |   | Hans van Putten |  | Jan Aart van Twillert |   |
| 05     | sep 2017 | Irene van der Zwan |  | Hans van Putten |  | Joost Icke            |  |

**Status**

definitief



## Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Introduction and requirements</b>   | <b>1</b>  |
| 1.1      | Purpose and scope  | 1         |
| 1.2      | Version  | 2         |
| 1.2.1    | Version 5  | 2         |
| 1.3      | Constraints, non-functional and functional requirements  | 2         |
| 1.3.1    | Constraints  | 3         |
| 1.3.2    | Non-functional requirements  | 3         |
| 1.3.3    | Functional requirements  | 8         |
| 1.4      | Interfaces   | 10        |
| <b>2</b> | <b>Use cases</b>   | <b>11</b> |
| 2.1      | Use case 1 Collect relevant subsoil information  | 11        |
| 2.1.1    | Import data  | 12        |
| 2.1.2    | Show supported data on map   | 14        |
| 2.1.3    | Show data in table   | 14        |
| 2.1.4    | Show data in cross section or length profile (segment).  | 14        |
| 2.1.5    | Start a new project  | 14        |
| 2.1.6    | Open an existing project   | 14        |
| 2.1.7    | Save current project   | 14        |
| 2.2      | Use case 2 User must be able to combine subsoil information and view the combination                         | 15        |
| 2.2.1    | Combine items in the cross section (one to one)  | 15        |
| 2.2.2    | Connect items in batch (several to one)  | 16        |
| 2.2.3    | View combination in a cross section.   | 16        |
| 2.2.4    | Incorporate settlements underneath an embankment.  | 17        |
| 2.3      | Use case 3 User must be able to adapt the WTI-SOS 2017 to local situation.                                   | 17        |
| 2.3.1    | Save a selection of the WTI-SOS 2017 as a new project  | 17        |
| 2.3.2    | Splitting the soil segments per failure mechanism  | 18        |
| 2.3.3    | Deleting soil profiles per soil segment  | 18        |
| 2.3.4    | Changing probability of the soil profiles  | 18        |
| 2.3.5    | Make and edit soil profiles  | 18        |
| 2.3.6    | Adding 1D and 2D soil profiles to a segment  | 18        |
| 2.3.7    | Copy/paste segments for one failure mechanism to the next  | 18        |
| 2.3.8    | Add materials to the material table  | 18        |
| 2.3.9    | Deleting items   | 19        |
| 2.4      | Use case 4 Define subsoil schematization for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'   | 19        |
| 2.4.1    | Define aquifer layers per soil profile.  | 20        |
| 2.4.2    | Save soil segments for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'.                        | 20        |
| 2.4.3    | Define soil parameters for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'.                    | 20        |
| 2.4.4    | Define yield stresses or POP per 2D soil profile (optional for undrained calculations).                      | 20        |
| 2.4.5    | Filter the soil parameters needed for the use for failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'. | 20        |
| 2.4.6    | Define interpolation method of non-aquifers per soilprofile.   | 20        |

|       |  |    |
|-------|--|----|
| 2.5   | Use case 5 Define subsoil schematization for the failure mechanism Piping (STPH)   | 20 |
| 2.5.1 | Define 1D soil profiles in 2D soil profiles.                                       | 21 |
| 2.5.2 | Define aquifer layers per soil profile.  | 21 |
| 2.5.3 | Define soil parameters for the failure mechanism Piping (STPH).                    | 21 |
| 2.5.4 | Save soil segments for the failure mechanism Piping (STPH).                        | 21 |
| 2.5.5 | Filter the soil parameters needed for the use for failure mechanism Piping (STPH). | 21 |
| 2.6   | Use case 6 Export data for use in other applications                               | 21 |
| 2.6.1 | Make a selection of the soil parameters.   | 22 |
| 2.6.2 | Export   | 22 |
| 2.6.3 | Import (part of) tables  | 22 |
| 2.7   | Error handling   | 22 |
| 2.7.1 | Validation messages  | 22 |
| 2.7.2 | Log messages   | 23 |

### **3 Literature** **25**

## **Bijlage(n)**

### **A Glossary** **A-1**

### **B Input files** **B-1**

|     |  |     |
|-----|--|-----|
| B.1 | Materials                              | B-1 |
| B.2 | 2D profiles                            | B-1 |
| B.3 | 1D profiles                            | B-1 |
| B.4 | Segments                               | B-3 |
| B.5 | Surface line and characteristic points | B-3 |
| B.6 | GEF files                              | B-6 |
| B.7 | Shapefiles                             | B-6 |

### **C Soil parameters** **C-1**

|     |   |     |
|-----|---|-----|
| C.1 | Soil parameters for filter Macrostablieiteit: | C-1 |
| C.2 | Materialparameters for Piping:                | C-3 |
| C.3 | Soil parameters for Zettingsvloeiing:         | C-4 |

### **D Combination of surface line and 2D profile** **D-1**

### **E Description functional requirements** **E-1**

# 1 Introduction and requirements

This document contains the requirements and functional design for the application D-Soil Model, which will be part of the WTI 2017 software applications. In chapter one a short introduction is given, followed by the non-functional and functional requirements. Chapter 2 contains the functional design described in use cases.

## 1.1 Purpose and scope

The application supports the (stochastic) subsoil schematizations for the failure mechanism macro stability and piping and the storage of material parameters for liquefaction.

A subsoil schematization for macro stability and piping consists of segments; dike sections. The subsoil of these segments is described via soil profiles, profile properties, layer properties and material properties.

D-Soil Model is a software tool for the schematization of the subsoil and is developed for the assessment of primary dikes according to the WTI 2017. In this process of assessment the schematization of a stochastic subsoil model (WTI-SOS 2017) is a major source of information. This information is used in the basis modulen and Ringtoets (see figure below). The D-Soil Model development focuses on use of this stochastic subsoil model (WTI-SOS 2017).

For background on the context of the WTI project and on the derivation or motivation of the supported schematizations, the reader is referred to the VTV 2017 and to its supporting technical reports and their background reports.

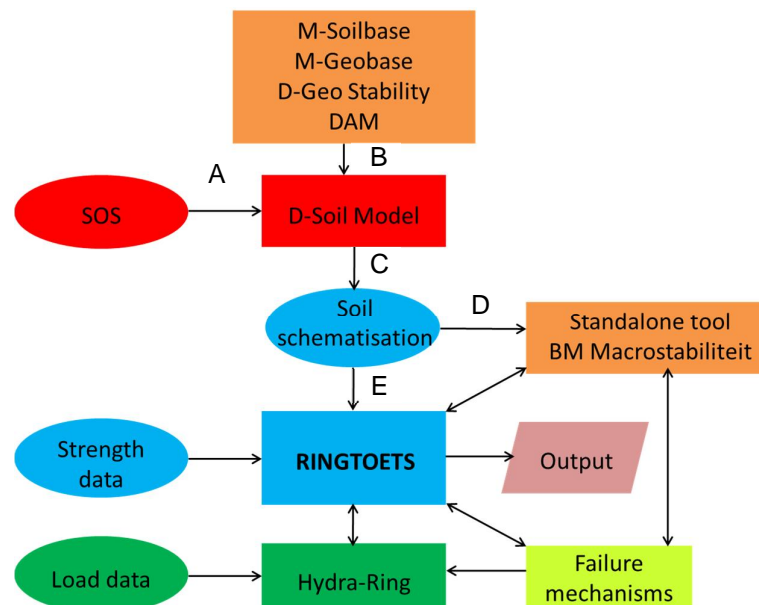


Figure 1.1 WTI components

D-Soil Model is connected to several other components of the WTI 2017 as follows:

- A. Data can be imported from the SOS database. See 2.1.1.

- B. Data can be imported from data that is used by or created by tools that are not part of WTI (e.g. DAM or D-Geo Stability). This also includes data described by industry standards as GEF-CPT for cone penetration tests (“Sonderingen” in Dutch) or GEF-Bore for borings (“Boringen” in Dutch). See 2.1.1.
- C. D-Soil Model is a pre-processor that support the creation the soil schematization. See 2.4.2
- D. The Ringtoets application can read the soil schematization. See 2.5.4.
- E. The standalone tool BM – Macrostabiliteit can read the soil schematization.

A glossary of used terms is placed in appendix A.

## 1.2 Version

The present document is associated with the software delivery of D-Soil model by September 1st, 2016, i.e. version D-Soil Model 16.1.3. The present document heavily relies on the Functional Design and Requirements [1] written by Raymond van der Meij (Deltares) and reviewed by Erik Vastenborg (Deltares). The associated counterpart from Rijkswaterstaat WVL has been Bianca Hardeman.

In this document, revisions have been applied to mutually align the document with the state of the software. Moreover, the document is modified in order to meet the document standards as agreed upon by Deltares and Rijkswaterstaat, in personae Louis Verhagen (Deltares), Hans van Putten (Deltares) and Hillie Wams (Rijkswaterstaat CIV). The actual modifications have been carried out in 2016 by Irene van der Zwan (Deltares).

This Functional Design is closely related to the other documents on D-Soil Model:

| Title                                       | Content  |
|---|--|
| Functional design                           | This document  |
| Technical Design D-Soil Model [2]           | Definition of the different software components and their interaction          |
| Test plan and Test report [3]               | Reports all test levels of the V model, as prescribed by the overall test plan |
| Technical Design Macro stability kernel [4] | Definition of the different software components and their interaction          |
| Technical Design Piping kernel [5]          | Definition of the different software components and their interaction          |

Table 1.1 Other system documents

### 1.2.1 Version 5

These are the changes in this version of the document compared to the previous version.

- Use case 4 Added 2.4.6. Define interpolation method of non-aquifers
- Appendix C Added shear strength model C-Phi/Su calc.

Only these changes are reviewed.

## 1.3 Constraints, non-functional and functional requirements

### 1.3.1 Constraints

- CNS 1 As a general constraint, the software design needs to comply with the general design description for WTI software, contained in a separate document: De Waal, 2016 [6].
- CNS 2 As a general constraint, the User Interface needs to comply with the relevant general requirements and further rules for the programming, documentation and testing of WTI software. This set of requirements and rules is contained document in Knoeff, De Waal, 2014 [7].
- CNS 3 The User Interface is developed in C#.

### 1.3.2 Non-functional requirements

- NFR2 The regular conventions, standards, tools and libraries for Deltares Systems software will be used. (must have).

This will be met by using these conventions, standards, tools and libraries during development and coding of the application.

- NFR3 Data definitions will follow existing and emerging standards such as IRIS as much as possible. (must have)

For WBI there are agreements on data formats and parameter names from within the cluster datamanagement [11]. These are implemented in this application and checked with the testscripts.

- NFR6 Ringtoets and its computational core must perform sufficient error checks on the validity and completeness of data during import or input, as well as during a computation. Ringtoets needs to show warnings and error messages in an error message dialog, and write them also to a log file. The message text needs to be clear in what went wrong and where it went wrong (context). The message finally needs to supply suggestions for improvement wherever possible. (must have)

This will be met by a validation method which checks all input. All errors and warning found will be displayed in a validation table. All messages will contain the proper subject as well as a clear description of the error. Where possible, it will advise on suggestions for improvement.

- NFR7 Ringtoets must support the selection of different logging modes for the computational core. The logging form should show the log information of the latest computation. This information can help the user when a computation does not succeed or when the user wants to analyse the quality of the calculation results. (must have)

Not applicable for D-Soil Model; the user interface does support calculations.

- NFR8 Output of detailed deterministic results must enable all users to trace back the correctness of the implemented mechanism models.

Not applicable for D-Soil Model; the user interface does support calculations.

NFR9 Output of intermediate probabilistic results, in combination with documentation of the theoretical background, must enable expert users to trace back the correctness of the probabilistic procedures. (must have)

Not applicable for D-Soil Model; the user interface does support calculations.

NFR12 The user-interface may not cause crashes during regular usage. (must have)

This will be met by continuous testing the application using unit tests as well as by performing the test scripts that are part of the test plan [3].

NFR14 Consistency between the input data and the output data must be guaranteed. (must have)

Not applicable for D-Soil Model; the user interface does support calculations.

NFR15 The general required code coverage is 80%, except for the Delta Shell Light components, therefore the code coverage of 60% is required.

Applicable for D-Soil Model; 60% as it is built with Delta Shell Light components.

This will be met by reporting the results of the code coverage tests in the test report, conform test plan [3].

NFR16 Additional evaluation and acceptance tests need to emphasize the following aspects:

- a. The calculated boundary conditions should be comparable to those of the Hydra systems, if common procedures are used. (must have)
- b. The results should be comparable to those of PC-Ring, for the water systems and probabilistic procedures common to both. (should have)
- c. The results from deterministic mechanism models must be comparable to the results from existing VTV software for deterministic cross section analysis, as long as the schematization and boundary conditions are equal. (must have)
- d. The practical applicability, robustness and performance under representative circumstances must be proven during the evaluation period. (must have)

Items a ,b and c are not applicable for D-Soil Model; the user interface does not support calculations.

Item d is applicable for D-Soil Model.

Item d will be met by having the application undergo rigorous test usage during the evaluation period.

U158 Voor elke WTI applicatie moet worden aangetoond dat de netwerk-installatie ook werkt binnen een Citrix omgeving.

This is verified and demonstrated in the acceptance tests and corresponding report.

U13 Vanuit alle lopende programma's rondom toetsen, ontwerpen, programmeren verbeterprojecten en actieve zorgplicht wordt gewerkt aan standaard uitwisselingsformaten voor het uitwisselen van informatie. Daarbij wordt conform de

open standaard AQUO gewerkt, zodat wordt toegewerkt naar één standaard voor het uitwisselen van gegevens voor alle lopende processen. Ook het WTI 2017 instrumentarium gebruikt de open AQUO standaard zodat de data die straks voor WTI wordt verzameld herleidbaar is en in andere processen kan worden gebruikt.

See NFR 3.

- U124 De WTI Software moet robuust zijn voor kleine variaties in de invoer. Onder 'robuust' wordt verstaan: nooit een software crash. Dus: ofwel een melding dat invoer onjuist is, ofwel een melding dat een som niet convergeert, ofwel een antwoord retourneert.

See NFR 6, NFR 12.

- U125 Zodra een software component in een van de afzonderlijke lagen wordt gedeeld tussen twee of meer applicaties moet deze component in een bibliotheek worden ondergebracht. Met uitzondering van DeltaShell Light.

This requirement is not applicable, because besides DSL, there are no other components that are shared with other applications.

- U126 De componenten in de schil, de UI laag, de IO laag en de onderliggende bibliotheken zijn uitsluitend gebaseerd op C#. De ondersteuning voor deze breed toegepaste taal is optimaal voor MS-Windows systemen, met de mogelijkheid om (via de mono compiler) ook naar Linux te poorten.

See CNS 3, the complete software application is developed in C#.

- U127 De rekenbibliotheken hebben hun entry point in C#, maar zijn mogelijk in Fortran geïmplementeerd (dus niet verplicht). De rekenroutines zijn daardoor eenvoudig vanuit C# aan te roepen en vanuit Fortran zal dit gebeuren met een C++-tussenlaag.

Not applicable for D-Soil Model; the user interface does support calculations.

- U128 De componenten in bibliotheken mogen componenten uit andere bibliotheken aanroepen, zolang dit in een hiërarchische aanroepstructuur gebeurt.

This requirement is guaranteed by making use of the hierarchical architecture of DSL and the failure mechanism libraries.

- U129 Alle componenten binnen een bibliotheek moeten foutcodes retourneren met een gestandaardiseerde (nog nader vast te stellen) betekenis of gebruiken excepties om fouten door te geven.

The DSL software architecture is such that error return codes are fed back to the user in the prescribed language. Neat exception handling is guaranteed by using the standard C# exception handling features.

- U130 De gebruikte feedback functies (functies die gedetailleerde melding geven van voortgang, waarschuwingen en fouten) moeten een identieke (nog nader vast te stellen) interface hebben voor alle componenten in het raamwerk. De feedbackfuncties worden gedefinieerd in de UI laag, en vervolgens toegankelijk

gemaakt aan de software in de andere lagen en in de bibliotheken. Dit betekent dat de visuele verschijningsvorm kan verschillen per applicatie.

Not applicable for D-Soil Model; the user interface does support calculations.

- U132 De IO laag sluit altijd aan op een intern bestand voor opslag van de invoer- en (tussen)resultaten. Voor relatief kleine hoeveelheden data is dit bij voorkeur een XML bestand, met een rechtstreekse binding op de datastructuur van de IO laag. Voor grotere hoeveelheden data ligt een geoptimaliseerde database voor de hand. De IO laag kan eventueel ook meerdere alternatieve bestandsformaten ondersteunen.

See paragraph 2.1.6 and 2.1.7

- U133 De WTI tools worden standaard alleen uitgeleverd met een Nederlandstalige UI en met Nederlandstalige meldingen en rapportages.

This requirement is met by having Dutch language configuration files. The correct functioning is checked within the component test scripts, and reported in the test reports.

- U134 De UI en onderliggende bibliotheken en functies moeten wel zijn voorbereid op later configureerbare meertaligheid, door middel van bestanden. Dit geldt ook voor de feedback functies.

By using the language translation architecture and accompanying objects and methods of the DSL framework this is guaranteed. A check on the source code can verify this.

- U145 De naamgeving van objecten, parameters, functies moet over alle applicaties heen consistent zijn. Voor dat doel moet gebruik worden gemaakt van de actuele versies van de terminologielijst en de parameterlijst.

The latest versions of both the terminology and parameterlist are used within the software development as base documents for the naming of objects, parameters and functions. Inconsistencies in naming conventions between software and these documents are checked within the testscripts of the software.

- TAB1 Er moet een installatietest inclusief een testdataset worden meegeleverd met de applicatie, zodat technisch beheerders na installatie eenvoudig kunnen controleren of de applicatie werkt.

The presence of documents and testdata sets is checked for every official release. Furthermore they are part of the test procedures.

- TAB2 De applicaties moeten door gebruikers gebruikt kunnen worden met standaardrechten. Het moet dus niet nodig zijn om de applicatie uit te voeren met administrator rechten, met uitzondering van installatie.

This will be verified within the component and acceptance tests and will be reported in the accompanying reports.

TOI15 Uitkomsten moeten herleidbaar zijn tot de geschematiseerde gegevens, geschematiseerde gegevens moeten herleidbaar zijn tot brongegevens.

Not applicable for D-Soil Model; the user interface does support calculations; there are no results. The location and name of imported data is logged.

PSA3 Uitgangspunt bij de applicatiearchitectuur moet zijn dat de software in de productieomgeving geen licentiekosten kent en de implementatie bij RWS (en mogelijk andere organisaties) op basis van Citrix of SCCM moet plaats vinden.

The software is to be released with a license file describing the licenses for all components. None of these licenses involve any costs for the user.

R.18 Ringtoets werkt volgens data-afspraken zoals beschreven door cluster datamanagement op het gebied van hydraulische belastingen en sterkte eigenschappen van waterkeringen.

All data used within the software application is conform the AQUO standard (at the pre-set reference date). These have been registered in the terminology and parameter lists, see U145.

SLA 6 Beveiliging Software wordt door Deltares met een adequate beveiliging (autorisatie) opgeleverd. De relevante onderdelen van de Baseline Informatiebeveiliging Rijksdienst BIR 2012 geven invulling aan het voorschrift informatiebeveiliging rijksdienst VIR 2007 en is waar mogelijk van toepassing, per 1-1-2015 nader ingevuld. Indien software per 1-1-2015 nog niet aan de BIR voldoet, dient expliciet in de requirements 2015 implementatie van mogelijke maatregelen om aan de BIR te voldoen te worden beschreven.

This requirement will be met by filling out the BIR compliancy check documents provided by RWS and further explaining the so called explains.

Top 7 Software moet uitbreidbaar zijn voor andere processen: ontwerpen (in OI2018), beleidsstudies (vanaf 2017 of 2018?), voor beheer van de rivier (vanaf 2017). Consistentie tussen de software voor de verschillende processen is een eis. Toetsen (deze casus), Ontwerpen (vanaf 2018), tot 2017 is de software van WT12011 geldig, Beheer en onderhoud waterkeringen, Duiding bij crisis (duiding van de voorspelde data).

The chosen generic architecture framework guarantees the successful implementation hereof in any process (deterministic or probabilistic assessments, design or policy studies etc.). For the current application this means that the underlying architecture does not obstruct the extension of functionality fitting the envisioned purpose of the application in any way.

Top 10 De gebruiker kan bepalen waar de gegevens worden neergezet.

See 2.1.7.

Beheer1 Na een crash van de applicaties mogen de gegevens niet inconsistent zijn.

The application does not use a 'live' database; the database is read once and written once. During a crash only the loss of data is possible, not inconsistency.

### 1.3.3 Functional requirements

In table 1.2 the functional requirements are ranked from must-have to won't-have. In the last column the corresponding paragraph of chapter 2 is given. For the release of 15-12-2016 the must-haves and should-haves are implemented. The other requirements are part of this document to have an overview of possible further development of D-Soil Model.

The full description of the requirements is placed in appendix E.

| Description requirement  | MoSCoW    | Paragraph                                |
|--|-----------|--|
| REQ 3.1: Import data.  | must-have | 2.1.1                                    |
| REQ 3.3: Select relevant SOS information for project   | must-have | 2.3.1                                    |
| REQ 5.1: Supply the subsoil schematization and - parameters for the WTI macro stability kernel | must-have | 2.3.2; 2.3.3; 2.4.2; 2.4.3; 2.4.4; 2.4.6 |
| REQ 5.2: Supply the subsoil schematization and - parameters for the WTI piping kernel.         | must-have | 2.3.2; 2.3.3; 2.5.2; 2.5.3; 2.5.4        |
| REQ 5.4: All relevant subsoil information  | must-have | 2.4.4; 2.5.4                             |
| REQ 6.1: Stochastic characterization of the variables  | must-have | 2.4.3; 2.5.3                             |
| REQ 6.3: Separate segments for each failure mechanism  | must-have | 2.3.2; 2.3.3; 2.5.4                      |
| REQ 6.4: Definition of the location of the 1D profile for Piping and DFlowSlide                | must-have | 2.5.1                                    |
| REQ 6.5: Profile properties  | must-have | 2.4.4                                    |
| REQ 6.6: Layer properties  | must-have | 2.5.2                                    |
| REQ 7.1: Stochastic subsoil information  | must-have | 2.3.4                                    |
| REQ 8.2: Table view for soil parameters  | must-have | 2.1.3                                    |
| REQ 8.4: Profile view to modify soil profiles  | must-have | 2.1.4                                    |
| REQ 8.6: Show segments with labels   | must-have | 2.1.2                                    |
| REQ 8.10: 1D Scenario overview   | must-have | 2.1.4                                    |
| REQ 8.13: Show SOS scenario's in 2D profiles   | must-have | 2.2.1                                    |
| REQ 9.1: Name soil materials   | must-have | 2.4.5; 2.5.5; 2.6.1                      |
| REQ 9.2: Edit the chances of a SOS scenario  | must-have | 2.3.4                                    |
| REQ 9.3: Turn a 1D profile into a 2D profile   | must-have | 2.3.5                                    |
| REQ 9.4: Draw 2D sti files   | must-have | 2.3.5                                    |
| REQ 9.5: Have reference points to draw surface lines on 2D profiles                            | must-have | 2.2.1                                    |
| REQ 9.7: Define soil layers  | must-have | 2.3.5                                    |
| REQ 9.8: Allocate soil material to layer   | must-have | 2.3.8                                    |
| REQ 9.9: Define layer as aquifer or aquitard   | must-have | 2.4.2                                    |
| REQ 9.10: Enter yield stresses for macro stability   | must-have | 2.4.4                                    |
| REQ 9.12: Modify the location of de borehole or CPT in the 2D profile.                         | must-have | 2.2.3                                    |
| REQ 9.14: Minimal validity check on the data   | must-have | 2.7.1                                    |
| REQ 9.18(a): Add another 1D profile to an existing 2D profile                                  | must-have | 2.2.1                                    |
| REQ 9.20: Incorporate settlements underneath an embankment                                     | must-have | 2.2.4                                    |

| Description requirement   | MoSCoW       | Paragraph                                |
|---|--------------|--|
| REQ 9.23: Import soil area's and segments   | must-have    | 2.1.4                                    |
| U139: Elke applicatie moet de mogelijkheid geven om invoer- en uitvoer ten dele per tabel te exporteren naar - en/of te importeren van - CSV bestanden. Daarnaast kan een invoer in Excel mogelijk zijn   | must-have    | 2.1.1, 2.6.2                             |
| U140: Elke applicatie moet de mogelijkheid geven om (ruimtelijke) invoer- en uitvoerdata ten dele per tabel te exporteren naar - en/of importeren van - shp bestanden. Dit faciliteert aansluiting op willekeurige en versie-onafhankelijke GIS software. | must-have    | 2.6.2.2                                  |
| REQ 3.2: Import and view all SOS data   | should-have  | 2.1.2; 2.1.3; 2.1.4;                     |
| REQ 3.4: Import relevant reference data   | should-have  | 2.1.1                                    |
| REQ 7.2: Allocation of CPT's and boreholes to a segment   | should-have  | 2.2.2                                    |
| REQ 7.3: Overview of all available borings and CPT's in a segment or cross section  | should-have  | 2.1.1; 2.1.2; 2.1.3                      |
| REQ 7.4: Overview of all available SOS scenario's in a segment  | should-have  | 2.2.3                                    |
| REQ 8.7: Show all soil investigation with labels in map view  | should-have  | 2.1.2                                    |
| REQ 8.8: Visualize the surface lines with their characteristic points   | should-have  | 2.2.1                                    |
| REQ 8.12: Show data from AHN or a WMS server, or other shape files  | should-have  | 2.1.2, partly implemented                |
| REQ 8.14: Draw SOS profiles in one segment on the same height for comparison  | should-have  | 2.1.4                                    |
| REQ 8.15: Show ground investigation simultaneously to REQ 39 at the same reference level  | should-have  | 2.1.4                                    |
| REQ 8.16: Compatibility between different views   | should-have  | 1.3                                      |
| REQ 8.17: Visibility of yield stress  | should-have  | 2.4.4                                    |
| REQ 9.11: Copy/ paste segments for one failure mechanism to the next  | should-have  | 2.3.7                                    |
| REQ 9.21: Visualize minimum and maximum of layer boundaries from the SOS data   | should-have  | 2.1.4                                    |
| REQ 9.24: Table import/export   | should-have  | 2.6.2; 2.6.3                             |
| FR17: Validation of input data in user interface forms (on the fly). For example validation on syntax, completeness, limits and consistency. (should have)  | should-have  | 2.7.1                                    |
| REQ 5.3: Supply the subsoil schematization and - parameters for the WTI flow slide kernel.  | nice-to-have | Partly implemented <sup>1</sup><br>2.4.5 |

<sup>1</sup> The required material parameters, for D-Flow Slide are part of the material table via filter Zettingsvloeiing [appendix C].

| Description requirement  | MoSCoW   | Paragraph       |
|--|--|-----------------|
| REQ 6.2: Determination of soil parameters  | nice-to-have   | Not implemented |
| REQ 8.1: Reference line  | nice-to-have   | Not implemented |
| REQ 8.3: Map view for soil area's  | nice-to-have   | Not implemented |
| REQ 8.5: Automatically project boreholes and CPT onto a cross section                          | nice-to-have   | Not implemented |
| REQ 8.11: View Gef files with GefPlotTool  | nice-to-have   | Not implemented |
| REQ 9.6: Interpretation tools  | nice-to-have   | Not implemented |
| REQ 9.13: Logging of all changes to the database   | nice-to-have   | Not implemented |
| REQ 9.15: Extensive validity check on the data for Ringtoets                                   | nice-to-have   | Not implemented |
| REQ 9.16: Define n and gamma per material parameter for determination of design values         | nice-to-have   | Not implemented |
| REQ 9.17: Store lab data   | nice-to-have   | Not implemented |
| REQ 9.18(b): The user must be able to build a 2D schematization based on multiple 1D profiles. | nice-to-have   | Not implemented |
| REQ 9.19: Draw a new subsoil configuration   | nice-to-have   | Not implemented |
| REQ 9.22: Longitudinal cut based on dike material  | nice-to-have   | Not implemented |
| REQ 4.1: Existing M-Soil Base functionality.   | won't have; M-Soil Base functionality is not described in any document | Not implemented |

Table 1.2 Functional requirements

## 1.4 Interfaces

Figure 1.1 contains the context diagram of D-Soil Model. There is no API available; import is done by importing different kinds of formats (see paragraph 2.1.1), export is done by saving the project (paragraph 2.1.7) or exporting of tables or map layers (paragraph 2.6.2).

Using D-Soil Model the user can provide subsoil information to the WTI software. The schematization, made in D-Soil Model, can be imported in the WTI software.

Each WTI application can define which data to use from the D-Soil Model file (\*.soil).

## 2 Use cases

D-Soil Model is a software tool for schematization of the subsoil and is developed for the assessment of primary dikes according to the WTI 2017. In this process of assessment the given schematization of a stochastic subsoil model (WTI-SOS 2017) is a major source of information. The D-Soil Model development focusses on use of this stochastic subsoil model. The process of subsoil schematization consists of the following steps:

1. Collect relevant subsoil information
2. Combine and compare these information
3. Define subsoil schematization for macro stability
4. Define subsoil schematization for piping
5. Store the schematization
6. Export data for use in other applications

The user must be able to make a local schematization using the WTI-SOS 2017<sup>2</sup> and use this schematization for calculations of the failure mechanisms Macro stability and Piping. Local schematization means a schematization for a selection of segments and more detailed schematization.

This process is described in following use cases. There is one type of user: the one who makes the subsoil schematization.

Per user case a table is presented with the actions to support, the associated functional requirements and the subparagraph number.

### 2.1 Use case 1 Collect relevant subsoil information

The user must be able to import the following data.

Input files:

- a. Materials - optional
- b. Existing 2D profiles - optional
- c. WTI-SOS 2017  
Content of WTI-SOS 2017:  
1D profiles  
Segments
- d. Geometric data (surface lines with characteristic points)
- e. Soil survey; cone penetration tests (cpt), borings – optional
- f. Maps; geo-related information in shape files – optional

More details of this files in table 2.2.

#### *Explanation*

The main functionality of D-Soil Model is to let the user combine different information about the subsoil, to make a schematization of the subsoil.

<sup>2</sup> D-Soil Model can be used without the WTI-SOS 2017. But for the use of a D-Soil Model project in Ringtoets it is necessary that segments are present in the project, so the WTI-SOS 2017 is recommended.

| <b>Actions to support</b>    | <b>Requirement</b>                    | <b>Paragraph</b>    |
|------------------------------|---------------------------------------|---------------------|
| Import data                  | 3 / 7.3                               | 2.1.1               |
| Show data on map             | 3.2 / 8.6 / 8.7 / 8.12                | 2.1.2               |
| Show data in table           | 3.2 / 8.2                             | 2.1.3               |
| Show data in a cross section | 3.2 / 8.1 / 8.3 / 8.14 / 8.15 / 9. 23 | 2.1.4               |
| Start, open and save project | U123                                  | 2.1.5, 2.1.6, 2.1.7 |

Table 2.1 Use case 1

## 2.1.1 Import data

Data formats to import:

|   | <b>File</b>  | <b>Data</b>  | <b>View</b>                 |
|---|--|--|-----------------------------|
| a | materials.mdb (only files created with MSoilBase version 14.1.1.4) | Materials parameters including                                   | Table                       |
| b | *.geo (only files created with D-Geo Stability version 16.1.2.1)   | 2D profile   | Table / Cross section       |
| b | *.sti (only files created with D-Geo Stability version 16.1.2.1)   | 2D profile and soil parameters                                   | Table / Cross section       |
| c | soilprofiles.csv   | 1D profile   | Table / Cross section       |
| c | segments.csv   | Relation between segment and scenario (=profile and probability) | Table / Map / Cross section |
| c | segments.shp   | Segment lines  | Map                         |
| d | surfacedlines.csv  | X,y,z coordinates (RD, m NAP)                                    | Table / Cross section       |
| d | characteristicpoints.csv   | X,y,z coordinates (RD, m NAP)                                    | Table / Cross section       |
| e | *.gef  | CPT, Boring  | Map <sup>3</sup>   Table/   |
| f | *.shp  | Not defined  | Map                         |

Table 2.2 Data formats import

The file formats are described in detail in appendix B.

All data can be imported separately, except mutually interdependent items:

- Characteristic points can only be imported if connecting surface lines are present in the project.
- Soil segments (csv) can only be imported if connecting soil profiles are present in the project.
- Soil segments (shp) can only be imported if connecting soil segments (csv) is present in the project.

<sup>3</sup> The application can import borehole and CPT as GEF-file. The location of the borehole and CPT can be viewed in map. If the location in RD is known, it is plotted in the right location. If the RD location is not known, it is not plotted on the map.

For each failure mechanism the subsoil is described in soil segments consisting of one of more scenario(s). A scenario is a soil profile with a probability. These soil profiles are described in either 1D or 2D layer schematizations. A soil segment can have a combination of 1D and 2D soil profiles. Each layer is described with at least all the parameters needed for the relevant failure mechanism. This output is gathered in one file (\*.soil), which can be directly imported in Ringtoets or BM – Macrostablieiteit (connection with D-Flowslide is not operational).

The building blocks of the subsoil schematization in D-Soil Model and the data formats are presented in figure 2.1.

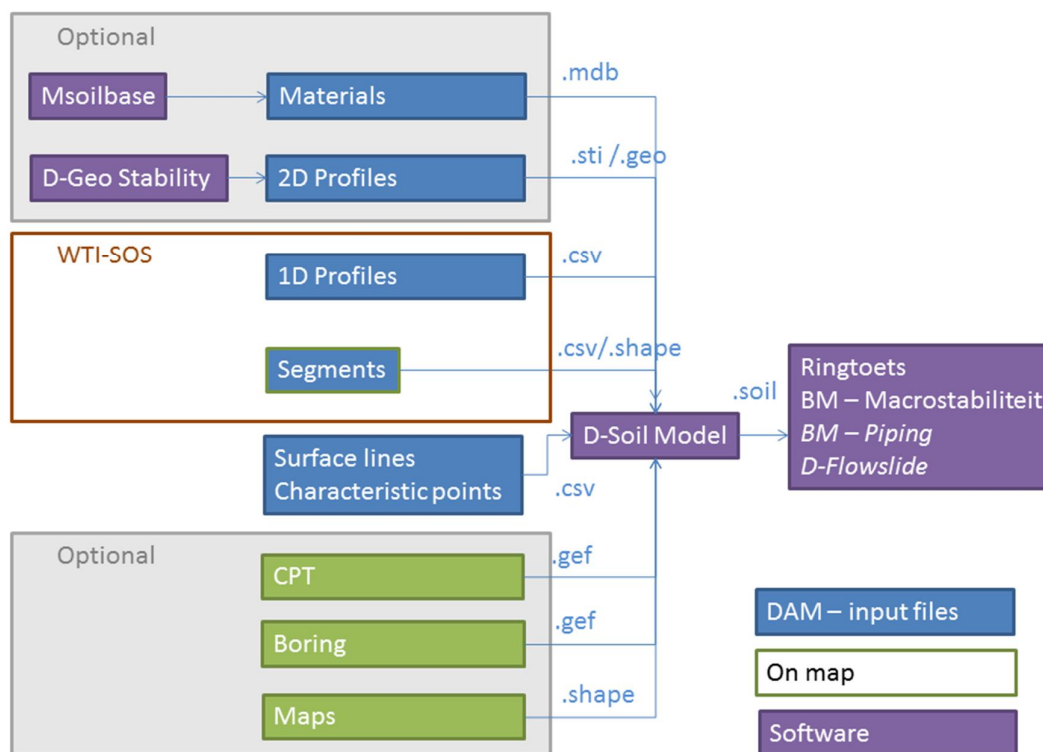


Figure 2.1 Building blocks

When a D-Soil Model project is used in Ringtoets or BM – Macrostablieiteit, a minimum of data is required; soil profiles, soil segments, surface lines (incl. characteristic points). Other input data is optional and is back-ground information for the schematization; as soil material databases and 2D-soilprofiles, cone penetration tests (cpt) and borings and other map layers then PDOK.

The purple boxes refer to software, the blue boxes to similar input files of DAM and the green to other data. A green outline means that the data can be shown on a map.

When importing 1D profiles or geo-files (without reading a mdb file first) there are no soil parameters available, only material names. These names will be added to the material table with default parameters.

Materials and profiles can also be user-defined in D-Soil Model, so without the import of data, see also paragraph 2.3.5 and 2.3.8.

The file formats are described in appendix B.

#### 2.1.2 Show supported data on map

If data contains coordinates, the information must be shown on a map with labels (name of id of the item). This map can have a background map (PDOK or Open street map). Also other shapes must be shown on the map, as extra information. Examples: hydraulic head of aquifers, polder level map.

For general functionality of the map window, see Brinkman 2014 [8].

#### 2.1.3 Show data in table

All imported data must be visible in a table, per row one item and information about this item in columns.

For general functionality about tables in UI, see Brinkman 2014 [8].

#### 2.1.4 Show data in cross section or length profile (segment).

##### *Soil profiles*

1D Soil profiles of WTI-SOS 2017 must be visible in a cross section so the user can see the layers in different (adjustable) colors.

The layers of the SOS soil profiles, modal and their minimum and maximum values of the layer limits must be clear in the cross section.

2D Soil profiles (\*.sti-files) must be visible in a cross section so the user can see the layers in different (adjustable) colors.

##### *Surface lines*

Surface lines must be visible in a cross section.

##### *Soil segments*

Show all 1D profiles of 1 segment on the same reference level. The user must get a good visual overview of all available scenarios of soil profiles.

For general functionality of the cross section window, see Brinkman 2014 [8].

#### 2.1.5 Start a new project

It must be possible to start a new project. An existing project must be closed and after a check with the user for saving the project, all its data should be removed from the user interface.

#### 2.1.6 Open an existing project

It must be possible to open an existing D-Soil Model project file.

#### 2.1.7 Save current project

It must be possible to save all the data to a project database on an user-defined location.

Units of the parameters are saved in the base and derived units of the International System of Units (SI-units). In appendix C the display units of the parameters are given.

A user must be warned if he wants to close the application without saving changes.

## 2.2 Use case 2 User must be able to combine subsoil information and view the combination

### Explanation

The main functionality of D-Soil Model is to let the user combine different information about the subsoil, to make a schematization of the subsoil. Not all combinations are useful. Combination of the surface line results in new 2D profiles.

In table below are the combinations mentioned of the base item and the item to add (blue).

|              | Cpt | Boring | 1D Profile | 2D Profile | Segment | Surface line                 |
|--------------|-----|--------|------------|------------|---------|------------------------------|
| Cpt          |     |        |            |            |         |                              |
| Boring       |     |        |            |            |         |                              |
| 1D Profile   | x   | x      | x          |            | x       | x                            |
| 2D Profile   | x   | x      | x          |            | x       | x                            |
| Segment      | x   | x      |            |            |         | x (only for macro stability) |
| Surface line |     |        | x          | x          |         |                              |

Table 2.3 Combinations

| Actions to support                                | Requirements from [1]               | Paragraph |
|---|-------------------------------------|-----------|
| Combine items in the cross section (one to one)   | 7.3 / 8.3 / 8.8 / 8.9 / 8.13/ 9.5 / | 2.2.1     |
| Connect items in batch (several to one)           | 7.3 / 8.5                           | 2.2.2     |
| View combination in a cross section.              | 7.3 / 7.4 /9.14 / 9.18              | 2.2.3     |
| Incorporate settlements underneath an embankment. | 9.20                                | 2.2.4     |

Table 2.4 Use case 2

### 2.2.1 Combine items in the cross section (one to one)

Paragraph 2.1.4. describes how imported data must be visualized in the cross section window. When the combining the data as described in paragraphs below, the view of the data is also combined; the view of the separate data remains when combining. Most important is the Z-value; all data must be visualized at the same level.

#### 2.2.1.1 Combinations of 1D Profile

A 1D Profile can be combined with:

- Cpt
- Boring
- 1D profile  
In WTI-SOS 2017 a 1D profile is already combined with other 1D Soil profiles of the same soil segment.
- Segment  
In the WT-SOS 2017 the connection is already present; the segment contains soil scenarios; profiles with a probability.
- Surface line

Combining a 1D profile with a surface line results in a 2D Soil profile. So the combination creates a new item.

#### 2.2.1.2 *Combinations of 2D Profile*

A 2D Profile can be combined with:

- Cpt
- Boring
- 1D profile
- Segment
- Surface line

The combination of a 2D Soil profile and a surface line results in a new 2D profile. The desired behavior is described in appendix D.

#### 2.2.1.3 *Combinations of segments*

A segment can be combined with:

- Cpt
- Boring
- Surface line

The combination of a segment (only macro stability) and a surface line results in a segment with all new 2D profiles by combining the surface line with each 1D profile of the segment. The probability of the profiles stays unchanged.

#### 2.2.1.4 *Combinations of surface*

A surface line can be combined with:

- 1D Profile
- 2D Profile

Combining a surface line with a 1D profile results in a 2D profile. So the combination creates a new item.

Combining a surface line with a 2D profile results in a new 2D profile. The design of how the combination should be made is described in appendix D.

#### 2.2.2 *Connect items in batch (several to one)*

The combination of cpt/borings to a segment can be done in batch, not only one by one. The user can make a selection of the cpts or borings in the table or on the map and connect them to a segment.

#### 2.2.3 *View combination in a cross section.*

To all combinations it is important that the Z-values remain intact (in m +NAP); show items at the right height. There is no definition of the x-value of 1D profiles, only Z values.

For some combination there are more detailed requirements:

##### 2.2.3.1 *1D profile – other 1D profiles of the soil segment*

All 1D profiles of one soil segment must be visible at the same time. With large (>6) numbers of 1D profiles a 'filmstrip' is provided, so the user can scroll through the 1D profiles.

##### 2.2.3.2 *2D profile - cpts and borings*

The cpt and boring are placed in the middle of the 2D soil profile. The user can drag them to the desired X-coordinate.

2.2.3.3 *2D profile – surface line*

When combining 2D profiles and surface lines there is a mapping necessary for the x-coordinates.

This mapping is done based on the reference line. The user can define this X-value in the 2D profile. In appendix D is explained how this combination should function.

2.2.3.4 *Soil segment – Cpt/borings*

If a soil segment is combined with cpt and borings, a cross section of the soil segment is needed. The soil segment is drawn as a straight line and the cpts and borings are situated relatively among this line. This is called a length profile.

2.2.4 Incorporate settlements underneath an embankment.

The user must be able to define settlements underneath the embankment.

After combining a 1D soil profile the user can draw vertical geometry lines under the slope until the aquifer layer. So the user can define the settlement by dragging the soil layers under the embankment. This is not automated because a divided aquifer layer is not accepted by the macro stability kernel.

**2.3 Use case 3 User must be able to adapt the WTI-SOS 2017 to local situation.**

*Explanation*

The WTI-SOS 2017 is a general schematization of the subsoil at the inner toe of the primary dikes in the Netherlands. To perform the assessment it is needed that this schematization is adapted to the local situation (more detailed).

| <b>Actions to support</b>                                  | <b>Requirement from [1]</b> | <b>Paragraph</b> |
|--|-----------------------------|------------------|
| Save a selection of the WTI-SOS 2017 as a new project      | 3.3                         | 2.3.1            |
| Splitting the soil segments per failure mechanism          | 5.1 / 6.3                   | 2.3.2            |
| Deleting soil profiles per segment                         | 5.1 / 6.3                   | 2.3.3            |
| Changing probability of the soil profiles                  | 7.1 / 9.2                   | 2.3.4            |
| Make and edit 2D soil profiles                             | 9.3 / 9.4 / 9.7 / 9.18      | 2.3.5            |
| Adding 1D and 2D soil profiles to a soil segment           | 9                           | 2.3.6            |
| Copy/ paste segments for one failure mechanism to the next | 9.11                        | 2.3.7            |
| Add materials to the material table                        | 9.8                         | 2.3.8            |

Table 2.5 Use case 3

2.3.1 Save a selection of the WTI-SOS 2017 as a new project

The user can make a selection of segments, based on failure mechanism and/or location, and save this as a project. All soil profiles of these soil segments are included in this project, as well as all their materials. Also by user connected cpts and borings are included in this project.

### 2.3.2 Splitting the soil segments per failure mechanism

The user can add a split location to a soil segment in the map or in the length profile. When splitting the soil segment, all soil profiles and their probability are connected to both new soil segments. The name of the new segments consists of the old name and a number.

### 2.3.3 Deleting soil profiles per soil segment

The user can remove soil profile(s) from a soil segment. If the total probability is not 100%, a message should be given. The probability of a soil profile can be zero.

### 2.3.4 Changing probability of the soil profiles

A soil segments consists of one or more scenarios. A soil scenario is defined by a soil profile and its probability.

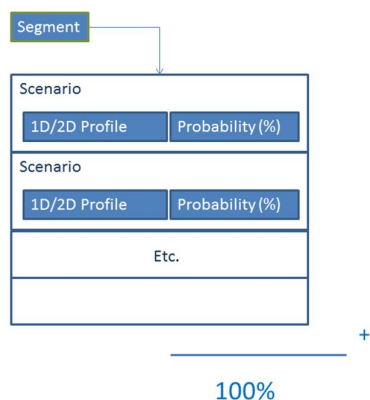


Figure 2.2 Soil scenarios

The user can edit the probability of soil profile(s) of a soil segment. If the total of the scenarios is not 100%, a message should be given.

### 2.3.5 Make and edit soil profiles

The user can make (1D and 2D) soil profiles either from scratch, either by changing existing profiles. The user can (re)define soil layers. Per layer a soil material can be (re)defined. Layers of existing profiles can be changed by changing levels, materials or deleting layers. If there is no soil assigned to a layer, a message is given in validation tab. For editing 2D profiles in the cross section window is the general functionality of the geometry editor described in DSLFormsGeo – Functional Design [13].

### 2.3.6 Adding 1D and 2D soil profiles to a segment

The user can add soil profile(s) to a soil segment with a probability (a scenario). If the total probability of the scenarios is not 100%, a message should be given.

### 2.3.7 Copy/paste segments for one failure mechanism to the next

The user can copy a segment of one failure mechanism and use it for another failure mechanism. This is not implemented because the desired functionality caused is not clear yet.

### 2.3.8 Add materials to the material table

The user can add new materials to the material table, so this can be used in new or changed soil profiles. The soil parameters must be entered by the user (or imported via a mdb file).

2.3.9 Deleting items

Deleting of items is not possible if the item is used in the project.

By 'use' is mend combination with other data or being a part of other data, as mentioned in table below:

|                 | Material | Cpt | Boring  | 1D Soil profile | 2D Soil profile | Soil segment  | Surface line |
|-----------------|----------|-----|---------|-----------------|-----------------|---------------|--------------|
| Material        |          |     | Part of | Part of         | Part of         |               |              |
| Cpt             |          |     |         | Combined with   | Combined with   | Combined with |              |
| Boring          |          |     |         | Combined with   | Combined with   | Combined with |              |
| 1D Soil profile |          |     |         |                 |                 | Part of       |              |
| 2D Soil profile |          |     |         |                 |                 | Part of       |              |
| Soil segment    |          |     |         |                 |                 |               |              |
| Surface line    |          |     |         | New item        | New item        | New item      |              |

Table 2.6 Use of items

There has to be a check for possible combination when the user wants to delete an item. If the combination is present in the project, deleting is disabled.

Exception is the surface line; this can be combined to a new item, so there is no reason to disable deleting.

2.4 Use case 4 Define subsoil schematization for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'

Explanation

For the assessment the user must be able to define the subsoil schematization for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'.

Actions to support

Save soil segments for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'.

| Actions to support  | Requirement from [1]          | Paragraph |
|---|-------------------------------|-----------|
| Define aquifer layers per soil profile.   | 5.1 / 6.6                     | 2.4.1     |
| Save soil segments for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'.     | 5.1                           | 2.4.2     |
| Define soil parameters for the failure mechanism 'Macrostablieiteit binnenwaarts (STBI)'. | 5.1 / 6.1 / 7.1               | 2.4.3     |
| Define yield stresses per 2D soil profile (optional for undrained calculations).          | 5.1 / 6.3 / 6.5 / 8.17 / 9.10 | 2.4.4     |
| Filter of the soil parameters needed for the use in BM-Macrostablieiteit                  | 9.1                           | 2.4.5     |
| Define interpolation method   | Projectplan 2017              | 2.4.6     |

|                              |  |  |
|------------------------------|--|--|
| per layers per soil profile. |  |  |
|------------------------------|--|--|

Table 2.7 Use case 4

- 2.4.1 Define aquifer layers per soil profile.  
The user must be able to define a layer as an aquifer. A soil profile can contain more than one aquifer.
- 2.4.2 Save soil segments for the failure mechanism 'Macrostabilliteit binnenwaarts (STBI)'.  
The user must be able to save the soil segment with all their connected data, such as the soil profiles (including yield stresses), materials, cpt and borings.
- 2.4.3 Define soil parameters for the failure mechanism 'Macrostabilliteit binnenwaarts (STBI)'.  
The user must be able to define the soil parameters needed for the failure mechanism 'Macrostabilliteit binnenwaarts (STBI)'. These soil parameters are defined in appendix C. Note that this concerns the soil parameters. Other parameters from [11], such as yield stresses, are layer properties and are not mentioned in this table.
- 2.4.4 Define yield stresses or POP per 2D soil profile (optional for undrained calculations).  
The user can define yield stresses in a 2D soil profile. For the definition of POP and yield stresses, see the Schematiseringshandleiding Macrostabilliteit [14].
- 2.4.5 Filter the soil parameters needed for the use for failure mechanism 'Macrostabilliteit binnenwaarts (STBI)'.  
This filter is defined in appendix C.  
  
Note: User must also be able to define and filter the soil parameters needed for the use of D-Flowslide (failure mechanism Zettingsvloeiing).  
This filter is defined in appendix C.
- 2.4.6 Define interpolation method of non-aquifers per soilprofile.  
The user must be able to define the interpolation method of pore pressure generation of non-aquifer layers. Default value is 'automatisch':
  - For aquifer layers and layers with PL1 the interpolation method is always hydrostatic.
  - For all other layers the interpolation method is linear. However, the user can overrule this by selecting 'hydrostatisch' for the layer.

## 2.5 Use case 5 Define subsoil schematization for the failure mechanism Piping (STPH)

### Explanation

For the assessment the user must be able to define the subsoil schematization for the failure mechanism Piping (STPH).

| Actions to support  | Requirements from [1] | Paragraph |
|---|-----------------------|-----------|
| Define 1D soil profiles in 2D soil profiles.                    | 5.2 / 6.4             | 2.5.1     |
| Define aquifer layers per soil profile.                         | 5.2                   | 2.5.2     |
| Define soil parameters for the failure mechanism Piping (STPH). | 5.2 / 6.1 / 7.1       | 2.5.3     |

|   |           |       |
|---|-----------|-------|
| Save soil segments for the failure mechanism Piping (STPH).         | 5.2 / 6.3 | 2.5.4 |
| Filter the soil parameters needed for the use in Ringtoets - Piping | 9.1       | 2.4.5 |

Table 2.8 Use case 5

- 2.5.1 Define 1D soil profiles in 2D soil profiles.  
When 2D soil profiles are used, the user must be able to define a failure mechanism location where a 1D soil profile is available for the piping kernel.
- 2.5.2 Define aquifer layers per soil profile.  
The user must be able to define a layer as an aquifer. A soil profile can contain more than one aquifer.
- 2.5.3 Define soil parameters for the failure mechanism Piping (STPH).  
The user must be able to define the soil parameters needed for the failure mechanism Piping (STPH). These soil parameters are defined in appendix C.  
Note that this concerns the soil parameters. Other parameters from [11], such as top and cover bottom layer, are profile properties and are not mentioned in this table.
- 2.5.4 Save soil segments for the failure mechanism Piping (STPH).  
The user must be able to save the soil segment with all their connected data, such as the soil profiles, materials, cpt and borings.
- 2.5.5 Filter the soil parameters needed for the use for failure mechanism Piping (STPH).  
This filter is defined in appendix C.

## 2.6 Use case 6 Export data for use in other applications

### *Explanation*

D-Soil Model is developed for the WTI-2017. Therefore it is necessary that the schematizations from D-Soil Model can be used in Ringtoets and the Basis Module (BM - Macrostablieiteit).

### *Actions to support*

Make a selection for the soil parameters needed for the use:

- for failure mechanism Piping (STPH).
- for failure mechanism Macrostablieiteit binnenwaarts (STBI).
- of deterministic calculations (Basis Modulen)
- of probabilistic calculations (Ringtoets)

| <b>Actions to support</b>   | <b>Requirements from [1]</b> | <b>Paragraph</b> |
|---|------------------------------|------------------|
| Make a selection of the soil parameters needed for the use: <ul style="list-style-type: none"> <li>• for failure mechanism Piping (STPH).</li> <li>• for failure mechanism Macrostablieiteit</li> </ul> | 9.1                          | 2.6.1            |

|  |      |       |
|--|------|-------|
| binnenwaarts (STBI).<br>• of deterministic calculations (Basis Modulen)<br>• of probabilistic calculations (Ringtoets) |      |       |
| Export (part of) tables  | 9.24 | 2.6.2 |
| Import (part of) tables  | 9.24 | 2.6.3 |

Table 2.9 Use case 6

## 2.6.1 Make a selection of the soil parameters.

The usage of a D-Soil Model project in Ringtoets or the Basis Modulen differs in soil parameters (the use of deterministic or probabilistic values) and the failure mechanism. The user must be able to see this difference, so the user knows which parameters are used.

## 2.6.2 Export

Requirement 9.24 corresponds with requirements U139 and U140.

### 2.6.2.1 Tables

Complete tables from D-Soil Model must be exportable to a csv file (defacto standard). Also part of tables (columns, rows or cells) must be exportable by copying and pasting.

### 2.6.2.2 Map layers

Map layers must be exportable to a shape file (ESRI standard).

### 2.6.2.3 Map as picture

The map must be exportable as a picture in \*.png, \*.bmp and \*.jpg format (industry standards).

## 2.6.3 Import (part of) tables

Complete tables and part of tables (columns, rows or cells) must be importable by copying and pasting.

## 2.7 Error handling

In case of malfunction of the program the user must be informed via messages. This takes place via log messages and validation messages. There are two tabs; 'Log' and 'Validation' in the tables window.

### 2.7.1 Validation messages

Validation means checking the input data against certain requirements. This results in a list of errors and warnings. If there are no errors, calculations in a Basis Module and/or Ringtoets are possible, otherwise calculation is prohibited. If there are warnings, calculation is discouraged, but not prohibited.

The project can always be saved, even if there are errors (and/or warnings) in the validation window.

Validation happens against simple requirements:

Material parameters:

- an exceeded minimum and maximum value (like mentioned in appendix C)
- absence of parameters (like mentioned in appendix C)

Only the visible materials will be validated

#### Layers

- No soil assigned; layers must be linked to a material

#### Segments

- Total of probabilities is not equal to 100%

The user will be informed about the errors and warnings and if present, the user will be supported to solve them. This support is a suggested repair action, when possible.

The repair option shows the severity (error or warning), the subject (object to which the error or warning applies), the properties (one or more properties of the subject to which the error or warning applies) and the suggested repair action (example: "Assign maximum value").

#### 2.7.2 Log messages

After each import by the user, the activity is mentioned in the log window.

Possible log messages about the imported data are given in the log window. Possible errors are non-compatible data (example: GEFs referring to a tiff-file) or missing data (example; 1D profiles with materials without defined parameters).



### 3 Literature

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- 4 Brinkman, R. et al.(2016), WTI2017 Failure Mechanisms - Macro Stability Kernel, Deltares report 1230095-002-HYE-0012
- 5 Visschedijk, M. et al. (2015), WTI2017 Failure Mechanisms - Piping Kernel, Deltares report 1230084-008-GEO-0001
- 6 De Waal, J.P. de (2016), Basisrapport WTI 2017, Deltares report 122078-001-GEO-004
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- 9 Geotechnisch uitwisselformaat voor boor-data (GEF-bore-report) versie 1.0.0, CUR, maart 2002
- 10 Geotechnical exchange format for cpt-data, CUR, april 2004
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- 12 Lam, K.S (2015), WTI Terminologielijst versie 1.0, eind 2015, Deltares memo 1220081-006-GEO-0002
- 13 Markus, A (2016), DSLFormsGeo – Functional Design, Deltares report 1221017-002,
- 14 Duinen, A. van, et al (2016), Schematiseringshandleiding Macrostablieit, Deltares report 1220083-008-GEO-0005
- 15 Förster, U., et al (2016), Schematiseringshandleiding Piping bij dijken, Deltares report 1220084-006-GEO-0001
- 16 Zwan, I. van der (2017), D-Soil Model Projectplan 2017, Deltares report 11200580-HYE-0002



## A Glossary

Following glossary is partly a selection from Terminologielijst [6], completed with terms used in this document

| Term (ENG)                   | Term (NL)                        | Definition   |
|------------------------------|----------------------------------|--|
| 1D (soil) profile            | 1D-<br>(ondergrond)profiel       | Description of a subsoil profile consisting of only horizontal layers, defined in levels.  |
| 2D (soil) profile            | 2D-<br>(ondergrond)profiel       | Description of a subsoil profile description with soil areas.  |
| aquifer                      | aquifer                          | Soil layer with a high permeability compared to aquitards (i.e. Sand layers).  |
| aquitard                     | aquitard                         | Soil layer with a low permeability compared to aquifers (i.e. clay layers). The horizontal flow in a aquitard is very low, while a vertical flow could be significant.   |
| berm                         | berm                             | Enforcement in dike profile, also named shoulder.  |
| characteristic points        | karakteristieke punten           | Characteristic points of the surface level, right-angled at the dike.  |
| crest                        | kruin                            | 1. Area between inner and outer crest. 2. Highest point in dike geometry 3 Outer crest line  |
| crest inner slope            | kruin binnentalud                | The intersection point of the slope at the polder side and the crest of the dike   |
| deterministic                | deterministisch                  | During assessment the parameter is considered as 'known' and not modeled as a stochast.  |
| failure mechanism            | faalmechanisme                   | Process that leads to the failure of the system. This is often the result of a sequence of partial processes, derived from partial failure or the system, but without complete function loss.                        |
| geometry                     | hoogtegeometrie                  | Collection of points in RD coordinates on a straight line, perpendicular on the dike line with a height in m+NAP, which represent the geometry of the dike. Outside/riverside is always visualized on the left side. |
| inner slope                  | binnentalud                      | Sloping face of the embankment at the inner side.  |
| inside toe                   | teen dijk                        | Lower boundary of the embankment at the land side (transition to ground level)   |
| (soil)layer <sup>4</sup>     | binnenwaarts<br>(ondergrond)laag | Homogeneous part of the subsoil profile defined by material and depth.   |
| macro stability              | macrostabiliteit                 | The mechanism that causes slope shear failure of dike embankments  |
| soil (material) <sup>4</sup> | materiaal                        | Name and parameters of soil material   |
| outside slope                | buitentalud                      | Sloping face of the embankment at the water side.  |
| outside toe                  | teen dijk<br>buitenwaarts        | Lower boundary of the embankment at the water side (transition to ground level or foreland)  |

<sup>4</sup> The long term (i.e. soil layer-ondergrondlaag), is preferred. When lay-out and readability is an issue (i.e. in UI or diagrams) short terms are used.

| <b>Term (ENG)</b>               | <b>Term (NL)</b>                   | <b>Definition</b>  |
|---------------------------------|------------------------------------|--|
| probabilistic analysis          | probabilistische analyse           | Probabilistic determination of failure probability, using stochastically distributed variables for loading and strength.   |
| (soil) profile shoulder         | (ondergrond) profiel berm          | A sequence of subsoil layers, either 1D or 2D. See berm  |
| (soil) scenario <sup>4</sup>    | (ondergrond) scenario              | Soil profile with certain occurrence probability, in case of stochastic subsoil modeling   |
| (soil) segment <sup>4</sup>     | (ondergrond) segment               | In the SOSWTI2017 the dikes are divided in segments. Soil segments are line elements (soil areas are polygons). To each segment soil scenarios with possible soil profiles are assigned. |
| stochastic (soil) scenario      | stochastisch (ondergrond) scenario | The soil profile, together with its chance of occurrence, is a scenario.   |
| stochastic variable             | stochastische variabele            | Stochastic variable is a variable whose value is subject to variations due to chance.  |
| stochastic (as in WTI-SOS 2017) | stochastisch                       | 'Stochastic' means that a certain aspect is variable. These variability is visible in the chances of occurrence of the soil profiles.  |
| subsoil schematization          | ondergrond-schematisatie           | A schematic reproduction of (a part of) the subsoil for a certain area.  |
| surface line                    | hoogtegeometrie                    | See geometry   |
| toe dike inner side             | teen dijk binnenwaarts             | The intersection point of the surface level at the dike side and the slope of the shoulder at the inner side (if no shoulder: dike)  |
| toe dike outer side             | teen dijk buitenwaarts             | The intersection point of the slope of the berm at the outer side and the surface level at the outer side  |
| (vertical) yield stress         | grensspanning                      | Vertical yield stress per soil layer   |

Table A.1 Glossary

## B Input files

In this appendix the files which can be imported are described. The names of the files are user defined; via the import menu an user can select the file. The names of columns in these files are not case-sensitive. All data, except cpt and boring, can be edited in D-Soil base.

### B.1 Materials

Material database, made in MSoilbase version 14.1.1.4 can be imported. It contains the materials and their parameters. Not all WTI-parameters will be present.

Materials from existing profiles will be imported with the profile import;

- 1D profiles: material names
- 2D profiles: material names and (deterministic) material parameters

Materials and the parameters can also be edited in D-Soil Model after importing.

### B.2 2D profiles

D-Geo Stability files (\*.sti / \*.geo) can be imported in D-Soil Model when it is generated with D-Geo Stability 16.1.2.1. Depending on the type of file data is imported in D-Soil Model; \*.geo contains only a geometry and \*.sti contains the geometry and soil parameters.

### B.3 1D profiles

The soilprofile file is a table in csv format with the following columns.

| ame                         | Type     | Unit  | Required | Description   |
|-----------------------------|----------|-------|----------|---|
| soilprofile_id <sup>1</sup> | StringId | -     | yes      | Name of Soil Profile  |
| soil_name <sup>1</sup>      | StringId | -     | yes      | Reference to soil (in soilmaterials.mdb).   |
| soil_color <sup>2</sup>     | StringId | -     | no       | Color used in the cross section. Bisque is default or in case of typo. <sup>3</sup>   |
| soil_type <sup>2</sup>      | StringId | -     | no       | This column is obsolete. This parameter has to be set in the soil database, but even then it is not used anymore to define aquifer layers. There is now a new parameter "IsAquifer" to define aquifers.<br>Possible options:<br>- Clay<br>- Loam<br>- Gravel<br>- Peat<br>- Sand (default or in case of typo) |
| top_level <sup>1</sup>      | Float    | m NAP | yes      | Level of top of layer.  |
| max-d                       | Float    | m NAP | no       | Optional SOS parameter holding the maximum value for the top of the layer.  |
| min-d                       | Float    | m NAP | no       | Optional SOS parameter holding the minimum value for the top of the layer.  |
| remark                      | StringId | -     | no       | Optional SOS parameter to be used   |

| ame | Type | Unit | Required | Description  |
|-----|------|------|----------|--|
|     |      |      |          | for remarks on max-d and min-d or other specifics for the layer. |

Table B.1 1-D profiles.csv

<sup>1</sup>When importing a csv file with missing or incorrect headers for these required data, the file is not imported and a message is given “Een of meer kolomnamen onbekend – <column name>”

<sup>2</sup>When importing a csv file with missing or incorrect headers for these required data (example: soiltype instead of soil\_type) a message is given:” Een of meer kolomnamen onbekend – <column name>”. And the column is filled with the default values (Zand for soil\_type and Bisque for soil\_color)

<sup>3</sup> Possible colors:

|                  |                |                      |                   |             |
|------------------|----------------|----------------------|-------------------|-------------|
| AliceBlue        | DarkOliveGreen | Indigo               | MediumPurple      | Purple      |
| AntiqueWhite     | DarkOrange     | Ivory                | MediumSeaGreen    | Red         |
| Aqua             | DarkOrchid     | Khaki                | MediumSlateBlue   | RosyBrown   |
| Aquamarine       | DarkRed        | Lavender             | MediumSpringGreen | RoyalBlue   |
| Azure            | DarkSalmon     | LavenderBlush        | MediumTurquoise   | SaddleBrown |
| Beige            | DarkSeaGreen   | LawnGreen            | MediumVioletRed   | Salmon      |
| Bisque (default) | DarkSlateBlue  | LemonChiffon         | MidnightBlue      | SandyBrown  |
| Black            | DarkSlateGray  | LightBlue            | MintCream         | SeaGreen    |
| BlanchedAlmond   | DarkTurquoise  | LightCoral           | MistyRose         | SeaShell    |
| Blue             | DarkViolet     | LightCyan            | Moccasin          | Sienna      |
| BlueViolet       | DeepPink       | LightGoldenrodYellow | NavajoWhite       | Silver      |
| Brown            | DeepSkyBlue    | LightGreen           | Navy              | SkyBlue     |
| BurlyWood        | DimGray        | LightGray            | OldLace           | SlateBlue   |
| CadetBlue        | DodgerBlue     | LightPink            | Olive             | SlateGray   |
| Chartreuse       | Firebrick      | LightSalmon          | OliveDrab         | Snow        |
| Chocolate        | FloralWhite    | LightSeaGreen        | Orange            | SpringGreen |
| Coral            | ForestGreen    | LightSkyBlue         | OrangeRed         | SteelBlue   |
| CornflowerBlue   | Fuchsia        | LightSlateGray       | Orchid            | Tan         |
| Cornsilk         | Gainsboro      | LightSteelBlue       | PaleGoldenrod     | Teal        |
| Crimson          | GhostWhite     | LightYellow          | PaleGreen         | Thistle     |
| Cyan             | Gold           | Lime                 | PaleTurquoise     | Tomato      |
| DarkBlue         | Goldenrod      | LimeGreen            | PaleVioletRed     | Turquoise   |
| DarkCyan         | Gray           | Linen                | PapayaWhip        | Violet      |
| DarkGoldenrod    | Green          | Magenta              | PeachPuff         | Wheat       |
| DarkGray         | GreenYellow    | Maroon               | Peru              | White       |
| DarkGreen        | Honeydew       | MediumAquamarine     | Pink              | WhiteSmoke  |
| DarkKhaki        | HotPink        | MediumBlue           | Plum              | Yellow      |
| DarkMagenta      | IndianRed      | MediumOrchid         | PowderBlue        | YellowG     |

The soil\_name, soil\_type and soil\_color are placed in the material table in D-Soil Model.

If the combination of these three items is not consequent, the first combination is presented in D-Soil Model.

Example:

| ile_id            | top_level | soil_name | soil_type | soil_color |
|-------------------|-----------|-----------|-----------|------------|
| Segment_36006_1D1 | 3         | H_Ro_z&k  | Clay      | Chocolate  |

|                   |      |          |      |           |
|-------------------|------|----------|------|-----------|
| Segment_36006_1D1 | 2.25 | H_Rg_zg  | Clay | Gold      |
| Segment_36006_1D1 | -3.5 | H_Ro_z&k | Sand | Chocolate |
| Segment_36006_1D1 | -4.5 | P_Rg_zm  | Sand | PaleGreen |
| Segment_36006_1D1 | -13  | P_Ova_sd | Sand | Peru      |
| Segment_36006_1D1 | -17  | P_Rg_zm  | Sand | Peru      |
| Segment_36006_1D1 | -25  | P_Rg_zg  | Sand | Linen     |

Table B.2 Soilprofiles.csv

H\_Ro\_z&k will be presented as 'Clay'.  
P\_Rg\_zm will be presented as 'PaleGreen'

#### B.4 Segments

The segments consists of two different files; a \*.csv and a \*.shape file.

\*.csv file:

| Name             | Type     | Unit | Required | Description   |
|------------------|----------|------|----------|---|
| segment_id       | StringId | -    | Yes      | Name of segment   |
| soilprofile_id   | StringId | -    | Yes      | Reference to 1D-Soil profile                                  |
| probability      | Float    | %    | yes      | Chance of occurrence of profile (value between 0.0 and 100.0) |
| calculation_type | StringId | -    | yes      | - Piping<br>- Stability                                       |

Table B.3 Segments.csv

\*.shape file:

The table view of the WTI-SOS shape file presents a dijkkring number, the length of the segment, a segment id and a unique segment number (=segment\_id from csv file):

|   | LENGTH    | Segment | Segmentnr |
|---|-----------|---------|-----------|
| 9 | 3352.3996 | 17      | 9017      |
| 9 | 4663.8887 | 11      | 9011      |
| 9 | 4824.1161 | 1       | 9001      |
| 9 | 3842.2141 | 2       | 9002      |
| 9 | 4120.1497 | 3       | 9003      |
| 9 | 3394.6365 | 4       | 9004      |

Table B.4 segments.shape

#### B.5 Surface line and characteristic points

A specification of a surface line and corresponding characteristic points are used to create 2D profiles from 1D profiles or adjust 2D profiles with a new surface line.

## Surface line

The surface line file is a csv-file containing an ID of the location in the first column, in the following columns the X- and Y coordinates (in RD-coordinates) and the Z value (height in m NAP). The coordinates have to be consecutive in a line.

Example:

| LOCATIONID | X1       | Y1       | Z1    | Xn       | Yn       | Zn    |          |          |       |     |
|------------|----------|----------|-------|----------|----------|-------|----------|----------|-------|-----|
| AD640M00   | 160146   | 424333.5 | 6.763 | 160145.8 | 424332.6 | 7.082 | 160145.6 | 424331.6 | 7.492 | etc |
| AD642M50   | 159891.6 | 424372.9 | 6.319 | 159891.5 | 424371.9 | 6.328 | 159891.4 | 424370.9 | 6.333 | etc |
| AD645M00   | 159641.7 | 424402.4 | 6.128 | 159641.6 | 424401.4 | 6.17  | 159641.5 | 424400.4 | 6.183 | etc |
| AD647M30   | 159374   | 424357.3 | 0.841 | 159374.1 | 424356.3 | 1.11  | 159374.2 | 424355.3 | 1.165 | etc |

Enz.

| Name       | Type     | Unit  | Req uired | Description             |
|------------|----------|-------|-----------|-------------------------|
| LOCATIONID | StringId | -     | yes       | Name of surface line    |
| X1         | Float    | m     | yes       | X coordinate 1-st point |
| Y1         | Float    | m     | yes       | Y coordinate 1-st point |
| Z1         | Float    | m NAP | yes       | Z coordinate 1-st point |
| .....      |          |       |           |                         |
| Xn         | Float    | m     | yes       | X coordinate n-th point |
| Yn         | Float    | m     | yes       | Y coordinate n-th point |
| Zn         | Float    | m NAP | yes       | Z coordinate n-th point |

Table B.5 Surfceline.csv

## Characteristic points

Characteristic points are certain points on the surface line which enables to combine surface lines and are used for the waternet creator of the stability kernel.

The characteristic points file is a csv-file containing an ID of the location in the first column, in the following columns the X- and Y coordinates (in RD-coordinates) and the Z value (height in m NAP) of the characteristic points. For combining the surface line with the corresponding characteristic points the locationID (Key id) in both files must be equal.

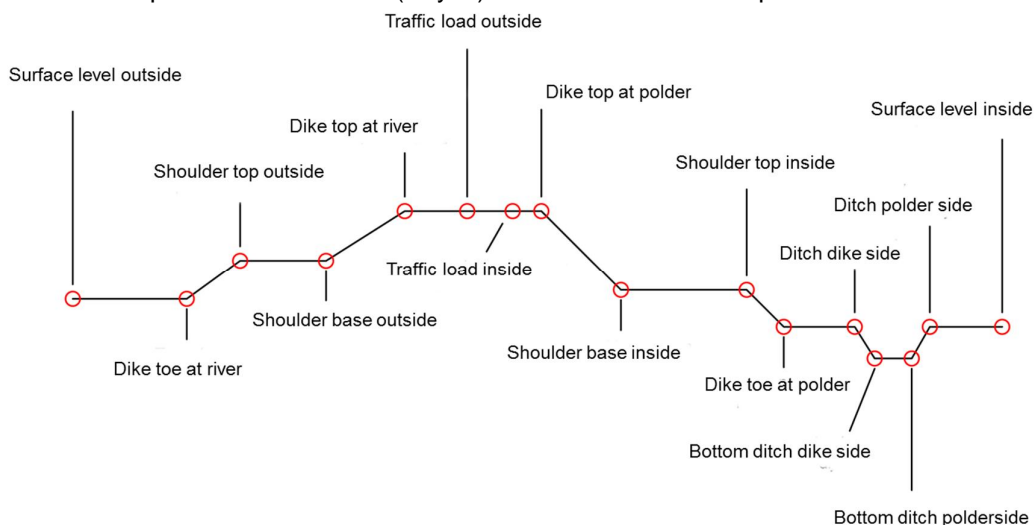


Figure B.1 Characteristic points

Example:

| D        | X_Maaiveld<br>binnenwaarts | Y_Maaiveld<br>binnenwaarts | Z_Maaiveld<br>binnenwaarts | X_Insteek sloot<br>polderzijde | Y_Insteek sloot<br>polderzijde | Z_Insteek sloot<br>polderzijde | X_Slootbodem<br>polderzijde | Y_Slootbodem<br>polderzijde | Z_Slootbodem<br>polderzijde | Enz. |
|----------|----------------------------|----------------------------|----------------------------|--------------------------------|--------------------------------|--------------------------------|-----------------------------|-----------------------------|-----------------------------|------|
| AD720M00 | 153999.5                   | 422183.9                   | 3.588                      | 153938.1                       | 422198.1                       | 3.462                          | 153935.2                    | 422198.8                    | 2.769                       |      |
| AD722M50 | 153945.8                   | 421957.2                   | 3.33                       | 153881.9                       | 421961                         | 3.204                          | 153878.9                    | 421961.1                    | 2.633                       |      |
| AD724M90 | 153887.2                   | 421695.5                   | 2.77                       | 153828.9                       | 421710                         | 2.878                          | 153828                      | 421710.2                    | 2.832                       |      |
| AD727M50 | 153816.8                   | 421456.3                   | 2.75                       | 153763.3                       | 421469.4                       | 2.759                          | 153759.5                    | 421470.4                    | 2.332                       |      |
| AD730M00 | 153755.5                   | 421213.4                   | 3.101                      | 153710                         | 421224.8                       | 2.787                          | 153709                      | 421225.1                    | 2.75                        |      |

Table B.6 Characteristic points.csv

The sequence of the columns is fixed.

| Name                             | Type     | Unit  | Required        | Description                                     |                                     |
|----------------------------------|----------|-------|-----------------|---|-------------------------------------|
| LOCATIONID                       | StringId | -     | yes             | Reference to surface line (in surfacelines.csv) |                                     |
| X_Maaiveld buitenwaarts          | Float    | m     | yes             | Coordinates of surface level outside            |                                     |
| Y_Maaiveld buitenwaarts          | Float    | m     | yes             |   |                                     |
| Z_Maaiveld buitenwaarts          | Float    | m NAP | yes             |   |                                     |
| X_Teen dijk buitenwaarts         | Float    | m     | Yes             | Coordinates of dike toe at river                |                                     |
| Y_Teen dijk buitenwaarts         | Float    | m     | Yes             |   |                                     |
| Z_Teen dijk buitenwaarts         | Float    | m NAP | Yes             |   |                                     |
| X_Kruin buitenberm               | Float    | m     | no <sup>5</sup> | Coordinates of shoulder top outside             |                                     |
| Y_Kruin buitenberm               | Float    | m     | no              |   |                                     |
| Z_Kruin buitenberm               | Float    | m NAP | no              |   |                                     |
| X_Insteek buitenberm             | Float    | m     | no              | Coordinates of shoulder base outside            |                                     |
| Y_Insteek buitenberm             | Float    | m     | no              |   |                                     |
| Z_Insteek buitenberm             | Float    | m NAP | no              |   |                                     |
| X_Kruin buitentalud              | Float    | m     | yes             | Coordinates of dike top at river                |                                     |
| Y_Kruin buitentalud              | Float    | m     | yes             |   |                                     |
| Z_Kruin buitentalud              | Float    | m NAP | yes             |   |                                     |
| X_Verkeersbelasting buitenwaarts | kant     | Float | m               | no  | Coordinates of traffic load outside |
| Y_Verkeersbelasting buitenwaarts | kant     | Float | m               | no  |                                     |
| Z_Verkeersbelasting buitenwaarts | kant     | Float | m NAP           | no  |                                     |
| X_Verkeersbelasting binnenwaarts | kant     | Float | m               | no  | Coordinates of traffic load inside  |

- <sup>5</sup> • When a characteristic item is absent at one location, but present in others, the value of -1 is given for X, Y en Z. Absence is possible for sloot (ditch), berm and verkeersbelasting (traffic load).

| Name                             | Type | Unit  | Required | Description |                                       |
|----------------------------------|------|-------|----------|-------------|---------------------------------------|
| Y_Verkeersbelasting binnenwaarts | kant | Float | m        | no          |                                       |
| Z_Verkeersbelasting binnenwaarts | kant | Float | m NAP    | no          |                                       |
| X_Kruin binnentalud              |      | Float | m        | yes         | Coordinates of dike top at polder     |
| Y_Kruin binnentalud              |      | Float | m        | yes         |                                       |
| Z_Kruin binnentalud              |      | Float | m NAP    | yes         |                                       |
| X_Insteek binnenberm             |      | Float | m        | no          | Coordinates of shoulder base inside   |
| Y_Insteek binnenberm             |      | Float | m        | no          |                                       |
| Z_Insteek binnenberm             |      | Float | m NAP    | no          |                                       |
| X_Kruin binnenberm               |      | Float | m        | no          | Coordinates of shoulder top inside    |
| Y_Kruin binnenberm               |      | Float | m        | no          |                                       |
| Z_Kruin binnenberm               |      | Float | m NAP    | no          |                                       |
| X_Teen dijk binnenwaarts         |      | Float | m        | yes         | Coordinates of dike toe at polder     |
| Y_Teen dijk binnenwaarts         |      | Float | m        | yes         |                                       |
| Z_Teen dijk binnenwaarts         |      | Float | m NAP    | yes         |                                       |
| X_Insteek sloot dijkzijde        |      | Float | m        | no          | Coordinates of ditch dike side        |
| Y_Insteek sloot dijkzijde        |      | Float | m        | no          |                                       |
| Z_Insteek sloot dijkzijde        |      | Float | m NAP    | no          |                                       |
| X_Slootbodem dijkzijde           |      | Float | m        | no          | Coordinates of bottom ditch dike side |
| Y_Slootbodem dijkzijde           |      | Float | m        | no          |                                       |
| Z_Slootbodem dijkzijde           |      | Float | m NAP    | no          |                                       |
| X_Slootbodem polderzijde         |      | Float | m        | no          | Coordinates of bottom                 |
| Y_Slootbodem polderzijde         |      | Float | m        | no          |                                       |
| Z_Slootbodem polderzijde         |      | Float | m NAP    | no          |                                       |
| X_Insteek sloot polderzijde      |      | Float | m        | no          | Coordinates of ditch polder side      |
| Y_Insteek sloot polderzijde      |      | Float | m        | no          |                                       |
| Z_Insteek sloot polderzijde      |      | Float | m NAP    | no          |                                       |
| X_Maaiveld binnenwaarts          |      | Float | m        | yes         | Coordinates of surface level inside   |
| Y_Maaiveld binnenwaarts          |      | Float | m        | yes         |                                       |
| Z_Maaiveld binnenwaarts          |      | Float | m NAP    | yes         |                                       |

Table B.7 Columns of characteristic points.csv

## B.6 GEF files

\*.GEF files can be imported when file is conform CUR reports [8 for borings] [9 for cpt] and vertical reference is in m NAP (#ZID: 31000=NAP).

Only \*.GEF files with X, Y-coordinates in Rijks Driehoekstelsel (#XYID: 31000=RD) can be plotted on the map.

## B.7 Shapefiles

Any other geo-referred data can be imported to be shown in the map window. Only requirement is the used coordinate system: Rijks Driehoekstelsel (RDnew).

## C Soil parameters

In following tables the material parameters are arranged per failure mechanism; Macrostablieit, Piping and Zettingsvloeiing. The filter 'all' will show the parameters of all three failuremechanisms.

Explanation of columns:

|                      |   |
|----------------------|---|
| WTI-ID               | Id in parameterlist [10]  |
| Determinist/stochast | A number of parameters can be entered as determinist and as stochast. When parameter is stochast there is an extra column, starting with (S). The columns are not connected to each other via calculations. |
| Default value        | Default values in D-Soil Model are mostly NaN; Not a number. Default value of stochasts: lognormal distribution, with 'Gemiddelde' and 'Afwijking': NaN   |
| Min. value           | Kernels can demand minimum and maximum values. Since D-Soil Model can provide data for several kernels, the minimum and maximum values in D-Soil Model are the outer boundaries of the kernel values.       |
| Max. value           | see Min. value.   |

### C.1 Soil parameters for filter Macrostablieit:

| WTI-ID | Parameter        | Display unit         | Description                              | Name in D-Soil Model | Determinist /stochast | Default value /distribution / variation | Min. value | Max. value |
|--------|------------------|----------------------|--|----------------------|-----------------------|---|------------|------------|
| n.a.   | n.a.             | n.a.                 | Soilname                                 | Naam                 | n.a.                  | Undetermined                            | n.a.       | n.a.       |
| n.a.   | n.a.             | ARGB-code            | Color                                    | Kleur                | n.a.                  | White                                   | n.a.       | n.a.       |
| n.a.   | n.a.             | n.a.                 | Type                                     | Grondtype            | n.a.                  | Sand                                    | n.a.       | n.a.       |
| n.a.   | n.a.             | n.a.                 | Description                              | Beschrijving         | n.a.                  | empty                                   | n.a.       | n.a.       |
| M04    | $\gamma_{unsat}$ | [kN/m <sup>3</sup> ] | Unit weight of soil above phreatic level | Onverzadigd gewicht  | D/S                   | NaN/logn/NaN                            | 0.001      | 100        |

| WTI-ID | Parameter            | Display unit         | Description  | Name in D-Soil Model | Determinist /stochast | Default value /distribution / variation | Min. value | Max. value |
|--------|----------------------|----------------------|--|----------------------|-----------------------|---|------------|------------|
| M03    | $\gamma_{sat}$       | [kN/m <sup>3</sup> ] | Unit weight of soil below phreatic level   | Verzadigd gewicht    | D/S                   | NaN/logn/NaN                            | 0.001      | 100        |
| n.a.   | Shear strength model | n.a.                 | Shear strength model (choice between <b>C-Phi</b> , <b>Su-calculated</b> and <b>CPhi/Su calc.</b> )  | Schuifsterkte model  | D/S                   | C-Phi                                   | n.a.       | n.a.       |
| M05    | $c'$                 | [kN/m <sup>2</sup> ] | Cohesion   | Cohesie              | D/S                   | NaN/logn/NaN                            | 0          | $\infty$   |
| M06    | $\varphi'$           | [graden]             | Friction angle of shearing resistance  | Wrijvingshoek        | D/S                   | NaN/logn/NaN                            | 0          | 89         |
| M14    | S                    | [-]                  | Undrained shear strength ratio (normally consolidated)   | Schuifsterkte ratio  | D/S                   | NaN/logn/NaN                            | 0          | 1000000000 |
| M15    | $m$                  | [-]                  | Strength increase exponent   | Sterkte toename exp  | D/S                   | NaN/logn/NaN                            | 0          | 1          |
| n.a.   | Use POP              | n.a.                 | Checkbox to chose between POP and yield stress.<br>'Use POP' = TRUE:<br>POP editable.<br>'Use POP' = FALSE :<br>POP non-editable (=default). | Gebruik POP          | n.a.                  | FALSE                                   | n.a.       | n.a.       |
| n.a.   | POP                  | [kN/m <sup>2</sup> ] | Pre overburden pressure  | POP                  | D/S                   | NaN/logn/NaN                            | 0          | 10000      |

Table C.1 Parameters filter macrostability

**C.2 Materialparameters for Piping:**

| WTI-ID | Parameter                      | Display Unit         | Description  | Name in D-Soil Model | Determinist/stochast | Default value /distribution / variation | Minimum value | Maximum value |
|--------|--------------------------------|----------------------|--|----------------------|----------------------|---|---------------|---------------|
| n.a.   | n.a.                           | n.a.                 | Soilname   | Naam                 | n.a.                 | Undetermined                            | n.a.          | n.a.          |
| n.a.   | n.a.                           | ARGB-code            | Color  | Kleur                | n.a.                 | White                                   | n.a.          | n.a.          |
| n.a.   | n.a.                           | n.a.                 | Type   | Grondtype            | n.a.                 | Sand                                    | n.a.          | n.a.          |
| n.a.   | n.a.                           | n.a.                 | Description  | Beschrijving         | n.a.                 | empty                                   | n.a.          | n.a.          |
| M08    | PipingLayer.BelowPhreaticLevel | [kN/m <sup>3</sup> ] | Unit weight below phreatic level                     | Verzadigd gewicht    | D/S                  | NaN/logn/NaN                            | 0             | 100           |
| M13    | D70                            | [μm]                 | 70% fractile of the aquifers grain size distribution | D70                  | D/S                  | NaN/logn/NaN                            | 0.01          | 1000000       |
| M15    | DarcyPermeability              | [m/s]                | Permeability (Darcy)                                 | Doorlatendheid       | D/S                  | NaN/logn/NaN                            | 0             | 1000          |

Table C.2 Parameters filter Piping

### C.3 Soil parameters for Zettingsvloeiing:

| WTI-ID     | Parameter             | Display unit        | Description   | Name in D-Soil Model | Determinist/stochastic | Default value | Minimum value | Maximum value |
|------------|-----------------------|---------------------|---|----------------------|------------------------|---------------|---------------|---------------|
| n.a.       | n.a.                  | n.a.                | Soilname  | Naam                 | n.a.                   | Undetermined  | n.a.          | n.a.          |
| n.a.       | n.a.                  | ARGB-code           | Color   | Kleur                | n.a.                   | White         | n.a.          | n.a.          |
| n.a.       | <i>Soil type</i>      | n.a.                | Type  | Grondtype            | n.a.                   | Sand          | n.a.          | n.a.          |
| n.a.       | n.a.                  | n.a.                | Description   | Beschrijving         | n.a.                   | NaN           | n.a.          | n.a.          |
|            | $\varphi'$            | [graden]            | Friction angle of shearing resistance   | Wrijvingshoek        | D                      | NaN           | 0             | 89            |
|            | $s_2$                 | [-]                 | Value of s at maximum contraction   | s2                   | D                      | NaN           | 1.1           | 1.4           |
| <i>M09</i> | <i>D15</i>            | [ $\mu\text{m}$ ]   | Fine grain size   | D15                  | D                      | NaN           | 30            | 2000          |
| <i>M08</i> | <i>D50</i>            | [ $\mu\text{m}$ ]   | Median grain size   | D50                  | D                      | NaN           | 30            | 2000          |
|            | $n$                   | [-]                 | Porosity  | Porositeit           | D                      | NaN           | 0.3           | 0.6           |
|            | $n_{min}$             | [-]                 | Minimum porosity  | Min. porositeit      | D                      | NaN           | 0.3           | 0.6           |
|            | $n_{max}$             | [-]                 | Maximum porosity  | Max. porositeit      | D                      | NaN           | 0.3           | 0.6           |
|            | $\epsilon_{vol, dm0}$ | [-]                 | Value of $\epsilon_{vol, dm}$ at mean effective stress $p_0$                              | Epsvoldm0            | D                      | NaN           | 0.0003        | 0.03          |
|            | $K_{s0}$              | [ $\text{kN/m}^2$ ] | Value of Ks at average stress $p_0'$  | Ks0                  | D                      | NaN           | 10000         | 140000        |
|            | $\gamma_{sand}$       | [ $\text{kN/m}^3$ ] | Unit weight of grains   | Gamma korrel         | D                      | NaN           | 20            | 30            |
|            | $m$                   | [-]                 | Parameter describing $f(s)$ , defined in equation: $f(s) = A s^m - B s^r / (s_{max} - s)$ | m                    | D                      | NaN           | 1.5           | 3             |

| WTI-ID | Parameter | Display unit | Description   | Name in D-Soil Model | Determinist/stochastic | Default value | Minimum value | Maximum value |
|--------|-----------|--------------|---|----------------------|------------------------|---------------|---------------|---------------|
|        | $u$       | [-]          | Parameter describing the influence of $p'$ on $K_s$ defined in equation: $K_s = K_{s0} (p' / p_0')^u$   | $u$                  | D                      | NaN           | 0.5           | 1.5           |
|        | $v$       | [-]          | Parameter describing the influence of $p'_{CON}$ on $\epsilon_{vol;dm}$ , defined in equation: $\epsilon_{vol;dm} = \epsilon_{vol;dm0} (p_{CON}' / p_0')^v$ | $v$                  | D                      | NaN           | 0.5           | 1.5           |
|        | $r$       | [-]          | Parameter describing $f(s)$ , defined in equation: $f(s) = A s^m - B s^r / (s_{max} - s)$   | $r$                  | D                      | NaN           | 7             | 7             |

Table C.3 Parameters filter zettingsvloeiing



## D Combination of surface line and 2D profile

The combination of a surface line and a 2D profile is possible by adding a reference line to the 2D profile. This reference line and the middle of the characteristic points 'kruin buitentallud' and 'kruin binnentalud' are mapped upon each other. The reference line is a x-value, part of the 2D profile.

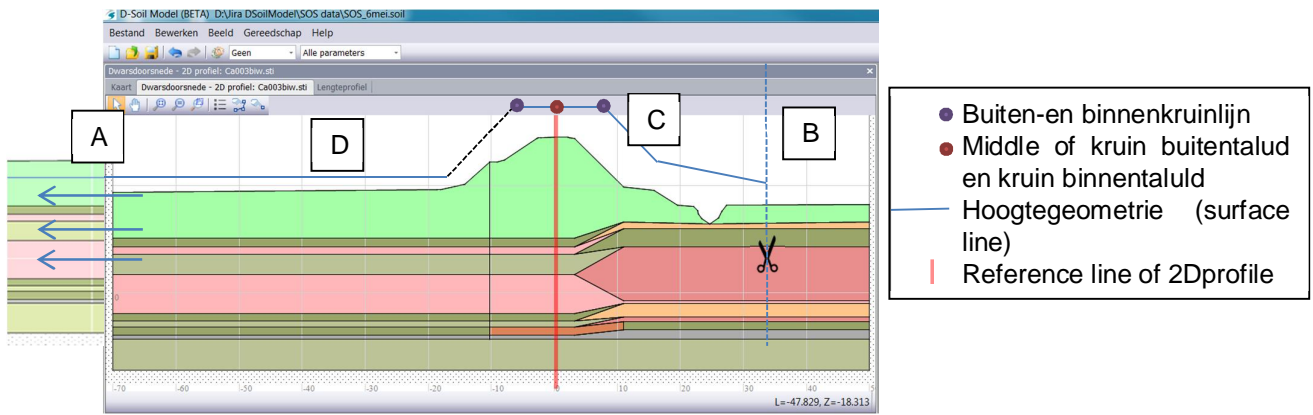


Figure D.1 Combination of surface line and 2D-profile

## Combination of surface line and 2D profile

The combination follows the rules:

- Middle between 'kruin buitentalud' en 'kruin binnentalud' at the surface line is mapped on the reference line of the 2D profile (x-values are equal);
- When the surface line is longer than the 2D profile (situation A in figure); the 2D profile is enlarged to boundary of surface line.
- When the surface line is smaller than the 2D profile (situation B in figure); the 2D profile is cut off to boundary of surface line.
- When surface line is heigher than 2D profile (situation C in figure); the 'space' between surface line and 2D profile is filled with 'opvulmateriaal', to be defined by user.
- when surface line is lower than 2D profile (situation D in figure); this area of the 2D profile is removed.

Extra rule for situation A:

- When 2D profile contains non-horizontal layer boundaries, the Z-value at the boundary is maintained:

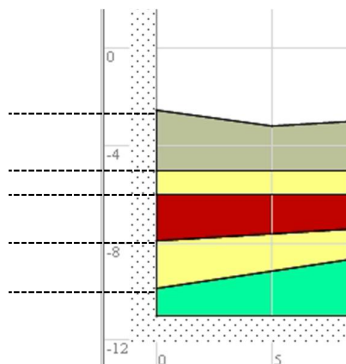


Figure D.2 Non-horizontal layers

## E Description functional requirements

| Eis ID    | Eis omschrijving  |
|-----------|---|
| REQ 3     | Format of import data.  |
| REQ 3.1   | Format of import data. The required import files are: geo-file, sti file and mdb file from D-GeoStability; for subsoil schematizations (2D profiles) and strength parameters. • csv files; description of the segments and 1Dsoil profiles. shape files; location of segments, 2D) profiles, CPT's, borings.  |
| REQ 3.2   | REQ 3.2 Import and view all SOS data. The user must be able to get an overview of all available SOS subsoil schematizations. A user must be able to import all SOS segments and browse through them. The user must get a good visual overview of all available scenarios of soil profiles.  |
| REQ 3.3   | Select relevant SOS information for project. Only the relevant part of the SOS database needs to be read. The user defines the relevant area, a reference line, or the user specifies the segments from a list. Only the SOS data relevant data is imported into the D-Soil Model project.  |
| REQ 3.4   | Import relevant reference data. Also data which is not passed through to Ringtoets should be showed in order to make good subsoil schematizations. The following items need to be shown in a relevant window: Surface lines, Characteristic points, Outside water level, PL lines, Polder water level. Note: A surface line with characteristic points and the actual polder water level can be imported and placed above a relevant 2D cross section. Surface lines will be combined with all possible subsoil scenarios in Ringtoets. They will not be available as a separate object in D-Soil Model. Also, the outer water level and other PL lines can be viewed for reference in the cross sections of the 2D profile.  |
| REQ 4(.1) | All existing M-SoilBase functionality must be present in D-Soil Model   |
| REQ 5     | The application gathers the (stochastic) subsoil schematizations input and parameters for the following kernels: • WTI macro stability kernel, WTI piping kernel, WTI flow slide kernel. D-Soil Model can save this output into one file.   |
| REQ 5.1   | In order to supply the kernels with the right input, the application supports the schematisation, storage and management of the subsoil schematisation for the failure mechanism macrostability. A subsoil schematisation or a macrostability mechanism consists of:<br>One or more soil segments (polylines).<br>Per soil segment per mechanism one (stochastic)soil profile schematisation.<br>Per (stochastic) soil profile schematisation one or more 1D and/or 2D soil profiles scenarios with a probability of appearance and profile properties (e.g. preconsolidationpressure) if applicable.<br>Per 1D or 2D soil profile scenario one or more soil layers with layer properties (e.g. aquifer yes/no) if applicable.<br>• Per soil layer one soil material with soil material properties.<br>• Surface line profiles related to the soil segment, if applicable .<br>All inputs are defined in the technical design document of the macrosstability kernel. |
| REQ 5.2   | Supply the subsoil schematization and –parameters for the WTI piping kernel. A subsoil schematization for piping consists of the same type of dataset as the data for the macro stability kernel. Within a segment, each surface line must be combined with all available stochastic subsoil scenarios to form all piping input scenarios. All piping inputs are defined in the technical design document of the piping kernel.   |
| REQ 5.3   | Supply the subsoil schematization and -parameters for the WTI flow slide kernel. A subsoil schematization for flow slide consists of the same type of dataset as the data for the macro stability kernel. Within a segment, each surface line must be combined with all available stochastic subsoil scenarios to form all flow slide input scenarios. All flow slide inputs are defined in the technical design document of the flow slide kernel.   |
| REQ 5.4   | Each kernel has a list of variables defined in its own technical design. Each of these variables that have to do with subsoil information must be provided by D-Soil Model. In addition of these mechanism related variables, all general soil related properties need to be stored as well.  |
| REQ 6     | For each failure mechanism the subsoil is described in soil segments" consisting of one of more scenario(s) of a soil profile" with a probability of appearance. These soil profiles are described in either 1D or 2D layer schematization. A soil segment can have a combination of 1Dand 2D soil profiles. Each layer is described with at least all the parameters needed for the relevant failure mechanism. This output is gathered in one file, which can be directly imported in Ringtoets.  |
| REQ 6.1   | Stochastic characterization of the variables. A stochastic variable has a distribution. All stochastic variables can be stored as a mean value with a distribution.   |
| REQ 6.2   | Automatically derive the stochastic parameters from a set lab data (e.g. field or labdata) for a given distribution. For example the mean and standard deviation for a lognormal distribution fo ra given set labdata.  |
| REQ 6.3   | Separate segments for each failure mechanism. The SOS segment boundaries can be different, depending upon the failure mechanism. Each mechanism has its own segment boundaries.   |

| Eis ID  | Eis omschrijving   |
|---------|--|
| REQ 6.4 | Definition of the location of the 1D profile for Piping and DFlowSlide. 2D profiles exist for piping and flow slide analyses. The current kernels can only handle 1D schematizations. The D-Soil Model user must be able to define the location of the 1D profile per 2D profile per mechanism.  |
| REQ 6.5 | The application must support profile properties. Profile properties are information which is related and can be allocated to a soil profile. Thus far, the yield stress (Pre-consolidation stress) is the only profile property being used.  |
| REQ 6.6 | The application must support layer properties. Layer properties are information which is related and can be allocated to a soil layer. Thus far, the "is aquifer" property is the only available layer property. In future, leak agelength sor dampingfactors may also be transferred to layer properties.   |
| REQ 7   | Stochastic schematization of subsoil. All the parameters of above described schematization can consist of stochastic variables or "as is" value (characteristic value or design value). All stochastic variables can be stored as a mean value with distribution parameters and the distribution type.   |
| REQ 7.1 | Stochastic subsoil modelling consists of soil segments (lines), each with soilprofiles with a probability of appearance. Per failure mechanism the segments are defined. This stochastic subsoil modelling is presented in D-Soil Model.   |
| REQ 7.2 | Allocation of CPT's and boreholes on a map and to a segment. Imported CPT's and borings are shown on a map and can be matched to a segment.<br>The application must support the allocation of soil profile scenarios to a soil segment. A soil profile scenario consists of a 1D or 2D soil profile with a probability of appearance.  |
| REQ 7.3 | Overview of all available borings and CPT's in a segment/crosssection. All available ground investigation information in a section can be scrolled through and preferably dragged/dropped into a SOS scenario for viewing purposes.  |
| REQ 7.4 | Overview of all available SOS scenario's in a segment. All available SOS scenarios per segment per mechanism must be presented. Preferably, available CPT's and borings can be matched with one SOS scenario.  |
| REQ 8   | View the building blocks of the subsoil schematization   |
| REQ 8.1 | A reference line can be imported form a GIS. This reference line can, for example, be used for the projection of soil investigation in longitudinal direction or to import SOS data in a relevant section.   |
| REQ 8.2 | Table view for soil parameters The application must support the several views to show (parts of) the subsoil schematisation. Table view to show all the information in a tabular format. The soil materials properties will only be shown in table view (not in graphical views). Property view to show details (information)of the selected object and if applicable the relation with other information(objects).  |
| REQ 8.3 | Map view for soi areas<br>The application will support in map view the division of the soil areas (polygons) in which the soil profile scenarios can be allocated to. Graphical map view (in RD) with a detailed topographic map in the background to refer the spatial information of the subsoil schematisation.<br>Since this means the implementation of (advanced) GIS functionality, soil segments (polylines) instead of soil areas are acceptable if future development towards soil areas maintain open. A soil segment or soil area is allocated to one of the failure mechanisms and cannot overlap other segments or areas with the same mechanism.  |
| REQ 8.4 | Profile view to modify soil profiles .The application must support in profile view the drawing and modification of 1D and 2D soil profiles. 1D and 2D soil profile can be viewed in map view in case the location of the soil profile is available in RD (point or line). Modification of the location must be able in future development of the application. The application must support in profile view the drawing and modification of 1D and 2D soil profiles. Visualize the surface lines with their characteristic points. The application must give an overview in scenarios view of the soil profile scenarios for a soil area or segment. Since this might mean a major change in the software architecture an overview of the soil profile scenarios in another way than a scenarios view is acceptable if future development towards scenarios view maintain open. |
| REQ 8.5 | Automatically project boreholes and CPT onto a cross section. Borehole and CPT can be allocated automatically to one or more soil profiles if it lies within a certain (user defined) distance of this cross section. If the location in RD is known the borehole or CPT is plotted perpendicular to the 2D profile if the borehole or CPT is within a user defined distance. This distance is set per cross section and is default 100 meter. The CPT/boring and the soilprofile are plotted on the same vertical referencelevel (e.g. NAP) and scale   |
| REQ 8.6 | Segments have an ID that the user can relate to. This ID must be presented in mapview  |
| REQ 8.7 | Show all soil investigation with labels in mapview The name of the boring or CTP must be visible to the user in mapview  |
| REQ 8.8 | Visualize the surface lines with their characteristic points. A user must be able to view surface lines and characteristic points on top of a 2D and/ or 2D cross section.   |
| REQ 8.9 | Select boreholes and CPT's onto a cross section. If automatic plotting (RE08.5) is not possible, the borehole or CPT can be dragged by the user to the right location in the 2D profile. The height reference of a borehole or CPT is assumed to be the same as in the soil profile and plotted in the height reference of the 2D profile  |

| Eis ID   | Eis omschrijving   |
|----------|--|
| REQ 8.10 | The application must give an overview in scenarios view of the soil profile scenarios for a soil area or segment. Since this might mean a major change in the software architecture an overview of the soil profile scenarios in another way than a scenarios view is acceptable if future development towards scenarios view maintains open. This scenarios view is not yet required in this version of the application if an overview of the scenarios per soil area or segments is provided in another manner (see also REO 5.1). En zie plaatje in Functional design document. |
| REQ 8.11 | View files in file-related software. a. CPT's and borings in GEF format can be shown in an external program like GefPlotTool by doubleclicking the names in D-Soil Model. b. Open *.sti in DGeoStability by doubleclicking the name in D-Soil Model.   |
| REQ 8.12 | In map view, relevant background information must be shown. Standard relevant information is AHN information and information from a (later to be specified) WMS server.  |
| REQ 8.13 | Show SOS scenario's in 2D profiles. All relevant SOS scenario's (the ones from the same segment) must be visible in a 2D profile at the same reference level. The user will use this additional information to make sure the 2D subsoil schematization fits the SOS segments.  |
| REQ 8.14 | Draw SOS profiles in one segment on the same height for comparison. When plotting SOS profiles next to one another, they must be plotted relative to a same reference level (e.g. NAP) and scale for simple comparison. The minimum and maximum value of the layers must also be shown.  |
| REQ 8.15 | Show ground investigation simultaneously to REQ 8.14 at the same reference level. When plotting soil investigations (CPT's and borings) on a reference line next to one another, they must be plotted relative to a same reference level (e.g. NAP) for simple comparison.   |
| REQ 8.16 | Synchronization between different views. The user can switch between different kind of views of the data by clicking on the name. E.g. clicking on segment A in the table window, also selects this segment on the map and the properties of this segment are shown on the map. Applicable for names of: Soilsegments, soilprofiles, material, layer, CPT, boring, surface lines   |
| REQ 8.17 | Visibility of yield stress Yield stresses are plotted in the 2D profile as points with optional labels (label =Spanningswaarde).   |
| REQ 9    | Edit and generate the building blocks of the subsoil schematization The user is able to edit all the building blocks. The user is responsible for the edits, D-Soil Model gives validations messages when applicable (e.g. minimum and maximum values). The user is supported by the application with tools.   |
| REQ 9.1  | The soil materials can be named or renamed and the material properties can be created and modified in table view. Modification of the soil materials automatically updates the soil materials in the regarding soil layers. The material properties can be filtered on failure mechanism and calculationmodel if applicable.   |
| REQ 9.2  | The probably of appearance of one SOS scenario can be changed. The user is responsible for letting these scenarios add up to 100 percent. The interface should be such that the user can check this easily.  |
| REQ 9.3  | An existing 1D profile can be changed into a 2D profile so that the user can make changes in the cross section. A reference surface line needs to be drawn in this profile.  |
| REQ 9.4  | A user can make changes in a cross section in a similar way he can do in DGeoStability.  |
| REQ 9.5  | Have reference points to draw surface lines on 2D profiles. Surface lines and characteristic points must be plotted onto a 2D profile. As a referencepoint, the x-value of the outer crest line will be used. This means that, for each 2D profile, the location of the initial outer crest characteristic point must be stored. The user can move the reference point If no width of the cross section is known, the default is set to 100 meters. Other mapping methods are in consideration for more reliable mapping.  |
| REQ 9.6  | Soil interpretationtools are available in D-Soil Model so that testing data (e.g. CPT's) can directly be transformed into information that is relevant to the user (e.g. 1D profile or strength parameter). For example the parameters required for undrained analyses like the POP or OCR and m can be automatically derived from CPT.  |
| REQ 9.7  | The application must support the user to draw two dimensional soil layering.   |
| REQ 9.8  | The application must support the allocation of a soil material to a soil layer in one or more soil profiles.   |
| REQ 9.9  | Define layer as aquifer or aquitard. A soil layer in a soil profile can be defined in profile view as an aquifer. All other layers are considered to be an aquitard..This is a layer property.   |
| REQ 9.10 | Enter yield stresses for macrostability. The pre-consolidation pressure can be entered as a profile property and as soil material property. If the pre-consolidation pressure is a profile property it can be entered as point in profileview. The yield stresses must be shown to the user in a visual manner.  |
| REQ 9.11 | Copy/pastesegments for one failure mechanism to the next. Different failure mechanisms can have different section lengths. Often, though they will be the same. A user must be able to copy a segment from one mechanism to another mechanism.   |
| REQ 9.12 | Modify the location of de borehole or CPT in the 2D profile. A CPT or borehole can be dragged to another location in the profile view. This will never alter the depth of the CPT or borehole, nor will it affect the "real" world position of the CPT or borehole.  |
| REQ 9.13 | Logging of all changes to the database<br>Each cross section will have a text field where the user can enter all relevant changes made to the input data.  |

| Eis ID   | Eis omschrijving  |
|----------|---|
| REQ 9.14 | Minimal validity check on the data. Minimal validation for the right values within given boundaries   |
| REQ 9.15 | Extensive validity check on the data for Ringtoets. Complete validation for a Ringtoets analyses where the user can ask if the data is complete to perform the analysis (as a WTI add-on). Validation is possible per failure mechanism.  |
| REQ 9.16 | Define n and gamma per material parameter for determination of stochastic or design values. Parameters to define the nature of the soil tests regarding one material need to be stored to be able to calculate stochastic values.   |
| REQ 9.17 | All test to derive parameters can be stored. This way, an extra test can be added and the relevant parameters can be updated.   |
| REQ 9.18 | Add another 1D profile to an existing 2D profile (a). The user must be able to build a 2D schematization based on multiple 1D profiles (b). A newly selected 1D profile is then valid in a predefined range. Different material properties underneath and next to an embankment can be selected. The surface line and dike material (including the internal geometry of the dike) can also be edited. |
| REQ 9.19 | Draw a new subsoil configuration. The user must be able to configure a new subsoil schematization from scratch.   |
| REQ 9.20 | Incorporate settlements underneath an embankment. The user must be able to define settlements (input cm settlement as input) underneath the embankment.   |
| REQ 9.21 | On a longitudinal cross section, the user is to be able to Visualize minimum and maximum of layer boundaries from the SOS data. For each 1D SOS scenario, the user must see the expected value of each layer boundary, together with the minimum and maximum value of the layer boundary.   |
| REQ 9.22 | Longitudinal cut based on dike material<br>If information regarding the dike core is known, the user must be able to cut a segment into smaller bits, locally specifying dike material, berm material or material besides the embankment.   |
| REQ 9.23 | On a longitudinal cross section, the user is to be able to Import soil areas and segments. The application can import soil areas (as a nice to have) and segments (must have) as shapefiles (polygons or polylines).  |
| REQ 9.24 | On a longitudinal cross section, the user is to be able to Table import/export. All the tables in D-Soil Model (tables in table window, yield stresses, Sigmatau curves etc.) must have an export as well as an import functionality (for table or column(s)).  |
| U139     | Elke applicatie moet de mogelijkheid geven om invoer- en uitvoer ten dele per tabel te exporteren naar - en/of te importeren van - CSV bestanden. Daarnaast kan een invoer in Excel mogelijk zijn   |
| U140     | Elke applicatie moet de mogelijkheid geven om (ruimtelijke) invoer- en uitvoerdata ten dele per tabel te exporteren naar - en/of importeren van - shp bestanden. Dit faciliteert aansluiting op willekeurige en versie-onafhankelijke GIS software.   |

Table E.1 Functional Requirements



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