

20-D-02513

Kerrie Ann Kirkwood  
kak59@uclive.ac.nz

Dear Kerrie Ann

Thank you for your email of 10 December 2020 requesting the following under the Official Information Act 1982 (the Act):

*I'd like to request a copy of the following report prepared for the Ministry of the Environment.*

*Parshotam, A. 2018. New Zealand SWAT: Deriving a New Zealand-wide soils dataset from the NZ-NSD for use in the Soil and Water Assessment Tool (SWAT) model. Project WL18033. Aqualinc Research Limited.*

The Ministry for the Environment has identified one document in scope of your request, the *New Zealand SWAT: Deriving a New Zealand-wide soils dataset from the NZ-NSD for use in the Soil and Water Assessment Tool (SWAT) model* report.

The requested report is part of a contract that was commissioned for the Environment Reporting programme but not used because the output data was not validated.

The requested report presents one method for deriving a national soil dataset for use with the SWAT model. As with all datasets to be used for modelling, you should ensure that you are satisfied with the quality of the derived dataset and that it is fit for your purpose.

You have the right to seek an investigation and review by the Office of the Ombudsman of my decision relating to this request, in accordance with section 28(3) of the Act. The relevant details can be found on their website at: [www.ombudsman.parliament.nz](http://www.ombudsman.parliament.nz).

Please note that due to the public interest in our work the Ministry for the Environment publishes responses to requests for official information on our [OIA responses page](#) shortly after the response has been sent. If you have any queries about this, please feel free to contact our Ministerial Services team: [ministerials@mfe.govt.nz](mailto:ministerials@mfe.govt.nz).

Yours sincerely



**John Robertson**  
Director, Environmental Reporting

**NEW ZEALAND SWAT:  
DERIVING A NEW ZEALAND-  
WIDE SOILS DATASET  
FROM THE NZ-NSD FOR  
USE IN THE SOIL AND  
WATER ASSESSMENT TOOL  
(SWAT)**



Released under the  
Official Information Act (1982)

**PREPARED FOR  
MfE**

WL18033  
06/25/2018

PREPARED BY  
Aroon Parshotam

Released under the  
Official Information Act (1982)

## Disclaimer

*This document has been prepared solely for the benefit of MfE. No liability is accepted by Aqualinc Research Ltd or any employee or sub-consultant of this Company with respect to its use by any other person.*

*This disclaimer shall apply notwithstanding that the document may be made available to other persons for an application for permission or approval or to fulfil a legal requirement.*

## Quality Control

Client	Ministry for the Environment
Document Title	New Zealand SWAT: Deriving a New Zealand-wide soils dataset from the NZ-NSD for use in the Soil and Water Assessment Tool (SWAT)
Document Number	1 Soils Report MfE.docx
Authors	Aroon Parshotam
Reviewed By	John Bright
Approved By	John Bright
Date Issued	06/25/2018
Project Number	WL18033
Document Status	FINAL
File Name	1 Soils SWAT_NZ.docx

## For more information regarding this document please contact

Aroon Parshotam  
Senior Water Resource Scientist/Engineer  
Aqualinc Research Limited  
(07) 858 4846  
aroon@aqualinc.co.nz

## The preferred citation for this document is:

Parshotam, 2018. New Zealand SWAT: Deriving a New Zealand-wide soils dataset from the NZ-NSD for use in the Soil and Water Assessment Tool (SWAT). Report prepared for Ministry for the Environment. Project: WL18033. Aqualinc Research Limited.

© All rights reserved. This publication may not be reproduced or copied in any form, without the permission of the Client. Such permission is to be given only in accordance with the terms of the Client's contract with Aqualinc Research Ltd. This copyright extends to all forms of copying and any storage of material in any kind of information retrieval system.

## Aqualinc Research Ltd

Christchurch / PO Box 20 462, Bishopdale 8543, +64 (0) 3 964 6521

Ashburton / PO Box 557, Ashburton 7740, +64 (0) 3 307 6680

Hamilton / PO Box 14 041, Enderley 3252, +64 (0) 7 858 4851

[www.aqualinc.com](http://www.aqualinc.com)

Released under the  
Official Information Act (1982)

# TABLE OF CONTENTS

<b>Executive Summary</b> .....	<b>1</b>
<b>1 Introduction</b> .....	<b>2</b>
<b>2 The Fundamental Soils Layer</b> .....	<b>3</b>
<b>3 The National Soil Database</b> .....	<b>3</b>
<b>4 SWAT Soils Input Data</b> .....	<b>4</b>
4.1 SNAM .....	7
4.2 HYDGRP .....	7
4.3 SOL_ZMX .....	11
4.4 ANION_EXCL .....	11
4.5 SOL_CRK .....	11
4.6 TEXTURE .....	12
4.7 SOL_Z (layer #) .....	12
4.8 SOL_BD (layer#).....	13
4.9 SOL_AWC (layer#) .....	14
4.10 SOL_K(layer #) .....	14
4.11 SOL_CBN(layer #) .....	16
4.12 SOL_CLAY (layer #) .....	17
4.13 SOL_SILT (layer #) .....	17
4.14 SOL_SAND (layer #) .....	17
4.15 SOL_ROCK (layer #) .....	18
4.16 SOL_ALB (top layer).....	18
4.17 USLE_K (top layer) .....	18
4.18 SOL_EC (layer #).....	19
4.19 SOL_CAL (layer #).....	19
4.20 SOL_PH (layer #).....	19
<b>5 NSD FSL Join</b> .....	<b>20</b>
5.1 Option 1. Linking by Soil Symbol .....	20
5.2 Option 2. Linking by NZSC. Method 1 .....	22
5.3 Option 3. Linking by NZSC. Method 2 .....	23
<b>6 User Soils</b> .....	<b>32</b>
<b>7 Discussion</b> .....	<b>34</b>
<b>8 References</b> .....	<b>35</b>

## Table of Figures

---

Figure 1: Observation dates in the NSD.....	4
Figure 2: Relationship between fine clay and COLE, data from the NSD. ....	12
Figure 3: Frequency distribution of bulk density in the NSD. ....	13
Figure 4: Relationship of Bulk density (g/cm <sup>3</sup> ) and Carbon (%) in the top layer of soil samples in the NSD.....	14
Figure 5: Relationship of Bulk density (g/cm <sup>3</sup> ) and Carbon (%) in the second layer of soil samples in the NSD. ....	14
Figure 6: Screenshot of the SPAW model for estimating K <sub>sat</sub> .....	16
Figure 7: Frequency (%) of Organic-C measurement data in the NSD. ....	17
Figure 8: Sample identifiers overlayed onto the FSL by location .....	21
Figure 9: Area near Westport showing the NSD site locations overlayed onto the DOMNZSC layer in the FSL .....	22

Released under the  
Official Information Act (1982)

## EXECUTIVE SUMMARY

The Soil and Water Assessment Tool (SWAT) model has been used worldwide for hydrological and water quality simulations.

Pre-processing of critical data such as soils can be laborious and time-consuming.

Soils databases are freely available in many countries and some countries have developed automated processes for transforming soils data into SWAT model format. This data is readily downloadable for use in process-based, environmental models. As tools, these models are invaluable for scientific purposes.

The objective of this work was to pre-process the NZ National Soils Database (NZ-NSD) to offer a New Zealand-level soils dataset in a format ready to be used in SWAT simulations.

A summary description of the SWAT variables required are given, including a discussion of these variables in a New Zealand context. These variables include soil texture, bulk density, hydrological groups, available water capacity, saturated hydraulic conductivity, erodibility factors, carbon, and soil albedo for individual horizons in the soil profile.

The NZ-NSD was joined to the New Zealand Fundamental Soils Layer (FSL) soil polygons by New Zealand Soil Classification (NZSC) codes. Methods for quality control and for filling missing data are developed and documented. These are discussed, as well as the numerous issues and problems involved with the process. Although the method was developed primarily in order to obtain a soils dataset to be used in the SWAT model, it prepares (and documents) a new soils layer with a lot more useful fields than are currently available in the FSL.

Released under the  
Official Information Act 1982

Soil data are essential inputs for many different types of biophysical, process-based environmental models. As tools, these models are invaluable for scientific purposes. Data and databases need to be developed in order to serve these models.

Numerous countries have pre-processed soils data for use in physically-based hydrological transport models such as SWAT. In Canada, Cordeiro *et al.* (2017) found that out of 14 063 unique soils in the Soil Landscapes of Canada (SLC), 11 838 had complete information and could be included in the dataset. Soils with missing records (15% of the total) for the required SWAT variables were removed from the analysis and compiled into a second soils list provided as a reference ("incomplete" dataset). Both these datasets are made publically available and may be downloaded.

The United States STATSGO database is distributed in state/territory and national extents. It is designed for state level, and river basin applications. The STATSGO2 database is a revised STATSGO and is distributed by the Natural Resources Conservation Service (NRCS). It is freely available at <http://soils.usda.gov/survey/geography/statsgo>. The SSURGO-Soil Survey Geographic Database is also distributed by NRCS. It has the most detailed level of soil mapping, and is structured on a county basis. It is designed for use by landowners, townships, and counties for natural resource planning and management. It consists of spatial and tabular data files. It is freely available at <http://soildatamart.nrcs.usda.gov/>. ArcMap Tools were developed to automatically convert 1) STATSGO (1994)-State Soil Geographic Databases, 2) The U.S. General Soil Map or STATSGO2 (2006), and 3) SSURGO2-Soil Survey Geographic Database into an ArcSWAT compatible form. The STATSGO and STATSGO2 databases are included in the SWAT database as a default.

A Pan European SWAT soil database was developed from the European Soil Database (ESDB) by Chambel-Leitão *et al.* (2012) for the EU *MyWater* Project.

In the absence of country databases, the FAO soils database has been used and datasets made available. For example, a SWAT Soil Database using FAO Soil and Terrain Database of East Africa (SOTER) data was prepared by Gies and Merwade is available at [https://web.ics.purdue.edu/~vmerwade/education/fao\\_soil\\_tutorial.pdf](https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf).

Gijsman, *et al.* (2007) parameterized soil inputs for crop simulation models using the WISE database developed during the 1990s. The WISE database was developed by the International Soil Reference and Information Centre in The Netherlands for the project "World Inventory of Soil Emission Potentials" (WISE). In this work 1125 soil profiles from around the world were converted into a format that could be used as input data to some commonly used biophysical computer models.

Every country has its soils databases in a slightly different format. Data is summarised from soil survey information and data is regularly updated for the scientific community to use. Legacy datasets (polygons and data) are often kept separate and not integrated into a 'supersoils' database. This means that different databases require different methodologies and approaches in creating SWAT Soil datasets. The methodology is usually published and supplemented with detailed information on the derivation of data. Specialised software has been created in order to visualise Soils Data (e.g. *Soil Data Viewer* from <http://docplayer.net/14707788-Soil-data-viewer-5-1-user-guide.html> to use with US Soils databases).

The Harmonized World Soil Database is a 30 arc-second raster database with over 15 000 different soil mapping units that combines existing regional and national updates of soil information worldwide (SOTER, ESDB, Soil Map of China, WISE) with the information contained within the 1:5 000 000 scale FAO-UNESCO Soil Map of the World (FAO, 1971-1981).

Soils information from World databases are available from the FAO soil portal at <http://www.fao.org/soils-portal>. This gives 1228 legacy maps from 80 countries around the world but New Zealand is not represented.

The pre-1992 (DSIR) NZ National Soils Database (NSD) contains much useful input data for process-based environmental models, such as SWAT. There are some general issues with the database that can easily be patched and data is rather sparse in some areas. The NSD joined to the LRI to form the FSL does not make use any soil data from soil surveys. It is for this reason that the FSL is regarded as a *pseudo-soil* map. Parshotam (1995) first utilised the NSD in a national assessment of soil carbon

changes using a physically-based mechanistic model. Here, a soil map was produced by grouping together soil attributes using cluster analysis. Tate *et al.* (1993) used the concept of “similar” soils to group soils for New Zealand carbon reporting purposes. There are alternative methods to interpolate point data and represent these spatially. The SLEEP tool spatially interpolates measured soil attributes and produces a continuous representation of soil. It uses location and measured soil attribute data, DEM (Digital Elevation Model), Red band of the satellite image, Infra-red band of the satellite image. It produces a soil attribute prediction (in Table and Raster Format) and a SLEEP-SWAT Format conversion. The idea behind the SLEEP tool is to divide a watershed or area into different zones or “facets” based on the average slope parameters and then derive a model for each facet relating the soil attributes to different terrain and environmental attributes. Further details are presented in (Ziadat *et al.*, 2015). The advantage with this approach is that it makes the most use of all data in databases and does not rely on specialised knowledge of soil classification systems.

This report is about pre-processing the NSD database to offer a NZ-level soils dataset in a format ready to be used in SWAT simulations. A summary description of the SWAT variables required are given, including a discussion of these variables in a New Zealand context. These variables include soil texture, bulk density, hydrological groups, available water capacity, saturated hydraulic conductivity, erodibility factors, carbon, and soil albedo for individual horizons in the soil profile.

The NSD was joined to Fundamental Soils Layer (FSL) soil polygons by New Zealand Soil Classification (NZSC) codes. The numerous problems faced, solutions and workarounds are discussed.

## 2 THE FUNDAMENTAL SOILS LAYER

The New Zealand Fundamental Soil Layer originates from an ‘expert derived’ join of attributes measured in the NSD and the polygon boundaries of the New Zealand Land Resource Inventory (NZLRI) to the NSD.

The NZLRI was not developed with soil data nor soil profile data to delineate soil spatial polygons, but the polygons were based on five physical factors (rock type, soil, slope, present type and severity of erosion, and vegetation), with a ‘homogeneous unit area’ recording the five physical factors simultaneously to a level of detail appropriate for presentation at a scale of 1:50,000. The approach aggregates the individual soil attributes and present soil information in a form of soil classification that generalises soil variability within one polygon into one value or class. In addition, one of the fundamental issues with the approach of aggregating point data into polygons is that a large proportion of the mapped polygons do not have any datapoints within them, and these polygons have been attributed through various correlation approaches. Attributes in the FSL were selected with consultation with stakeholders at the time and may not have considered the needs and requirements of models such as SWAT.

## 3 THE NATIONAL SOIL DATABASE

The pre-1992 NZ National Soil Database (NZ-NSD) developed by DSIR-Land Resources with (116 ‘observations’ in 1950s, 706 ‘observations’ in the 1960s, 502 ‘observations’ in the 1970s, 141 ‘observations’ in the 1980s and 21 ‘observations’ made in the 1990s which include 6 new data sets added in 1998) (See Figure 1). It is available in the public domain without licensing and not widely publicised. Currently, it is the only dataset in the National Soils Data Repository (NSDR). It is usual to refer to it as the NSD.

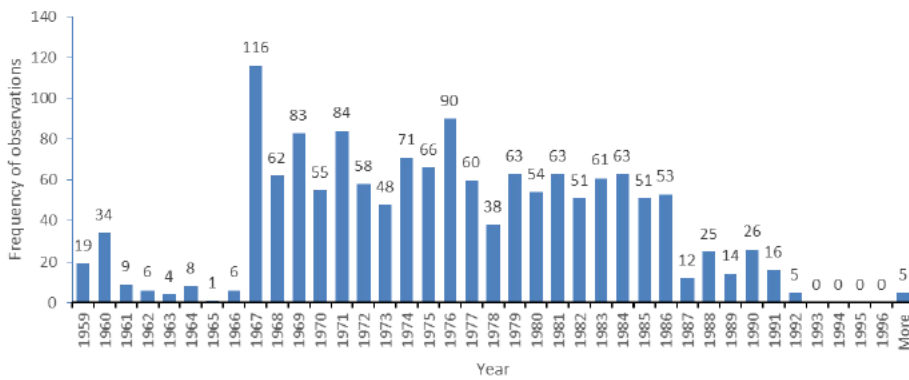


Figure 1: Observation dates in the NSD.

## 4 SWAT SOILS INPUT DATA

A brief description of the variables in the soil input file is given. These are listed in the order they appear within the file, and includes a discussion of these variables in a New Zealand context. The variables and source of data from relevant databases are summarised in Table 1.

Variable name	Definition	Units	Geodatabase/ Database	Table	Relevant fields
SNAM	Soil name. The soil name printed in HRU summary tables [optional]		FSL/NSD		Either 1) Main soil/ Soil symbol except for Gisborne, or 2) NZSC for all of New Zealand NSD SB sample identifiers
S5ID	[optional]		NSD		SB identifiers
HYDGRP	Soil hydrologic group (A,B,C,D)		NSD	site	MIDS tables
SOL_ZMX	Max rooting depth [required]	mm	FSL		PRD
			NSD		Maximum depth of soil profile
ANION_EXCL	Fraction of porosity (void space) from which anions are excluded [optional]	--	--	--	--

SOL_CRK	Crack volume potential of soil [optional]	-	NSD	moisture	COLE,  Default=0.5
TEXTURE	Soil texture [optional]		NSD	Site  horizon	Type qualifier (texture)  Texture
SOL_Z(layer #)	Depth from soil surface to bottom of layer	mm	NSD	horizon  sample	Horizon top Horizon Base  Sample top Sample base
SOIL_BD (layer#)	Moist bulk density [required]	g/cm <sup>3</sup>	NSD	moisture	Dry bulk density, Fine earth BD
SOL_AWC (layer #)	Available water capacity of soil layer [required]	v/v%	NSD	moisture	Total available water
SOL_K (layer #)	Saturated hydraulic conductivity [required]	mm/hr	NSD	particle size  chemistry	regression equations from clay, sand, silt, CEC, OM  Pedotransfer functions
SOL_CBN (layer #)	Carbon content [required]	% soil mass	NSD	chemistry	Carbon
CLAY (layer #)	Clay content [required]	% soil mass	NSD	particle size	FE2 (FE=fine earth)
SILT (layer #)	Silt content [required]	% soil mass	NSD	particle size	Si
SAND (layer #)	Sand content [required]	% soil mass	NSD	particle size	Sa
ROCK (layer #)	Rock fragment content [required]	% total mass	NSD	particle size	100-WS2 (WS2=whole soil less than 2mm)
SOL_ALB (top layer)	Moist soil albedo (top layer) [required]	---	NSD	horizon	Matrix colour code (Munsell)

USLE_K (top layer)	USLE equation soil erodibility factor [required]	0.013 (tonnes m <sup>2</sup> h)/m <sup>3</sup> tonne cm)	NSD	particle size	Silt, clay, sand, Org C
SOL_EC (layer #)	Electrical conductivity [Not currently active]	dS/m	---	---	---
SOL_CAL(layer #)	Soil CaCO <sub>3</sub> [Not currently active]	%	---	---	---
SOL_PH(layer #)	Soil pH [Not currently active]		---	---	---

**Table 1. Variables in the SWAT soil input file, and the source of data in tables from tables and fields in the NSD, and fields in the FSL**

The soil input file will hold data for up to 25 layers. There are very few soils in the NSD which exceed this number of layers and they are excluded.

The following is a brief description of the variables in the soil input file. Unless specified otherwise by layer #, it is assumed to be the topsoil of the soil profile.

Released under the Official Information Act (1982)

## 4.1 SNAM

This is the soil name. This name will be printed in the Hydrological Response Unit summary tables. A name and naming system has to be chosen when joining the FSL polygons with the NSD. A soil name is needed from the NSD and the FSL to link the point database with the spatial geodatabase. In fact, these names do not need to have any physical significance and could just be names of spatial areas.

A sample point is assumed to represent a spatial area or polygon, which may be drawn in numerous and arbitrary ways (using soil surveys, topography, etc.).

There are a few options with choosing a name. A name can be either local and site specific with Soil series & soil type, (e.g. Bruntwood silt loam) or using soil map symbols (e.g. OkS for Okareka steepland soils). Soils by soil map symbols are referred to as the main soil in the FSL and referred to as the 'soil symbol' in the NSD, a term going back to legacy maps of the 1950s. The soil name may be generic and not 'site-specific', and from New Zealand Soil Classification (NZSC) codes (eg. Mottled-weathered Orthic Brown Soil (MOMW)).

Sediment studies based on the GLEAMS model found soil 'symbols' convenient to describe the effect of sediment generated from local soils (Parshotam (2008) for Central Waitemata Harbour and Parshotam, *et al.* (2009) for the Tauranga Harbour) using data from the NSD and FSL. Internationally, names based on local soil names from soil surveys are more common.

The dominant (unique) NZSC name DOMNZSC in the FSL is chosen instead of the NZSC name, which includes combinations of soils (e.g. ROT+ROW).

## 4.2 HYDGRP

Soil hydrologic group (A, B, C, or D).

The United States Natural Resource Conservation Service (NRCS) classifies soils into four hydrologic groups based on the infiltration characteristics of the soil. A hydrologic group is a group of soils having similar runoff potential under similar storm and cover conditions. Soil properties that influence runoff potential are those that impact the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to seasonally high water table, saturated hydraulic conductivity, and depth to a very slowly permeable layer. The full definition and criteria for the assignment hydrologic groups (HSG) are given in the National Engineering Handbook, Part 630, Chapter 7 (accessed from [https://directives.s\\_egov.usda.gov/22526.wba](https://directives.s_egov.usda.gov/22526.wba)).

For soils with a hydrologic group that consists of more than one letter (e.g. "A/B", "B/C", "C/D"), its hydrologic group is determined by the presence or absence of adequate artificial drainage. If the field is artificially drained the hydrologic group moves to the first of the two classes.

In its simplest form, the hydrologic soil group is determined by the water transmitting soil layer with the lowest saturated hydraulic conductivity and depth to any layer that is more or less water impermeable or depth to a water table (if present). Generally, Soils are assigned to four hydrologic groups and three dual groups. Group A- high infiltration rate when wet, low runoff potential. Group B-moderate infiltration, low runoff potential. Group C- slow infiltration, higher runoff potential. Group D- very slow infiltration rate, highest runoff potential. The dual groups are A/D, B/D and C/D and these are used for certain wet soils that can be adequately drained. The leading letter refers to the drained condition and the second letter is the un-drained condition.

### Simplified Hydrologic Soil Group classification table

The simplified Hydrologic Soil Group classification table only uses soil texture information (Table 1). Details of this table are available online at [http://www.bwsr.state.mn.us/outreach/eLINK/Guidance/HSG\\_guidance.pdf](http://www.bwsr.state.mn.us/outreach/eLINK/Guidance/HSG_guidance.pdf)

Hydrologic soil group	Infiltration rate (in/h)	Soil textures
A	1.6	Gravel, Sandy gravel,

		Silty gravels
	0.8	Sand, Loamy sand, Sandy loam
B	0.3	Loam, silt loam
C	0.2	Sandy clay loam
D	0.06	Clay loam, silty clay loam, sandy clay, silty clay, clay

**Table 2. Simplified Hydrologic Soil Group classification table (MPCA, 2013)**

Table 3 was used to assign ALL texture classes in the NSD to Soil Hydrologic Groups based on Table 2 using texture classes only. The field texture is taken from the *horizons* table in the NSD and contains over 90% filled-in data.

Texture	Texture_Hydrological Group
FINE SANDY LOAM	B
SILT LOAM	B
BLACK LOAM	B
BLACK SAND	A
BROWN LOAM	B
CHANNEL SOIL	D
CLAY	D
CLAY LOAM	D
CLAY LOAM HILL SOIL	D
CLAY LOAM, PALE TOPSOIL PHASE	C
CLAY LOAM,EASY ROLLING PHASE	D
COARSE SANDY LOAM	A
DEEP CLAY	D
DEEP CLAY LOAM	D
DEEP FINE SANDY LOAM	A
DEEP FINE SANDY LOAM ON SAND	A
DEEP SANDY LOAM, LOAMY VARIANT	A
DEEP SILT LOAM	B
DEEP SILT LOAM ON CLAY LOAM	B
DEEP SILT LOAM ON FINE SANDY LOAM	B
DEEP SILT LOAM ON SAND	B
DEEP SILT LOAM ON SANDY LOAM	B
DEEP SILTY CLAY LOAM	D
DEEP SILTY CLAY LOAM, GREY SUBSOIL VARIANT	D
DEEP SILTY CLAY LOAM, PONDING PHASE	D
ERODED PHASE	D
FINE SANDY LOAM	A
FINE SANDY LOAM BURIED SOIL VARIANT	A
FINE SANDY LOAM, HILL SOIL	A
FRIABLE CLAY	D
GRAVELLY CLAY	D
GRAVELLY CLAY LOAM	C
GRAVELLY LOAMY SAND	A
GRAVELLY SANDY LOAM	A
GRAVELLY SILT LOAM	B
GRITTY SILT LOAM	B
HEAVY SILT LOAM	B
HILL SOIL	C
HUMIC BOULDERY SANDY LOAM	A
HUMIC FINE SAND	A
HUMIC FINE SANDY LOAM	A
HUMIC LOAMY FINE SAND	A
HUMIC LOAMY SAND,GLEYED VARIANT	A
HUMIC SANDY LOAM	A
HUMIC SILT LOAM	B

HUMIC SILT LOAM, BURIED TOPSOIL PHASE	B
HUMIC SILT LOAM, PLACIC SUBSOIL PHASE	B
HUMIC SILTY CLAY LOAM	D
LOAM	B
LOAM, MODERATELY DEEP VARIANT	B
LOAM-HILL SOIL	B
LOAMY CLAY	C
LOAMY SAND	A
LOAMY SAND (andesitic lahar vrt)	A
LOAMY SILT	B
MODERATELY DEEP FINE SANDY LOAM	A
MODERATELY DEEP SILT LOAM	B
MODERATELY DEEP SILTY CLAY LOAM	D
MOTTLED SILT LOAM	B
PEAT	C
PEAT DRAINED	C
PEAT UNDRAINED	C
PEATY LOAM	C
PEATY SAND	B
PEATY SILT LOAM	B
SAND	A
SAND LOAM	A
SANDY LOAM	A
SANDY LOAM (6A)	A
SANDY LOAM ROLLING PHASE	A
SANDY VARIANT	A
SHALLOW FINE SANDY LOAM	A
SHALLOW GRAVELLY SANDY LOAM	A
SHALLOW SANDY LOAM	A
SHALLOW SILT LOAM	B
SHALLOW SILTY CLAY LOAM	D
SHALLOW SILTY PEAT, DRAINED PHASE	C
SILT	C
SILT CLAY LOAM	D
SILT LOAM	B
SILT LOAM (TILL VARIANT)	B
SILT LOAM STEEPLAND SOIL	B
SILT LOAM STRONGLY GLEYED VARIANT	B
SILT LOAM STRONGLY MOTTLED PHASE	B
SILT LOAM, MODERATELY DEEP PHASE	B
SILT LOAM, ORGANIC SUBSOIL VARIANT	B
SILT LOAM, STRONG BROWN SUBSOIL PHASE	B
SILT, WHITE SUBSOIL VARIANT	C
SILTY CLAY	D
SILTY CLAY LOAM	D
SILTY CLAY LOAM, RED WEATHERED VARIANT	D
SLIGHTLY GRAVELLY VERY SHALLOW SANDY LOAM	A
STEEPLAND	C
STEEPLAND SOIL	C
STONY CLAY LOAM	C
STONY CLAY LOAM, STEEPLAND SOIL	D
STONY CLAY LOAM, HILL SOIL	C
STONY SILT LOAM	B
VARIANT SILTY CLAY LOAM	D
VERY SHALLOW STONY LOAM	A
VERY STONY SILT LOAM	B

**Table 3. Texture classes in the NSD assigned to Soil Hydrologic Groups.**

There appears to be very little in the literature on the runoff potential for peat-dominated catchments (See Menburu *et al.* (2015)). Organic soils are an exception and were classified as either C/D or B/D, based usually on location, with S-map factsheets (<https://smap.landcareresearch.co.nz/regional/>) being used as a guide. It is unclear how hydrological soil groups are defined in S-map in the literature. The following hydrological Soil group classifications in Table 4 were sourced for peat soils:

Texture	Hydrological Group
Peat	C
Peaty silt	C/D
Peaty loam	B/D
Peaty silt loam	B/D
Loamy peat	C/D
Peat	B/D
Shallow peat	C/D
Peaty clay	D
Peaty sandy loam	B/D

**Table 4. Peat soils assigned to hydrological groups**

Since SWAT only has Soil hydrological Groups A, B, C, or D and, based on the above table, all peat soils were classed group C for convenience. This was also generally classed according to the area peat soils are found in, in New Zealand.

A problem with the above classification method is that it is very simplistic and we have not used  $K_{sat}$  estimates of the least transmissive layer in the depth range and  $K_{sat}$  in the depth range to define hydrological soil groups nor the depth to the water impermeable layer nor depth to high water table.

An alternative method which reduces the number of classes considerably which was trialled was to define texture using USDA Soil Texture definitions and using an [NRCS texture calculator](#) or [excel macros](#). USDA uses 12 basic physical texture classes. The 12 classifications are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. In addition Sand is classified into coarse sand, sand, fine sand and very fine sand. And loamy sand is further classified into loamy coarse sand, loamy sand, loamy fine sand and loamy very fine sand. Sand loam is further divided into coarse sandy loam, sandy loam, fine sandy loam and very fine sandy loam.

Based on this texture classification, there were 4300 samples from the various horizons able to be categorised. These were filled with missing data from 8230 samples using the *nsd\_particlesize* table in the NSD.

Row Labels	Texture Symbol
clay	C
clay loam	ClLo
coarse sand	CoS
coarse sandy loam	CSL
fine sand	Sa
fine sandy loam	FSL
loam	Lo
loamy coarse sand	LCS
loamy fine sand	LFS
loamy sand	LoSa
sand	Sa
sandy clay loam	SaClLo
sandy loam	SaLo
silt	Si
silt loam	SiLo
silty clay	SiCl
silty clay loam	SiClLo

**Table 5. New categories used when texture data in the NSD was not available.**

Tables 3 and 4 need refining. Hydrologic soil groups are updated in the official US SSURGO soil survey data once a year, and refinements of the definition are updated regularly and are available from <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/ny/soils>.

Other methods based only on infiltration characteristics are given by Gies and Merwade using FAO Soil and Terrain Dataqbase of East Africa (available from [https://web.ics.purdue.edu/~vmerwade/education/fao\\_soil\\_tutorial.pdf](https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf)).

### 4.3 SOL\_ZMX

Maximum rooting depth of soil profile (mm)

If no depth is specified, the model assumes the roots can develop throughout the entire depth of the soil profile. The PRD (plant rooting depth) should be taken from the FSL, if there were more clarity about its derivation. It does not appear to be in the NSD and perhaps is an artefact of migrating the NZLRI to NZFSL.

For the current purposes, the maximum depth of all horizons where data is available is taken to be the maximum rooting depth. This may be the same as leaving the field blank.

Required.

### 4.4 ANION\_EXCL

This is the fraction of porosity (void space) from which anions are excluded.

If no value is entered, a default of 0.5 is set.

Optional.

### 4.5 SOL\_CRK

Potential or maximum crack volume of the soil profile expressed as a fraction of the total soil volume. A crack flow submodel was incorporated into SWAT and it is considered important in some soils and can contribute to movement of solutes to aquifers (Arnold *et al.*, 2005).

When some soils are subject to periods of wetting and drying, the formation of cracks in the soil leading up to the surface can drastically alter the landscape hydrology (Wilding and Puentes, 1988). Shrink-swell potential of a soil is a so a very important factor for building foundations.

High shrink-swell soils are associated with high clay content and predominantly smectitic clays; soils reported with other minerals such as kaolinite has also been observed to have high shrink-swell potential (Rivera, *et al.* 2014). Crack volume may be estimated from in situ soil moisture and Coefficient of Linear Extensibility (COLE) measurements; this is known as the COLE-predicted crack volume (Rivera, 2008). COLE is a swelling potential index. Because expandable clays in some soils are predominantly of fine clay size, COLE is reasonably well predicted from percent fine clay (Dasog *et al.*, 1988) and these values may be adjusted with the presence of coarse particles (Vaught *et al.* 2006).

To accurately predict surface runoff and infiltration in areas dominated by Vertisols, the temporal change in soil volume must be quantified. Bronswijk (1989, 1990) outlines methods used to determine the maximum crack volumes.

In United States studies, the easiest way of obtaining a COLE value for a particular soil is by locating it in the USDA-NRCS Soil Survey. The COLE recorded in USDA-NRCS Soil Survey data, however, is likely to be less accurate than direct measurement at a specific location because it is a number to be applied to the range of soils that fit a particular classification. This easy access to COLE for a soil is an advantage for using COLE to estimate crack volume. In some SWAT modelling studies, the cracking volume is assigned according to five grades from low to high.

In the NSD, there are 89 entries of COLE, 4130 entries with fine earth data and only 15 entries with both fine clay and COLE measurements. These were enough to produce the relationship given in Figure 2. Note the slope of about 0.002 compared to slopes given in Vaught *et al.* (2006) of 0.003.

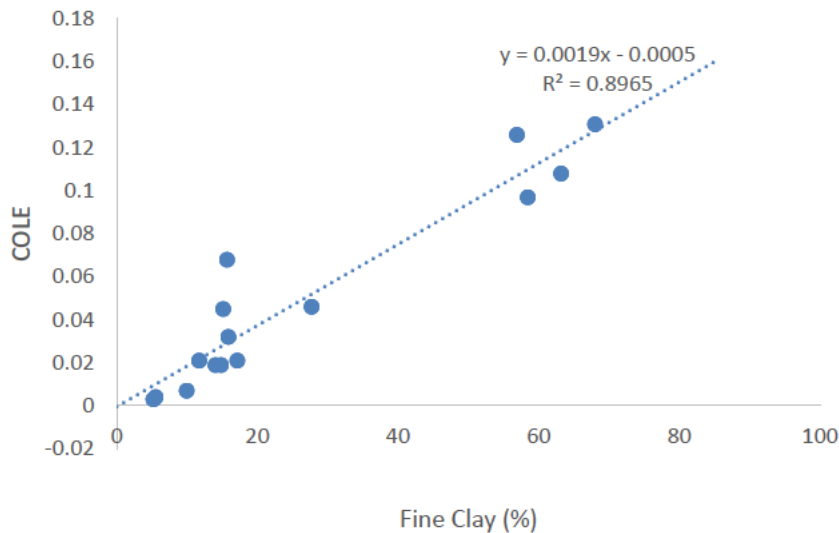


Figure 2: Relationship between fine clay and COLE, data from the NSD.

For now, a default value of 0.5 is used until it is established how COLE measurement values in the NSD may be useful in estimating Crack Volume using equations given in Bronswijk (1990) and Bauer et al. (1993).

#### 4.6 TEXTURE

Texture of soil layer. This data is not processed by the model and the line may be left blank. However, it may be used to define hydrological groups. It is useful to have this when checking soil parameter values in the SWAT soils database.

There are three methods by which this may be obtained.

- 1) NSD site table, Type qualifier field
- 2) NSD horizon table, Texture field
- 3) Defined according to clay, sand and silt% in the NSD and NRCS texture calculator or excel macros available online.

Where data in 2) is missing, data in 3) is used to fill missing data in 2). Additional 'texture' classes were assigned for peat or organic soils.

#### 4.7 SOL\_Z (layer #)

Depth from soil surface to bottom of layer (mm)

This is taken from the horizon table in the NSD. Every horizon in the NSD has a horizon top and horizon base, a sample top and a sample base. The sample top and base is a representative sample of the horizon top and base. Horizons are numbered 1,2,3,... with associated lab letters A, B, C, ... respectively. The sample top of the A horizon is taken as zero. In some instances, there is a negative value due to a litter layer, and the litter layer is not used and the top layer is assigned zero. In some instances, there may be a gap between horizons due to only taking representative samples in a horizon (eg. 0-7, 8-13, 13-20, 22-50, etc.). This is ignored and only the horizon base is taken. In some instances a horizon is missing altogether in the NSD (i.e. no data, no horizon), in which case the last layer with data is taken as the bottom horizon.

Required.

#### 4.8 SOL\_BD (layer#)

Moist bulk density ( $\text{g}/\text{cm}^3$ ). The range given in the SWAT manual for soil inputs are between  $1.1 \text{ g}/\text{cm}^3$  and  $1.9 \text{ g}/\text{cm}^3$

This expresses the ratio of the mass of solid particles to the total volume of soil. The SWAT manual specifies that *moist* bulk density determinations be made using the oven dry weight as the mass of the soil and the total volume of the soil is determined when the soil is at or near field capacity. This definition is the usual definition of *dry* bulk density in New Zealand but it is not usual to determine the soil volume when the soil is at or near field capacity. Bulk density is dependent on soil texture and the densities of soil mineral (sand, clay and silt) and organic matter particles, as well as their packing arrangement. Bulk density is also an indicator of soil compaction.

The NSD has two fields: the Dry bulk density which is a measurement of dry bulk density (avg= $1.14 \text{ g}/\text{cm}^3$  for all samples) on the whole soil, and fine earth dry bulk density (avg= $1.13 \text{ g}/\text{cm}^3$  for all samples) which is a measurement of dry bulk density on the fine earth fraction only. On the whole, the dry bulk density and fine earth dry bulk density are almost identical in the NSD. A frequency distribution of bulk density in the NSD is presented in Figure 3. The dry bulk density of the very high samples ( $>2 \text{ g}/\text{cm}^2$ ) are considerably higher than the dry bulk density of the fine earth fraction.

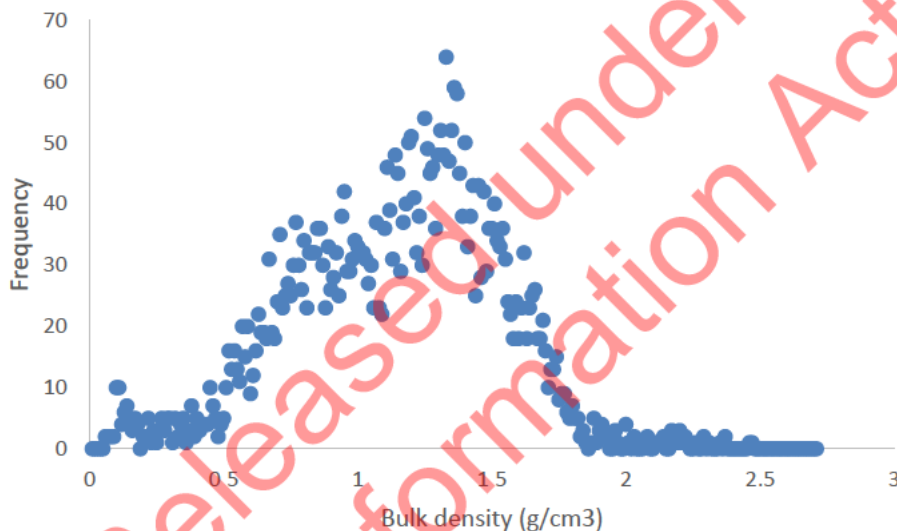


Figure 3: Frequency distribution of bulk density in the NSD.

The following regression equation in Figure 4 was obtained by regressing bulk density and carbon (%) for the top soil layer and used to fill missing data. A similar relationship given in Figure 5 was shown to hold for soils in the second layer with identical exponent but this equation was not used.

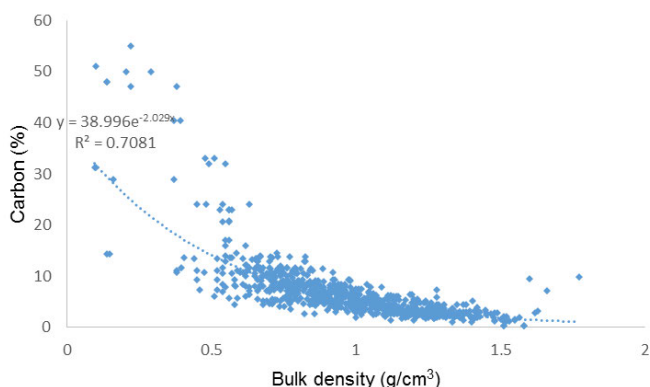


Figure 4: Relationship of Bulk density (g/cm<sup>3</sup>) and Carbon (%) in the top layer of soil samples in the NSD.

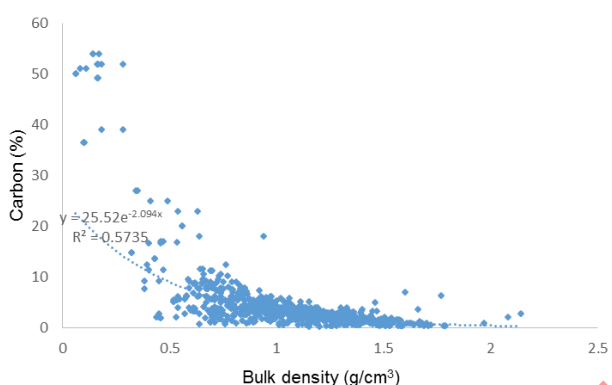


Figure 5: Relationship of Bulk density (g/cm<sup>3</sup>) and Carbon (%) in the second layer of soil samples in the NSD.

Regression equations for predicting soil bulk density have been developed around the world from soils databases and some are listed in Abdelbaki, (2016). These are usually functions involving organic matter, sand, clay, silt, water content and in some cases, depth.

#### 4.9 SOL\_AWC (layer#)

The available water capacity of the soil (mm water/mm soil). The plant available water, also referred to as the available water capacity.

This is calculated by  $AWC = FC - WP$  where  $AWC$  is the plant available water,  $FC$  is the water content at field capacity, and  $WP$  is the water content at permanent wilting point.

$AWC$  is estimated by determining the amount of water released between in situ field capacity and the permanent wilting point. The in situ field capacity is the soil water content at soil matric potential of -1/3 bar. The permanent wilting point is the soil water content at soil matric potential of -15 bar.

In the NSD, total available water is calculated as the difference between water content at tensions 15 bar and 0.1 bar with units (v/v%) and this value is taken.

Required.

#### 4.10 SOL\_K (layer #)

Saturated hydraulic conductivity (mm/h).

Saturated hydraulic conductivity  $K_{sat}$  is essential in modelling surface and subsurface flow as well as solute transport in soils and sediments. It relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The available water capacity

of the soil layer (Sol\_awc), saturated hydraulic conductivity (SOL\_K) and the soil depth (sol\_z) are found to be the most sensitive of the parameters which affect sediment yield loss of a watershed (Sarkar, et al. 2016).

$K_{sat}$  has been estimated intensively by soil physicists and hydrologists. These include empirical, quasi-physical, physically-based as well as numerical techniques. Among them, pedotransfer functions, i.e. regression-based models that make use of available information to provide estimates of other related factors that are needed, have attracted a great deal of attention over the last 30 years. Since measurement of  $K_{sat}$  is expensive, it is usually derived from pedotransfer functions. The limitations of pedotransfer functions depend on data used to train (or develop) and test (validate) them. Pedotransfer functions should not be used as an excuse for not collecting measurement data. These have also distracted us from a real need to measure this rather important parameter. Their predictive power should be improved as more data is collected, including new cheaper instruments to measure it.

Pedotransfer functions have been actively developed to link soil hydraulic properties to readily measureable characteristics e.g. soil texture, bulk density and organic matter. A list of useful regression equations (pedotransfer functions) frequently used in the international literature to estimate soil hydraulic conductivity,  $K_{sat}$ , is given in Ghanbarian *et al.* (2016). There are literally hundreds of pedotransfer functions to choose from in the literature.

For New Zealand soils, pedotransfer functions describing soil water properties over extensive areas of the country are limited by the lack of available data; pedotransfer functions available in the literature apply to other regions in the world developed in USA or Europe, where large datasets exist. There are no  $K_{sat}$  measurements given in the NSD. Physical pedotransfer functions used to compute  $K_{sat}$  for a range of New Zealand soils using a lengthy derivation are given by Pollacco *et al.* (2016); ensemble pedotransfer functions are given by Cichota, *et al.* (2013). Other hydraulic properties used to estimate volumetric water content contained in a sample of soil, ranging from 0-100%, given a specified tension or suction applied to the soil using pedotransfer functions are given by McNeill *et al.* (2018).

In the Overseer model, the saturated hydraulic conductivity is computed solely from clay content using the equation  $K_s = 14611 \text{ Clay}^{-3.48}$ , given in Wheeler (2016). Pollacco found this over-predicted  $K_{sat}$  data using data from Webb *et al.* (2010). Some methods to improve  $K_{sat}$  estimates based on data (morphology descriptors, soil-water characteristics) in New Zealand are given by Pollacco *et al.* (2014). This data is available in the NSD and may be utilised for completing the preparation of datasets for use in SWAT.

In this work, a number of pedotransfer functions were trialled but these gave very widely differing results. These were mostly based on clay percentage, or clay and silt percentages. There was the 'feeling' that pedotransfer functions do not *predict*, do not *determine*, do not *calculate*, do not *estimate* but only *guess* physically meaningful values and should only be used as a guide. There is no way to check these values with lack of measurement data in the NZ literature, or current databases.

A downloadable program called SPAW (available free from <https://hrsl.bars.usda.gov/SPAW/SPAWDownload.html>) is widely used in SWAT modelling and widely referred to in the literature. SPAW is a water budgeting tool for farm fields, ponds and inundated wetlands. The SPAW model performs daily hydrologic water budgeting using the SCS Runoff Curve Number method. Soil Water Characteristics is a program included with the SPAW installation. It is used to simulate soil water tension, conductivity and water holding capability based on the soil texture, with adjustments to account for gravel content, compaction, salinity, and organic matter (See Figure 6).

Officially Approved

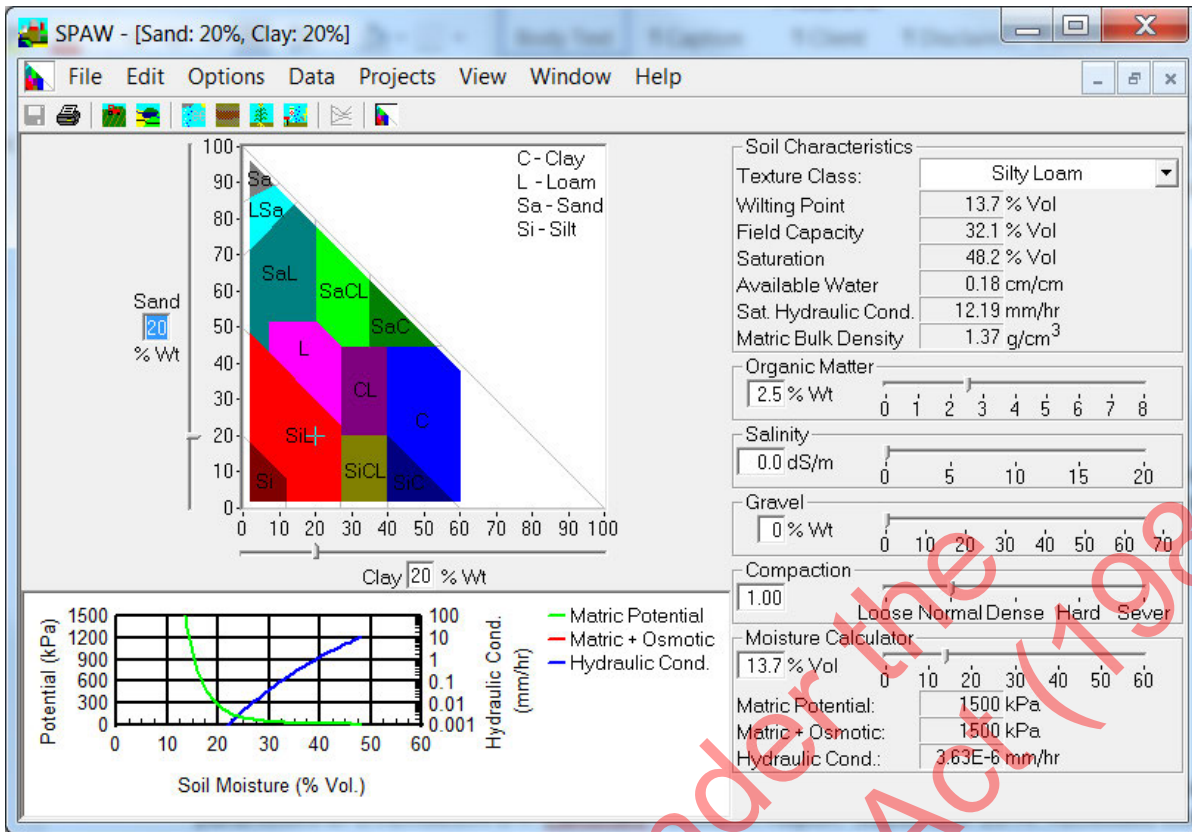


Figure 6: Screenshot of the SPAW model for estimating  $K_{sat}$

Details of SPAW are published by Saxton and Rawls, (2006). In the current work, results from SPAW gave reasonable results compared with results based on soil texture internationally and were able to match results from Webb *et al.* (2000) favourably, with no organic carbon measurement data given.

SPAW was used to estimate  $K_{sat}$  using textural data and organic matter data. Bulk density (SOL\_BD) and available water content was also estimated using SPAW and compared with measurement data in the NSD. Unfortunately, SPAW could only be used on data from one soil at a time.

#### 4.11 SOL\_CBN(layer #)

Organic carbon content (% soil mass)

When defined by soil mass, the soil is the portion of the sample that passes through a 2mm sieve.

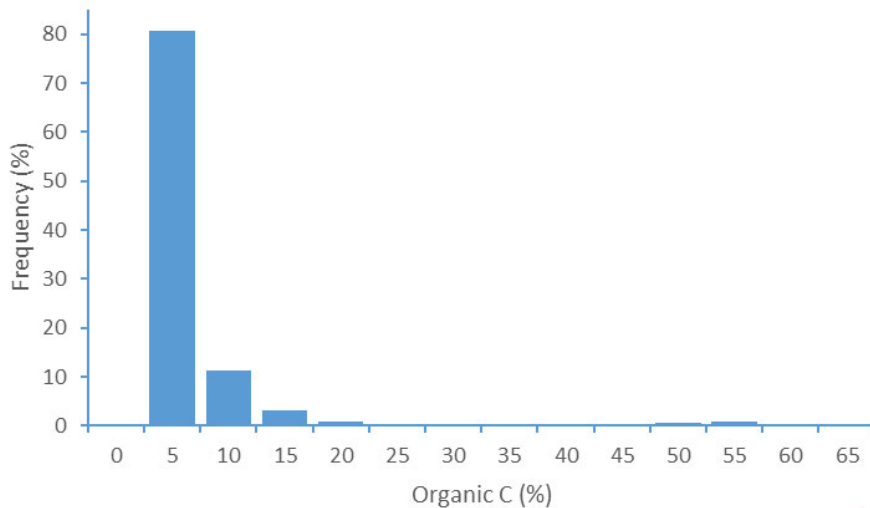


Figure 7: Frequency (%) of Organic-C measurement data in the NSD.

There are some (almost 3.5%) very high (>30%) organic-C values in the NSD which suggest that the soil sample was taken at a site with an almost peat-like soil. High organic-C values were usually unusual at depth.

Required.

#### 4.12 SOL\_CLAY (layer #)

Clay content (% of total mass). The percent of soil particles which are < 0.002 mm (2 μm) in equivalent diameter.

Required.

#### 4.13 SOL\_SILT (layer #)

Silt content (% of total mass). The percentage of soil particles which have an equivalent diameter between 0.05 and 0.002mm.

In the NSD the proportion of silt, *SILT* is 'calculated' from  $100 - (CLAY + SAND)$ , where *CLAY* and *SAND* are measured values of sand and clay proportions. As a result, there are a very small number of *SILT* values which are slightly negative (-2.38 being the largest negative) in the NSD. These are assigned zero.

The query is written in the NSD so that  $SILT = 100 - (CLAY + SAND)$ , and  $SILT = 0$ , if  $CLAY + SAND > 100$ .

Required.

#### 4.14 SOL\_SAND (layer #)

Sand content (% of total mass). The percentage of soil particles which have a diameter between 2.0 and 0.05 mm.

Required.

#### 4.15 SOL\_ROCK (layer #)

This is the rock fragment content (% of total mass). The percentage of soil particles which have a diameter > 2mm, i.e. the percent of the sample which does not pass through a 2mm sieve. In New Zealand, the term ROCK is not generally defined in this manner. Anything > 2mm is gravel, then comes stones, followed by rocks, and boulders (Milne, *et al.* 1995). There is a ROCK column in FSL and it has not been defined in the LRIS data dictionary v3. The presence of gravel has a significant effect on the mechanical and hydraulic properties of soil.

Required.

#### 4.16 SOL\_ALB (top layer)

This is the *moist* soil albedo.

The albedo is the ratio of the amount of solar radiation reflected by a body to the amount incident upon it, expressed as a fraction. A bare soil has a typical albedo of 0.17. The value for albedo should be reported when the soil is at or near field capacity. Albedo may be calculated from soil colour and spectral reflectance data (see Post *et al.*, 2000). Moist soil horizons in the NSD have a soil matrix colour code (Munsell colour system code) associated with them from which soil albedo may be estimated.

The most significant factors affecting soil albedo are the type and condition of vegetation covering the soil surface: soil moisture content, organic matter content, particle size, iron oxides, mineral composition, soluble salts and parent material (Baumgardner *et al.* 1985). Soil albedo is related to soil colour, moisture and roughness (Fontes, 1996). Soil colour is related to drainage properties.

The Munsell colour system is a colour space that specifies colours based on three colour dimensions: hue, value (lightness) and chroma (colour purity), also referred to as HVC. The Munsell colour value (in the horizon table, Matrix colour code of the NSD) is given in the format #/# where the first number is the medium value (lightness) and the second number is the chroma value (how weak or strong the colour is). YR is the Hue (or colour Yellow-Red), 6 is the value (or lightness/darkness) and 2 is the chroma (weak/strong). For example, in the code 10YR 6/3, it is the colour value 6 that needs to be taken in the following equation from Gijsman *et al.* (2007) to estimate soil albedo.

$$\text{Soil albedo (0.3 – 2.8 } \mu\text{m)} = 0.069 * (\text{colour value}) - 0.114. \quad r^2=0.93$$

For missing Munsell colour values, a default value of 0.13 (classified as brown by Gijsman *et al.* 2007) is used. It is uncertain whether the colour code reported in the NSD is a moist colour code and taken when the soil is at or near field capacity.

The Munsell colour code has been used to convert FAO soil datasets to albedo (e.g. Gies and Merwade, [https://web.ics.purdue.edu/~vmerwade/education/fao\\_soil\\_tutorial.pdf](https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf)).

Albedo is often measured directly today using new instruments (e.g. Sugathan, *et al.* 2014) and is also related to remote sensing. For example, Cierniewski *et al.* (2018) identified the effects of agricultural management practices on soil albedo using remote sensing.

#### 4.17 USLE\_K (top layer)

The soil erodibility factor (*K*-factor, or *K*) is a quantitative description of the inherent erodibility of a particular soil; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Soils high in clay have low *K* values, about 0.05 to 0.15 because they are resistant to detachment. Coarse textured soils, such as sandy soils, have low *K* value, about 0.05 to 0.2 because of low runoff even though these soils are easily detached. Medium textured soils, such as silt loam soils, have moderate *K* values, about 0.25 to 0.4 because they are moderately susceptible to detachment and they produce moderate runoff. Soils having a high silt content are most erodible of all soils. They are easily detached; tend to crust and produce high rates of runoff. Values of *K* for these soils tend to be greater than 0.4.

The erodibility factor is used as an input to the Universal Soil Loss Equation (USLE). This equation calculates soil erosion, which is inherently linked to sediment and nutrient transport. The erodibility factor was calculated using the method presented by Williams (1995), which is based on sand, silt, clay, and organic carbon content of the soil.

$$K_{USLE} = f_{csand} \cdot f_{cl-si} \cdot f_{orgc} \cdot f_{hisand}$$

Here,  $f_{csand}$  is a factor that gives low soil erodibility factors for soils with high coarse-sand contents and high values for soils with little sand,  $f_{cl-si}$  is a factor that gives low soil erodibility factors for soils with high clay to silt ratios,  $f_{orgc}$  is a factor that reduces soil erodibility for soils with high organic carbon content and  $f_{hisand}$  is a factor that reduces soil erodibility for soils with extremely high sand contents. The factors are calculated:

$$f_{csand} = (0.2 + 0.3e^{-0.256m_s(1-\frac{m_{silt}}{100})})$$

$$f_{cl-si} = (\frac{m_{silt}}{m_c + m_{silt}})^{0.3}$$

$$f_{orgc} = (1 - \frac{0.0256 \text{ orgC}}{\text{orgC} + e^{3.72-2.95\text{orgC}}})$$

$$f_{hisand} = 1 - \frac{0.7(1 - \frac{m_s}{100})}{(1 - \frac{m_s}{100}) + e^{-5.51+22.9(1-\frac{m_s}{100})}}$$

where  $m_s$  is the content of sand particle with particle size 0.05-2mm,  $m_{si}$  is the content of sediment with particle size 0.002-0.05mm,  $m_c$  is the content of clay with particle size less than 0.002mm. orgC is the organic carbon content of the soil layer (%).

The erodibility factor has the units (0.01 (ton.acre hr)/(acre-ft-ton in)) and the units were kept in Imperial units for consistency with the SWAT input format. The units are discussed by Foster *et al.* (1981). The range of values in the NSD agrees with ranges reported for Canada (Cordeiro, *et al.* 2016). USLE\_K is only required for the top soil layer and subsequent layers were assigned a value of zero.

The erodibility factor was calculated from data in the NSD.

Required.

#### 4.18 SOL\_EC (layer #)

Electrical conductivity (dS/m)

Not currently active

#### 4.19 SOL\_CAL (layer #)

Soil CaCO<sub>3</sub> (%). (0-50%)

Not currently active

#### 4.20 SOL\_PH (layer #)

Soil pH (3-10)

Not currently active

In a nationwide application of the SWAT model, the following has to be considered: 1) the use of as much NSD site identifiers (and corresponding good quality soils data), with as much one-to-one correspondence with soil classification 'name' and site identifier; 2) The NSD is very patchy with a lot of missing data; some tables in the NSD came from multiple sources and are not linked, and 3) the FSL is incomplete in the Gisborne area, and has to be treated in this area as an outlier, so one does not have the the option of using Soil symbols if a consistent system is required for the whole of New Zealand.

Table 6 gives a summary of the total number of unique names in the FSL and NSD by soil series, soil series codes, and soil type, and soil symbols and DOMNZSC (dominant NZSC).

	FSL	NSD
<b>Soil Series</b>	--	1915
<b>Soil Series codes</b>	1383	2069
<b>Soil type</b>	192	298*
<b>soil symbols (main soil)</b>	1962 including ice (ice), lake (lake), estu (estuaries), rive (river), town (town) and quar (quarries)	1938 Map symbols in nzmu 751 TP: Lab numbers associated with 950 unique correlation 'sets'
<b>DOMNZSC (dominant NZSC soil)</b>	201	--

Table 6. Number of Unique 'classes in the FSL and NSD

\*This includes repetition (e.g HUMIC SILT LOAM and (HUMIC) SILT LOAM).

There are three options for linking the FSL to the NSD.

### 5.1 Option 1. Linking by Soil Symbol

There seems to be a good correspondence (filed data) with Series mapping unit & Series number in the NSD with map unit and Map symbol in the NSD, but the correspondence is not one-to-one. For example the map symbol Ah could be Ahurir stony sand loam or Ahaura soils. And 27bH may be Ashcott hill soils or Ashcott sandy loam, hill soil. Also, AW and 90b could both be Awarua clay soils.

One obvious method is to overlay the re-projected NSD site location coordinates (point) polygons onto the FSL and intersect it within ArcGIS with the soil symbol layers (Figure 8). However, what is observed is that a great number of soil symbols and NZSC classes identified by overlaying do not correspond to information in the site table in the NSD. Also, the soil symbol identified by overlaying in many cases do not correspond to soil symbols within the correlation set in the *nzsoil* table of the NSD. Less than half of the total number of soil symbols could be picked up by intersection in this manner.



Figure 8: Sample identifiers overlaid onto the FSL by location

Ideally, what is needed is that every 'soil symbol' in the FSL needs to have a 'sample ID' associated with it. However, a unique one to one correspondence could not be obtained. Some (e.g. Soil symbol 47a) are associated with site ID's SB09289, SB09765, SB09630, SB09629, SB09631, SB09768, SB09628, and SB09627, and by choosing only one, ignores a lot of good datasets. There are 1323 sample ID's but only 473 identified from overlaying sample ID's and FSL polygons.

Although there are a greater number of SB identifiers that may be matched in the NSD by soil symbol, there are a greater proportion which require 'expert' knowledge and guessing to match soil symbol and site identifiers. A lot of very good quality data in the NSD may not be used at all.



### 5.3 Option 3. Linking by NZSC. Method 2

This method recognises the NSD as a database of point data, which it is. Associated with every (site) point in the NSD *site* table is a NZ Revised subgroup class, which is representative of a spatial area with the same soil. Spatial FSL DOMNZSC polygons which correspond to NZ Revised subgroup classes in the NSD could be used to find point data to represent spatial data.

There were so many factors to choose from using this method that the process needed to be done manually and by eye. The book *NZ Soil Classification* by Hewitt (2010) was used to match soils with no 'expert' knowledge necessary. Expert knowledge was necessary in matching soil symbols to derive the FSL, from having to choose a choice of soil symbols within a correlation set.

In choosing site numbers, sites were chosen to be representative with as much data as possible with no further processing necessary. Sites that did not need missing data to be estimated and added were given priority and a high quality value. The priority also was to choose sites with missing data that could easily be filled. If a site did not have coordinates, it was ignored. If there were two sites to choose and one had a litter layer which started with -20cm, the other which did not have a litter layer was chosen. Spelling mistakes that confound database querying were just considered an artefact of the database and not "fixed". For example, there is a "RF?" DOMNZSC class in the FSL which was not assigned RFA because there was no justification in doing so and was assigned a new class, RFU, for 'unknown'.

When assigning new codes for classes that exist in the FSL but not in the NSD, the following was considered. The original code was defined from the New Zealand Soil Classification by Hewitt (2010). Another soil from the same class which appeared to be similar was chosen, and if there were several to choose from, the soil with the greatest amount of data was chosen. When it was difficult, such as the case with anthropic soils AFST and ATT, a soil that was correlated was chosen instead from Hewitt (2010).

Sites with a large number of horizons and a lot of data were given priority.

There was no emphasis when choosing sites on whether it had the Munsell colour code or not.

Any data could be missing. There were some samples with missing horizons (e.g. SB09303 missing F). SB09506 starts at horizon C with no A or B.

A star score system was given to rate the data from one star to five stars. A five star had complete data and fewer stars had missing data and a comment added to record which data was missing.

It was found that later numbered samples often had more data and so the data was sorted by date when identifying.

A number of sites had a lot of excellent data to represent this class (e.g. PUJ, GOI, GAY, BAMP) but are not represented in the FSL. Table 7 shows the results of applying this reclassification system. The highlighted blue cells in the FSL.DOMNZSC represent soils that are not in the NSD which need to be assigned new subgroups according to Hewitt (2010). Ice, lake, quarries, town and estuaries are ignored for now but are treated as a soil later with sensible sediment parameter values later. Table 7 should be treated as a table to be continually refined.

NSD Site.NZ Revised subgroup	NSD Site.NZ Revised Soil class	FSL.DOMNZSC	New code to replace FSL.DOMNZSC that do not exist in NSD	comment/justification for replacing; with page number reference in Hewitt (2010)
		AFST	WGFU	Fill Anthropic. p.50; correlated with entisols, gley-raw soils
		ATT	WGFU	Truncated Anthropic Other soils. P.49; fill anthropic. p.50; correlated with entisols, gley-raw soils
BAM	Mottled Acid Brown Soil	BAM		
BAMP	Mottled-placic Acid Brown Soil			

BAO	Peaty Acid Brown Soil	BAO		
BAP	Placic Acid Brown Soil	BAP		
BAT	Typic Acid Brown Soil	BAT		
BFA	Acidic Firm Brown Soil	BFA		
		BFAL	BFA	Not referred to in Hewitt (2010).
		BFC	BFA	Cemented Firm Brown Soils, p.60
BFL	Allophanic Firm Brown Soil	BFL		
BFM	Mottled Firm Brown Soil	BFM		
		BFMA	BFM	Mottled-acidic Firm Brown Soils, p.59
BFP	Pallic Firm Brown Soil	BFP		
BFT	Typic Firm Brown Soil	BFT		
BLA	Acidic Allophanic Brown Soil	BLA		
BLAD	Acidic-pedal Allophanic Brown Soil	BLAD		
BLAM	Acidic-mafic Allophanic Brown Soil	BLAM		
BLD	Pedal Allophanic Brown Soil	BLD		
BLM	Mottled Allophanic Brown Soil	BLM		
BLT	Typic Allophanic Brown Soil	BLT		
BLX	Fragic Allophanic Brown Soil	BLX		
BMA	Acidic Mafic Brown Soil	BMA		
BMG	Magnesian Mafic Brown Soil	BMG		
BMM	Mottled Mafic Brown Soil	BMM		
BMMG	Mottled-magnesian Mafic Brown Soil			
BMT	Typic Mafic Brown Soil	BMT		
BO	Orthic Brown Soil			
BOA	Acidic Orthic Brown Soil	BOA		
		BOC	BO	Calcareous Orthic Brown Soils, p.62
BOH	Humose Orthic Brown Soil	BOH		
BOI	Immature Orthic Brown Soil	BOI		
BOM	Mottled Orthic Brown Soil	BOM		
BOMA	Mottled-acidic Orthic Brown Soil	BOMA		
BOP	Pallic Orthic Brown Soil	BOP		
BOT	Typic Orthic Brown Soil	BOT		
BSA	Acidic Sandy Brown Soil	BSA		
BSM	Mottled Sandy Brown Soil	BSM		
BSP	Pallic Sandy Brown Soil	BSP		
BST	Typic Sandy Brown Soil	BST		
BXT	Typic Oxidic Brown Soil	BXT		
		EMG	EMM	Mafic Melanic Soils. p.79
EMM	Mottled Mafic Melanic Soil	EMM		
EMT	Typic Mafic Melanic Soil	EMT		
EOC	Calcareous Orthic Melanic Soil	EOC		
EODC	Pedal-calcareous Orthic Melanic Soil	EODC		
EOJ	Argillic Orthic Melanic Soil	EOJ		
EOJC	Argillic-calcareous Orthic Melanic Soil	EOJC		
EOM	Mottled Orthic Melanic Soil	EOM		
EOT	Typic Orthic Melanic Soil	EOT		
EPJ	Argillic Perch-gley Melanic Soil			
EPT	Typic Perch-gley Melanic Soil	EPT		
		ERO	ERT	Peaty Rendzic melanic soils. p.80

EPV	Vertic Perch-gley Melanic Soil			
ERT	Typic Rendzic Melanic Soil	ERT		
ERW	Weathered Rendzic Melanic Soil	ERW		
		estu		estuary
		EVM	EVT	Mottled Vertic Melanic Soils, p.79
EVC	Calcareous Vertic Melanic Soil			
EVT	Typic Vertic Melanic Soil	EVT		
GAG	Granular Acid Gley Soil			
GAH	Humose Acid Gley Soil			
GAO	Peaty Acid Gley Soil	GAO		
		GAP	GAPH	Not referred to in Hewitt (2010).
GAPH	Placic-humose Acid Gley Soil			
GAT	Typic Acid Gley Soil	GAT		
GAY	Ultic Acid Gley Soil			
GOA	Acidic Orthic Gley Soil	GOA		
GOC	Calcareous Orthic Gley Soil	GOC		
GOE	Melanic Orthic Gley Soil	GOE		
GOI	Ironstone Orthic Gley Soil			
		GOM	GOT	Not referred to in Hewitt (2010).
GOO	Peaty Orthic Gley Soil	GOO		
		GOP	GOO	Not referred to in Hewitt (2010).
GOT	Typic Orthic Gley Soil	GOT		
GRA	Acidic Recent Gley Soil	GRA		
GRC	Calcareous Recent Gley Soil			
GRO	Peaty Recent Gley Soil	GRO		
GRQ	Saline Recent Gley Soil	GRQ		
GRT	Typic Recent Gley Soil	GRT		
GSC	Concretionary Sandy Gley Soil	GSC		
GSO	Peaty Sandy Gley Soil	GSO		
GST	Typic Sandy Gley Soil	GST		
GUF	Fluid Sulphuric Gley Soil	GUF		
GUFQ	Fluid-saline Sulphuric Gley Soil	GUFQ		
		ice		
		lake		
GUO	Peaty Sulphuric Gley Soil			
GUSQ	Sandy-saline Sulphuric Gley Soil			
LGT	Typic Gley Allophanic Soil	LGT		
LIM	Mottled Impeded Allophanic Soil	LIM		
LIT	Typic Impeded Allophanic Soil	LIT		
LOA	Acidic Orthic Allophanic Soil	LOA		
LOM	Mottled Orthic Allophanic Soil			
LOT	Typic Orthic Allophanic Soil	LOT		
LOV	Vitric Orthic Allophanic Soil	LOV		
LOVA	Vitric-acidic Orthic Allophanic Soil	LOVA		
LPT	Typic Perch-gley Allophanic Soil	LPT		
		MIM	MIW	Mottled Impeded Pumice Soils, p.108
		MIT	MIW	Typic Impeded Pumice Soils, p.108
MIW	Welded Impeded Pumice Soil	MIW		

		MOBA	MOBL	Not referred to in Hewitt (2010).
MOBL	Buried-allophanic Orthic Pumice Soil	MOBL		
		MOBT	MOBL	Not referred to in Hewitt (2010).
MOI	Immature Orthic Pumice Soil	MOI		
MOL	Allophanic Orthic Pumice Soil	MOL		
MOM	Mottled Orthic Pumice Soil	MOM		
MOT	Typic Orthic Pumice Soil	MOT		
MOZ	Podzolic Orthic Pumice Soil	MOZ		
		MPT	MOT	Typic Perch-gley Pumice Soils, p.107
NET	Typic Melanic Granular Soil			
NOA	Acidic Orthic Granular Soil	NOA		
NOM	Mottled Orthic Granular Soil	NOM		
NOMA	Mottled-acidic Orthic Granular Soil			
NOT	Typic Orthic Granular Soil	NOT		
		NPA	NXT	Acidic Perch-gley Granular Soils, p.73
		NPT	NXT	Typic Perch-gley Granular Soils, p.73
		NXA	NXT	Acidic Oxidic Granular Soils, p.74
NXL	Allophanic Oxidic Granular Soil			
		NXM	NXT	Mottled Oxidic Granular Soils, p.74
NXT	Typic Oxidic Granular Soil	NXT		
OFA	Acid Fibric Organic Soil	OFA		
OFS	Sphagmic Fibric Organic Soil	OFA		
OHA	Acid Humic Organic Soil	OHA		
OHM	Mellow Humic Organic Soil	OHM		
OLBZ	Buried-podzol Litter Organic Soil			
OLO	Orthic Litter Organic Soil			
OMA	Acid Mesic Organic Soil	OMA		
OMM	Mellow Mesic Organic Soil	OMM		
PID	Pedal Immature Pallic Soil	PID		
PIM	Mottled Immature Pallic Soil	PIM		
PIT	Typic Immature Pallic Soil	PIT		
		PJA	PJT	Aged Argillic Pallic Soils, p.97
PJC	Calcareous Argillic Pallic Soil	PJC		
PJM	Mottled Argillic Pallic Soil	PJM		
		PJN	PJT	Sodic Argillic Pallic Soils, p.97
PJT	Typic Argillic Pallic Soil	PJT		
PLM	Mottled Laminar Pallic Soil	PLM		
PLT	Typic Laminar Pallic Soil	PLT		
		PPF	PPJ	Not referred to in Hewitt (2010).
PP	Argillic Perch-gley Pallic Soil			
PPJ	Argillic Perch-gley Pallic Soil	PPJ		
PPJX	Argillic-fragic Perch-gley Pallic Soil	PPJX		
PPT	Typic Perch-gley Pallic Soil	PPT		
PPU	Duric Perch-gley Pallic Soil	PPU		
PPX	Fragic Perch-gley Pallic Soil	PPX		
PUJ	Argillic Duric Pallic Soil			
PUM	Mottled Duric Pallic Soil	PUM		
PXJ	Argillic Fragic Pallic Soil	PXJ		
		PXJC	PXJN	Argillic-calcareous Fragic Pallic Soils, p.96

		PXJM	PXJN	Argillic-mottled Fragic Pallic Soils, p.95
PXJN	Argillic-sodic Fragic Pallic Soil	PXJN		
PXM	Mottled Fragic Pallic Soil	PXM		
PXMC	Mottled-calcareous Fragic Pallic Soil	PXMC		
PXT	Typic Fragic Pallic Soil	PXT		
		quar		
		RF?	RFA	
RFA	Acidic Fluvial Recent Soil	RFA		
RFAW	Acidic-weathered Fluvial Recent Soil	RFAW		
RFM	Mottled Fluvial Recent Soil	RFM		
RFMA	Mottled-acidic Fluvial Recent Soil	RFMA		
RFMQ	Mottled-saline Fluvial Recent Soil	RFMQ		
RFT	Typic Fluvial Recent Soil	RFT		
RFW	Weathered Fluvial Recent Soil	RFW		
		rive		
		ROA	ROAW	Acidic Orthic Recent Soils p.120
ROAW	Acidic-weathered Orthic Recent Soil	ROAW		
ROM	Mottled Orthic Recent Soil	ROM		
ROT	Typic Orthic Recent Soil	ROT		
ROW	Weathered Orthic Recent Soil	ROW		
RSA	Acidic Sandy Recent Soil			
RSM	Mottled Sandy Recent Soil	RSM		
RST	Typic Sandy Recent Soil	RST		
		RTB	RTT	Not referred to in Hewitt (2010)
		RTBA	RTT	Not referred to in Hewitt (2010)
		RTBL	RTT	Buried-allophanic Tephric Recent Soils, p.119
		RTBP	RTT	Buried-pumice Tephric Recent Soils, p.119
		RTM	RTT	Mottled Tephric Recent Soils, p.119
RTT	Typic Tephric Recent Soil	RTT		
RXA	Acidic Rocky Recent Soil			
RXOA	Peaty-acidic Rocky Recent Soil			
RXT	Typic Rocky Recent Soil	RXT		
		SAH	SIT	Thick Aged-argillic Semiarid Soils,p.124
		SAM	SJM	Mottled Aged-argillic Semiarid Soils,p.124
		SAT	SJT	Typic Aged-argillic Semiarid Soils, p.124
		SAW	SIT	Weathered Aged-argillic Semiarid Soils, p.124
SIK	Alkaline Immature Semiarid Soil			
SIM	Mottled Immature Semiarid Soil			
SIT	Typic Immature Semiarid Soil	SIT		
SJK	Alkaline Argillic Semiarid Soil			
SJL	Laminar Argillic Semiarid Soil	SJL	SJT	

SJM	Mottled Argillic Semiarid Soil	SJM		
SJQ	Saline Argillic Semiarid Soil	SJQ		
SJT	Typic Argillic Semiarid Soil	SJT		
		town		
UDM	Mottled Densipan Ultic Soil	UDM		
UDP	Perch-gleyed Densipan Ultic Soil	UDP		
UEM	Mottled Albic Ultic Soil	UEM		
UEP	Perch-gleyed Albic Ultic Soil	UEP		
		UEY	UPT	Yellow Albic Ultic Soils, p.129
		UPS	UPT	Sandy Perch-gley Ultic Soils, p.129
UPT	Typic Perch-gley Ultic Soil	UPT		
UYG	Magnesian Yellow Ultic Soil			
UYM	Mottled Yellow Ultic Soil			
UYMZ	Mottled-podzolic Yellow Ultic Soil			
		UST	UYT	Typic Sandy Ultic Soils p.130
		UYM	UYT	Mottled Yellow Ultic Soils, p.130
UYT	Typic Yellow Ultic Soil	UYT	UYT	Typic Yellow Ultic Soils, p.130
UYZ	Podzolic Yellow Ultic Soil			
		WF	WGFU	Fluvial raw soils, p.113. No subgroups defined
		WGF	WGFU	Fluid Gley Raw Soils, p.112
WGFU	Fluid-sulphidic Gley Raw Soil	WGFU		
WGQ	Saline Gley Raw Soil			
		WH	WGQ	Hydrothermal Raw Soils, p.112
		WHA	WGQ	Active Hydrothermal Raw Soils, p.112
WO	Orthic Raw Soil	WO		
WS	Sandy Raw Soil	WS		
		WST	WS	Not referred to in Hewitt (2010).
		WT	WS	Tephritic raw soils, p.113
		WX	WS	Rocky raw soils, p.111
XNT	Typic Nodular Oxidic Soil	XNT		
XOB	Brown Orthic Oxidic Soil			
XOM	Mottled Orthic Oxidic Soil			
XOT	Typic Orthic Oxidic Soil	XOT		
XPN	Nodular Perch-gley Oxidic Soil			
XPT	Typic Perch-gley Oxidic Soil	XPT		
ZDH	Humose Densipan Podzol	ZDH		
ZDU	Humose Densipan Podzol			
ZDYH	Ultic-humose Densipan Podzol			
		ZGT	ZPU	Typic Groundwater-gley Podzols, p.114
ZOH	Humose Orthic Podzol	ZOH		
ZOT	Typic Orthic Podzol	ZOT		
ZPF	Fluid Perch-gley Podzol			
ZPH	Humose Perch-gley Podzol	ZPH		
ZPHQ	Humose-ortstein Perch-gley Podzol			
ZPOZ	Peaty-silt-mantled Perch-gley Podzol	ZPOZ		
ZPP	Placic Perch-gley Podzol	ZPP		
ZPQ	Ortstein Perch-gley Podzol			

ZPT	Typic Perch-gley Podzol	ZPT		
ZPU	Humus-pan Perch-gley Podzol	ZPU		
ZPZ	Silt-mantled Perch-gley Podzol	ZPZ		
		ZXF	ZPT	Firm pan podzols, p.104
ZXH	Humose Pan Podzol	ZXH		
ZXP	Placic Pan Podzol	ZXP		
ZXQ	Ortstein Pan Podzol	ZXQ		
ZXU	Humus-pan Pan Podzol	ZXU		

Table 7 The NSD NZ Revised subgroup symbols and corresponding full NSD Revised Soil classes. The highlighted blue cells in the FSL.DOMNZSC represent soils that are not in the NSD which need to be assigned new subgroups according to Hewitt (2010). Ice, lake, quarries, town and estuaries are ignored. Yellow highlighted ones show concerns which could affect the join process.

Table 8 shows the primary choice and a secondary choice is given along with a rating of the quantity and quality of data and a justification comment.

FSL.DOMNZSC	FSL.DOMNZSC amended	Primary choice	Secondary choice	Data rating	comment
AFST	AFST	SB09307	SB09308	***	no moisture, no PS
ATT	ATT	SB09307	SB09308	***	no moisture, no PS
BAM	BAM	SB09870		****	no moisture
BAO	BAO	SB08979		**	no moisture, no PS
BAP	BAP	SB09330		****	no moisture
BAT	BAT	SB10046	SB09917	****	
BFA	BFA	SB09447	SB09448	*****	
BFAL	BFA	SB09447		*****	
BFC	BFA	SB09947		*****	
BFL	BFL	SB10138		*****	
BFM	BFM	SB10163		*****	
BFMA	BFM	SB10163		*****	
BFP	BFP	SB10155		*****	
BFT	BFT	SB09942		*****	
BLA	BLA	SB09990		*****	
BLAD	BLAD	SB09885		*****	
BLAM	BLAM	SB09999		*****	
BLD	BLD	SB09941		*****	
BLM	BLM	SB08590		***	no moisture, no PS
BLT	BLT	SB010147	SB09911	*****	
BLX	BLX	SB09574		*****	
BMA	BMA	SB10135	SB09996	*****	
BMG	BMG	SB09588		****	no moisture
BMM	BMM	SB09210	SB09211	***	no moisture, no PS
BMT	BMT	SB09518		****	no moisture
BOA	BOA	SB10157		*****	
BOC	BO	SB09645		***	no moisture
BOH	BOH	SB10095		*****	
BOI	BOI	SB09749		*****	
BOM	BOM	SB10150		*****	
BOMA	BOMA	SB09978		*****	
BOP	BOP	SB10151		*****	
BOT	BOT	SB10178	SB10133	*****	
BSA	BSA	SB09973	SB09938	*****	
BSM	BSM	SB09859		****	no dry BD
BSP	BSP	SB10164		*****	
BST	BST	SB10013		*****	

BXT	BXT	SB08970		***	no moisture
EMG	EMM	SB10008		*****	
EMM	EMM	SB10008		*****	
EMT	EMT	SB09998		*****	
EOC	EOC	SB08562		**	no moisture, no PS
EODC	EODC	SB09353		**	no moisture, no PS
EOJ	EOJ	SB10100	SB09959	*****	
EOJC	EOJC	SB08040		**	no moisture, no PS
EOM	EOM	SB09370		**	no moisture, no PS
EOT	EOT	SB10103	SB09291		
EPT	EPT	SB09773		*****	
ERO	ERT	SB08717		**	no moisture, no PS
ERT	ERT	SB08717		**	no moisture, no PS
ERW	ERW	SB08303		**	no moisture, no PS
estu	estu				
EVM	EVT	SB09893		*****	
EVT	EVT	SB09893		*****	
GAO	GAO	SB08925		***	no moisture
GAP	GAPH	SB09506		***	no moisture
GAT	GAT	SB10017	SB09792	*****	
GOA	GOA	SB09803	SB09727	*****	
GOC	GOC	SB09377		*****	
GOE	GOE	SB10047	SB09636	*****	
GOM	GOT	SB10116	SB10091	*****	
GOO	GOO	SB09880		*****	
GOP	GOO	SB09880		** **	
GOT	GOT	SB09945	SB09933	*****	
GRA	GRA	SB09928	SB09925	*****	
GRO	GRO	SB09827	SB09927	** **	
GRQ	GRQ	SB09825		*****	
GRT	GRT	SB10123	SB09926	*****	
GSC	GSC	SB10032		*****	
GSO	GSO	SB10028		*****	
GST	GST	SB08675		**	no moisture, no PS
GUF	GUF	SB09309		**	no moisture, no PS
GUFQ	GUFQ	SB0930		**	no moisture, no PS
ice	ice				
lake	lake				
LGT	LGT	SB09909		*****	
LIM	LIM	SB09800		*****	
LIT	LIT	SB09313	SB09558	***	
LOA	LOA	SB09888	SB09842	*****	
LOT	LOT	SB 0119	SB10120	*****	
LOV	OV	SB09860	SB10090	*****	
LOVA	LOVA	SB09707		*****	
LPT	LPT	SB09709		*****	
MIM	MIW	SB09982		*****	
MIT	MIW	SB09982		*****	
MIW	MIW	SB09982		*****	
MOBA	MOBL	SB08994		**	incomplete psd, no moisture
MOBL	MOBL	SB08994		**	
MOBT	MOBT	SB08994		**	
MOI	MOI	SB09824	SB09796	*****	
MOL	MOL	SB09831		*****	D horizon missing
MOM	MOM	SB09798		*****	
MOT	MOT	SB09828		*****	
MOZ	MOZ	SB08847		*****	
MPT	MOT	SB09828		*****	
NOA	NOA	SB08226			no moisture, no PS
NOM	NOM	SB09450			no moisture
NOT	NOT	SB09947		*****	
NPA	NXT	SB09579		*****	
NPT	NXT	SB09579		*****	
NXA	NXT	SB09579		*****	

NXM	NXT	SB09579		*****	
NXT	NXT	SB09579		*****	
OFA	OFA	SB09948		***	no PS. Peat and sand, only E horizon
OFS	OFS	SB09334		**	no moisture, no PS
OHA	OHA	SB09993	SB09951	*****	
OHM	OHM	SB10114		*****	
OMA	OMA	SB09794		*****	
OMM	OMM	SB09850		*****	
PID	PID	SB10132		*****	
PIM	PIM	SB10104		*****	
PIT	PIT	SB10109	SB10108	*****	
PJA	PJT	SB09921	SB09961	*****	
PJC	PJC	SB09355		**	no moisture, no PS
PJM	PJM	SB09961	SB09921	*****	
PJN	PJT	SB10053		*****	
PJT	PJT	SB10053		*****	
PLM	PLM	SB09216		***	no moisture, no PS
PLT	PLT	SB10048	SB09838	*****	
PPF	PPJ	SB10094		*****	
PPJ	PPJ	SB10094		*****	
PPJX	PPJX	SB10099	SB10083	*****	
PPT	PPT	SB10152		*****	
PPU	PPU	SB09822		*****	
PPX	PPX	SB10002	SB09989	***	
PUM	PUM	SB09761		***	no moisture, no PS
PXJ	PXJ	SB09533		***	no moisture
PXJC	PXJN	SB09383		*****	
PXJM	PXJN	SB09383		*****	
PXJN	PXJN	SB09383		*****	
PXM	PXM	SB10129		***	
PXMC	PXMC	SB10129		*****	
PXT	PXT	SB10001		*****	
quar	quar				
RF?	RFA	SB08715		*****	
RFA	RFA	SB08715		*****	
RFAW	RFAW	SB08977		***	no moisture, no PS
RFM	RFM	SB10125		*****	
RFMA	RFMA	SB09790		*****	
RFMQ	RFMQ	SB09758		*****	
RFT	RFT	SB10102	SB10124	*****	
RFW	RFW	SB10105	SB10101	*****	
rive	rive				
ROA	ROAW	SB09491		***	
ROAW	ROAW	SB09491		***	
ROM	ROM	SB10154		*****	
ROT	ROT	SB10161		*****	
ROW	ROW	SB10111	SB10149	*****	
RSM	RSM	SB08671		****	
RST	RST	SB09819	SB09817	*****	
RTB	RTT	SB10179	SB09381		
RTBA	RTT	SB10179	SB09381		
RTBL	RTT	SB10179	SB09381		
RTBP	RTT	SB10179	SB09381		
RTM	RTT	SB10179	SB09381		
RTT	RTT	SB10179	SB09381		
RXT	RXT	SB10070		*****	no moisture
SAH	SIT	SB10162		*****	
SAM	SJM	SB09891		*****	
SAT	SJT	SB09900	SB09895	*****	
SAW	SIT	SB10162		*****	
SIT	SIT	SB10162		*****	
SJL	SJT	SB09895	SB09900	*****	
SJM	SJM	SB09891		*****	

SJQ	SJQ	SB09899		*****	
SJT	SJT	SB09895	SB09900	*****	
town	town				
UDM	UDM	SB10020	SB10019	*****	
UDP	UDP	SB10022	SB10021	*****	
UEM	UEM	SB09292		*****	
UEP	UEP	SB09542		****	no moisture
UEY	UPT	SB08923		****	no moisture
UPS	UPT	SB08923		****	no moisture
UPT	UPT	SB08923		****	no moisture
UST	UYT	SB09642		*****	
UYM	UYT	SB09642		*****	
UYT	UYT	SB09642		*****	
WF	WGFU	SB09307	SB09308	***	no moisture, no PS
WGF	WGFU	SB09307	SB09308	***	no moisture, no PS
WGFU	WGFU	SB09307	SB09308	***	no moisture, no PS
WH	WGQ	SB09299		***	no moisture, no PS
WHA	WGQ	SB09299		***	no moisture, no PS
WO	WO	SB08381		***	no moisture, no PS
WS	WS	SB08933		***	no moisture, no PS
WST	WS	SB08933		***	no moisture, no PS
WT	WS	SB08933		***	no moisture, no PS
WX	WS	SB08933		***	no moisture, no PS
XNT	XNT	SB10060		*****	
XOT	XOT	SB10061		*****	
XPT	XPT	SB10059		** **	
ZDH	ZDH	SB08756		*****	no moisture
ZGT	ZPU	SB09936		*****	
ZOH	ZOH	SB10121	SB09795	* **	
ZOT	ZOT	SB10080		*****	
ZPH	ZPH	SB09877		*****	
ZPOZ	ZPOZ	SB09514		****	no moisture
ZPP	ZPP	SB10014		*****	
ZPT	ZPT	SB08888		****	no moisture
ZPU	ZPU	SB09936		*****	
ZPZ	ZPZ	SB09979	SB09522	*****	
ZXF	ZPT	SB08888		****	no moisture
ZXH	ZXH	SB09975		*****	
ZXP	ZXP	SB09974		****	missing horizon
ZXQ	ZXQ	SB09783		*****	single horizon
ZXU	ZXU	SB07742		***	no moisture, no PS

Table 8. FSL DOMNZSC represents the dominant soil in the Fundamental Soils Layer (FSL) classified by the New Zealand Soil Classification (NZSC). The blue highlighted cells represent soils which do not have a corresponding NZ Revised soil class in the NSD. The FSL.DOMNZSC\_amended column represents similar soils from Hewitt (2010), with a good match of data from the NSD. A primary choice and a secondary choice is given along with a rating of the quantity and quality of data. Yellow highlighted ones show concerns which could affect the join process.

## 6 USER SOILS

An excel spreadsheet usersoils.xls is prepared and imported into SWAT2012.mdb as the usersoil table. The red highlighted entries indicate modelled data and not measurement data (Table 9). Silt which is determined from sand and clay percent is not highlighted in red if sand and clay values are given.

NLAYERS	HYDGRP	SOL_ZMX	ANION_EX_SOL_CRK	TEXTURE	SOL_Z1	SOL_BD1	SOL_AWC1	SOL_K1	SOL_CBN1	CLAY1	SILT1	SAND1	ROCK1	SOL_ALB1	USLE_K1
1	D	100	0.5	0.5 silty clay	100	1	0.17	26.94	9.4	34	54	12	0	0.162	0.229772
1	D	100	0.5	0.5 silty clay	100	1	0.17	26.94	9.4	34	54	12	0	0.162	0.229772
1	D	100	0.5	0.5 silty clay loam	100	1.06	0.14	17.87	8.2	42.82	48.04	9.14	0	0.162	0.232552
1	B	50	0.5	0.5 silt loam	50	1.05	0.22	48.52	6	14	65	21	0	0.093	0.225802
1	B	190	0.5	0.5 silt loam	190	0.86	0.23	103.06	7.9	8	62.3	29.7	0	0.093	0.239822
1	B	180	0.5	0.5 silt loam	180	0.395	0.15	41.15	11.6	24	54.65	21.35	7	0.093	0.196692
1	B	80	0.5	0.5 silt loam	80	1.01	0.318	14.36	5.3	34	53.65	12.35	0	0.162	0.226471
1	B	80	0.5	0.5 silt loam	80	1.01	0.318	14.36	5.3	34	53.65	12.35	0	0.162	0.226471
1	D	90	0.5	0.5 silty clay loam	90	0.94	0.295	11.13	4	30.36	51.01	18.63	0	0.093	0.193962
1	B	200	0.5	0.5 silt loam	200	0.865	0.248	39.32	8.6	29	61.58	9.42	0	0.024	0.276662
1	B	90	0.5	0.5 silt loam	90	0.858	0.304	20.98	5.6	31	64.79	4.21	0	0.093	0.351182

Table 9. Screenshot of Excel spreadsheet of usersoil.xls. Note that the red indicates ‘modelled’ data and not measurement data in the NSD. This data also represents data from the top horizon.

Datasets of this form are useful to a variety of research communities including hydrological, agricultural and water quality modellers and are publicly available at (e.g. SWAT usersoil Excel spreadsheet for Canada may be downloaded from <https://www.earth-syst-sci-data-discuss.net/essd-2017-66/>).

This file is finally imported into SWAT2012.mdb and may be modified using the SWAT Editor without having to go through the whole process again.

Table 10. Screenshot of MS Access database showing of usersoil table

For ice, lake and river class in the FSL, the following was assumed: Clay, sand, silt, rock=0; CBN=0.05; AWC=1; BD=1; SOIL\_Z1=100; USLE\_K1=0.1, SOL\_K1=0.01, SOL\_ALB1=0.1, Texture: blank, Hydrological Gp: D Also, the texture is water, otherwise the model would not run.

Estu: Clay (25), sand (25), silt (50), rock=0; CBN=5; SOL\_AWC=1, BD=1; SOL\_K=200; SOL\_ALB=0.25. USLE\_K= 0.65; Texture: estuary.

Quar: Clay (50), sand (25), silt (25), rock=0; CBN=1; SOL\_AWC=0, BD=1.2; SOL\_K=100; SOL\_ALB=0.25. USLE\_K= 0.65; Texture: quarry

town: Clay, sand, silt, rock=0; CBN=0.05; SOL\_AWC=0, BD=1; SOL\_K=0; SOL\_ALB=0.25; USLE\_K=0.1. Texture: town

The SWAT2012.mdb may be renamed SWAT2012NZ for New Zealand and this includes the “user soil” table as well as other parameters (landuse, etc.) that are relevant to New Zealand. However, it is more common to keep the file with the same name but to remember that it is local soils, landuse, tables that are used, when necessary.

The New Zealand Fundamental Soil Layer originates from an expert derived join of attributes measured in the National Soils Database (NSD) and the polygon boundaries of the New Zealand Land Resource Inventory (NZLRI). This process has been undocumented and part of the process in this work is to understand how the FSL was created from the NZLRI. It is understood that the join is by using Soil 'Symbols' and a rough analysis shows that perhaps less than a third of the data in the NSD might actually be used in the join.

Although the above work prepares a join between the NSD and the FSL polygons, to be used to prepare a country-wide soils dataset for use in the SWAT model, what has essentially been done in the process has been the creation of a new Fundamental Soils Layer based on joining the FSL (aka LRI) polygons to the NSD, and in the process providing many more new fields that are available in the NSD. However, much less than 200 of the 1500 of the datasets in the NSD is actually used to join using NZSC codes.

There were many issues identified with joining the LRI-FSL polygons to the NSD, and some of these are identified in this report. As a result, there is considerable uncertainty in the soil data input results to the SWAT model.

One of the main concerns is that the LRI-FSL as a pseudo soils map does not use any soil data such as soil legacy maps to delineate polygons. This means that other newer much improved techniques could also be used that also do not make use of soil data to delineate polygons. These methods may use most if not all datasets (including profile data) in the NSD, use DEM and satellite images to create a digital soil raster layer and produce soil datasets in SWAT input file format. The Soil-Landscape estimation and Evaluation Program (SLEEP) by FAO and SWAT modelling scientist's was developed to predict spatial distribution of soil attributes for environmental modelling (Ziadat *et al.* 2015). In that work, where more detailed soil survey maps were not available, data on geology, topography, vegetation, and climate were assembled and related to satellite images. SLEEP uses measured soil properties (e.g. soil depth and percentage content of clay, silt, sand, stone and organic matter) at different locations in a catchment along with the geographical co-ordinates of the measurement locations, to produce the spatially distributed soil properties for the whole catchment in the form of raster data, and for different soil horizons. These catchment distributed soil properties may be converted to database form. The model produces output suitable for SWAT. This means that much of the work this report on preparing data inputs for SWAT will need to be replaced using this much improved method.

Ideally, what is needed is a system where soil polygons are not changing all the time when new data is collected as done with newer digital soil mapping methods but rather a system where databases of point data are updated regularly. This also avoids the tedious overlay process within SWAT.

The use of S-map which supersedes FSL, was also explored in this work and was found to be quite useful for cross-checking. Parshotam and Robertson (2018) suggest that S-map when completed should provide a seamless digital soil map coverage for New Zealand and should complement existing data needed in SWAT. However, it seems that it is not only spatial layers that are important for SWAT but soil profile information and this is mostly given in the NSD. Much of the soil attributes data required by SWAT is not given in S-map, which might be more appropriate for farm systems models. S-map does however make use of soil legacy maps (from the 1950s) to delineate polygons in some areas around the country. A 'non-local' classification system is used. S-map online individual fact sheets or soil reports were of some use but databases would be of far greater use. There was also a cost involved with purchasing the soil polygons which used to be freely available and there were further reasons it was found not suitable for the project. S-map only covered a third of the country and a consistent methodology was required. A lot of data is given as a range (eg. 0-40% stones, clay 0-20%) and represents an area rather than a representative sample. Samples in the NSD is a representative sample using a well-established methodology and before a sample was taken, the site was scoped and a sample was taken to represent an area. As a statistical model, if one take lots of samples, one will continue to get S-map but if one take S-map as it is one will not get lots of sampling data. There is still a great need for more accurate soil profile data to build up a good working database. Concepts such as the hydrological groups would be useful and to this project but no reference was found to describe how it was determined within S-map. Pedotransfer functions used in S-map were referred to

in a general sense and it was difficult to find specific references as there are so many pedotransfer functions for the various soil attributes. There was no system for determining what was model data and what was measurement data.

Today, what is encouraged is that there should be two datasets: the first containing only raw 'measurement' data, and the second with "filled", or modelled data which is identified by its colour in red. This makes it clear to a user when one is using data of whether it is actual measurement data or data that is fitted from a model. There was no success with colour coding changes made in a working copy of the NSD. Error checking and fixing data in the NSD so that queries would perform better was documented.

This report does not address soil data resolution. The influences of soil data set resolution on hydrologic modelling is discussed by Peschel *et al.* (2006).

## 8 REFERENCES

- Abdelbaki AM. 2016. Evaluation of pedotransfer functions for predicting soil bulk density for U.S. soils. *Ain Shams Eng J.*, <http://dx.doi.org/10.1016/j.asej.2016.12.002>.
- Arnold, J.G., Potter, K.N., King, K.W., and Allen, P.M. 2005. Estimation of soil cracking and the effect on surface runoff in a Texas Blackland Prairie watershed. *Hydrological Processes*. Vol 19: 589-603. <https://doi.org/10.1002/hyp.5609>
- Bauer, J.U., S.H. Anderson, and K.S. McGinty. 1993. Quantifying desiccation cracking in a Missouri claypan soil. *Agricultural Research to Protect Water Quality, Soil and Water Cons. Soc. Minnesota*: 378-381.
- Baumgardner, M.F.; Sylva, L.F.; Biehl, L.L.; Stoner, E.R. Reflectance Properties of Soils. *Adv. Agron.* 1985, 38, 1-44.
- Bronswijk, J.J.B. 1989. Prediction of actual cracking and subsidence in clay soils. *Soil Science*. 148:87-93.
- Bronswijk, J.J.B. 1990. Shrinkage geometry of a heavy clay soil at various stresses, *Soil Science Soc. Am. J.* 54: 1500-1502.
- Chambel-Leitão, P., Almeida, C., Weynants, M. Tóth, G. & Tóth, B. and Neves, R. (2012). A European SWAT soil database Paper presented at the 2012 International SWAT Conference and Workshops, New Delhi, India
- Cichota, R., Vogeler, I., Snow, V., Webb, R. 2013. Ensemble pedotransfer functions to derive hydraulic properties for New Zealand soils. *Soil Research*. 51: 94-111.
- Cierniewski, J., Ceglarek, J., Karnieli, A., Ben-Dor, E., Królewicz, S. and Kaźmierowski, C. 2018. Shortwave Radiation Affected by Agricultural Practices. *Remote Sensing*. 10, 419, doi:10.3390/rs10030419
- Cordeiro, M. R. C., Lelyk, G., Kröbel, R., Legesse, G., Faramarzi, M., Masud, M. B., McAllister, T. 2017. Deriving Canada-wide soils dataset for use in Soil and Water Assessment Tool (SWAT). PANGAEA, <https://doi.org/10.1594/PANGAEA.877298>, Supplement to: Cordeiro, MRC et al. (2017): Deriving a country-wide soils dataset from the Soil Landscapes of Canada (SLC) database for use in Soil and Water Assessment Tool (SWAT) Simulations. *Earth System Science Data Discussions*, 30 pp, <https://doi.org/10.5194/essd-2017-66>.
- Dasog, G.S., Acton, D.F., Mermut, A.R., and De Jong, E., 1988. Shrink-swell potential and cracking in clay soils of Saskatchewan. *Can J. Soil Sci.* 68: 251-260. Accessed from <http://www.nrcresearchpress.com/doi/pdf/10.4141/cjss88-025>
- Fontes, A. F., 1996. Soil Albedo in relation to soil colour, moisture and roughness. PhD thesis. University of Arizona.

- Foster, G. R., McCool, D. K., Renard, K. G., and Moldenhauer, W. C. 1981. Conversion of the 466 universal soil loss equation, *Journal of Soil and Water Conservation*, 36, 355-359.
- Ghanbarian, B., Taslimitehrani, V., and Pachepsky, Y.A. 2016. Scale-dependent pedotransfer functions reliability for estimating saturated hydraulic conductivity. <https://arxiv.org/pdf/1610.06958v1.pdf>.
- Gies, L. and Merwade, V. Creating SWAT Soil Database using FAO Soil and Terrain Database of East Africa (SOTER) Data. Available from [https://web.ics.purdue.edu/~vmerwade/education/fao\\_soil\\_tutorial.pdf](https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf)
- Gijsman, A., Thornton, P.K. Hoogenboom, G. 2007. Using the WISE database to parameterize soil inputs for Crop Simulation Models. *Computers and Electronics in Agriculture*. 56(2): 85-100. <https://doi.org/10.1016/j.compag.2007.01.001>.
- Hewitt AE 2010. New Zealand Soil Classification. 3rd edn. Landcare Research Science Series No. 1. Lincoln, Manaaki Whenua Press.
- McNeill, S.J., Lilburne, L.R., Carrick, S., Webb, T.H. and Cuthill, T. 2018. Pedotransfer functions for the soil water characteristics of New Zealand soils using S-map information *Geoderma*. 326 96-110.
- Menberu, M.W., Haghighi, A.T., Ronkanen, A-K., Kværner, J. 2015. Runoff Curve Numbers for Peat-Dominated Watersheds. *J. Hyd Eng.* 20(4):04014058.
- Milne JDG, Clayden B, Singleton PL, Wilson AD 1995. Soil description handbook. Lincoln, Manaaki Whenua Press.
- Minnesota Pollution Control Agency, (MPCA). 2013. Minnesota Stormwater Manual, Overview of Basic Stormwater Concepts. Available online at: [http://stormwater.pca.state.mn.us/index.php/Main\\_Page](http://stormwater.pca.state.mn.us/index.php/Main_Page)
- Parshotam, A. Tate, K., Giltrap. 1995. Potential effects of climate and land use change on soil carbon and CO2 emissions from New Zealand's indigenous forests and unimproved grasslands. *Weather and Climate*. 152, 47-45. *Weather and Climate*. Accessed from [http://www.metsoc.org.nz/sites/default/files/journals/15/2/articles/1995\\_152\\_47-56\\_parshotam.pdf](http://www.metsoc.org.nz/sites/default/files/journals/15/2/articles/1995_152_47-56_parshotam.pdf)
- Parshotam A., 2008. Central Waitemata Harbour Contaminant Study. GLEAMS model results for rural and earthworks sediment loads from the catchment. Prepared by DHI Water & Environment Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2008/041.
- Parshotam, A., Wadhwa, S. and Mullan, B. (2009). Tauranga Harbour Sediment Study. Sediment Load Model Implementation and validation. NIWA report number HAM2009-007. Prepared for Environment Bay of Plenty.
- Peschel, J., Haan, P. and Lacey, R.E. 2007. Influences of soil dataset resolution on hydrologic modelling, *JAWRA Journal of the American Water Resources Association*. 42(5). Accessed from <https://doi.org/10.1111/j.1752-1688.2006.tb05307.x>
- Pollacco, J., Lilburne, L., Webb, T., and Wheeler, D. 2014. Preliminary assessment and review of soil parameters in OVERSEER 6.1 Landcare Research Report. September 2014. Accessed from <https://www.overseer.org.nz/files/download/214da86c9e6fc9b>.
- Pollacco, J.A.P, Webb, T., McNeill, S., Hu, W., Carrick, S., Hewitt, A., Lilburne, L. 2016. Physical pedotransfer functions to compute saturated hydraulic conductivity from bimodal characteristic curves for a range of New Zealand soils. *Hydrol. Earth Syst. Sci. Discuss.*, doi:10.5194/hess-2016-636
- Post, D.F., Fimbres, A., Matthias, A.D., Sano, E.E., Accioly, L., Batchily, A.K. and Ferreira, L.G., 2000, Predicting Soil Albedo from Soil Color and Spectral Reflectance Data. *Soil Sci. Soc. Am. J.* 64: 1027-1034.
- Rivera, L.D., Morgan, C.L.S., Kishne, A.S., McInnes, K.J., Hallmark, C.T. and Hutchinson, K.M. 2014. Estimating Crack Volume in Two Shrink-Swell Soils <https://www.researchgate.net/publication/228376762>
- Sarkar, S., Vaibhav, V., and Singh, A. 2016. Simulating hydrological processes in and agricultural watershed using SWAT Model. 2nd World Irrigation Forum, 6-8 November, Thailand. Accessed from [http://www.icid.org/wif2\\_full\\_papers/wif2\\_w.1.3.05.pdf](http://www.icid.org/wif2_full_papers/wif2_w.1.3.05.pdf)

- Saxton, K.E., and Rawls, 2006. W.J. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. *Soil Sci Soc. Am. J.* 79: 1569-1578.
- Sharpley, A. N., and Williams, J. R.: EPIC-erosion/productivity impact calculator: 1. Model 518 documentation, Technical Bulletin-United States Department of Agriculture, 1990. <http://epicapex.tamu.edu/files/2015/05/EpicModelDocumentation.pdf>
- Sheshukov, A., Daggupati, P., Lee, M-C., and Douglas-Mankin, 2009. ArcMap Tool for Pre-processing SSURGO Soil Database for ArcSWAT. Presented at the 5<sup>th</sup> SWAT International Conference in Boulder, CO – 5 -7 Aug, 2009. Accessed from <https://swat.tamu.edu/docs/swat/conferences/2009/C2-Sheshukov.pdf>
- Sugathan, N., Biju, V. and Renuka, G. 2014. Influence of soil moisture content on surface albedo and soil thermal parameters at a tropical station. *J. Earth Syst. Sci.* 125(5): 1115-1128.
- Tate, K.R., Giltrap, D.J., Claydon, J.J., Newsome, P.F., Atkinson, I., Taylor, M.D. & Lee, R. 1997. Organic carbon stocks in New Zealand's terrestrial ecosystems, *Journal of the Royal Society of New Zealand*, 27:3, 315-335, DOI: 10.1080/03014223.1997.9517541
- Vaught, R., Brye, K.R., Miller, D.M. 2006. Relationship among Coefficient of Linear Extensibility and Clay Fractions in Expansive, Stoney Soils. *Soil Sci Soc. Am. J.* 79: 1983-1990.
- Webb, T.H., Claydon, J.J., Harris, S.R. 2000. Quantifying variability of soil physical properties within soil series to address modern land-use issues on the Canterbury Plains, New Zealand. *Australian Journal of Soil Research*. 38(6): 1115-1129.
- Wheeler DM, and Rutherford JC 2016. *OVERSEER* Technical manual: Hydrology, AgResearch, ISSN: 2253-461X, Accessed from <https://www.overseer.org.nz/files/download/2b9a6d44dcc40d8>
- Williams, J.R. 1995. Chapter 25. The EPIC Model. p. 909-1000. In Singh, V.P. Ed., *Computer Models of Watershed Hydrology*. Water Resources Publications. Highlands Ranch. CO.
- Ziadat, F., Dhanesh, Y., Shoemate, D., Srinivasan, R., Narasimhan, B., and Tech, J. 2015. Soil-Landscape Estimation and Evaluation Program (SLEEP) to predict spatial distribution of soil attributes for environmental modelling. *Int J Agric & Biol Eng.* 8(3): 1-15. Accessed from [https://swat.tamu.edu/media/115182/sleep\\_ijabe.pdf](https://swat.tamu.edu/media/115182/sleep_ijabe.pdf).

## Appendix A: Relevant Tables in the NSD

The following gives a brief summary and description of the relevant tables in the NSD. There are 579 catalog id's which correspond to unique fieldnames. The tables are *nsd\_dictionary*, *nsd\_data*, *nsd\_chemistry*, *nsd\_horizon*, *nsd\_mineralogy*, *nsd\_moisture*, *nsd\_nzmethod*, *nsd\_nznote*, *nsd\_nzsoil*, *nsd\_particlesize*, *nsd\_sample*, *nsd\_site*, *nsd\_soilstore*, *nsd\_survey*, and *nzs\_xrayfluorescence*. In addition, there is a table *nsd\_nzmu*, which is not referred to in datadictionary and seems to have been added later and it is a strange that *Mapunit\_uid* table is not referenced anywhere

### Locations

This table is referred to in the data dictionary but does not exist. Location data may be found, however in the site table. It is also not referred to in the metadata table.

Fullname	fieldname	units	description
site_id	Identity	m	Site identity as in Site table
mg_east	East (NZMG)	m	Easting in NZMG Projection (Datum NZGD1949)
mg_north	North (NZMG)	m	Northing in NZMG Projection (Datum NZGD1949)
tm_east	East (NZTM)	m	Easting in NZTM Projection (Datum NZGD2000)
tm_north	North (NZTM)	m	Northing in NZTM Projection (Datum NZGD2000)

Table A1. The fields and their descriptions in the locations table in the NSD.

### Horizon.

This table gives good information about the depths of the individual soil horizons. Also included is the colour code. There is also texture information here.

Fullname	fieldname	description
Auger consistence	auger_consistence	An estimation of auger consistency.
Ident	ident	A unique identifier for the soil profile assigned in the laboratory.
Horizon number	horizon_number	A number assigned to the soil horizon in the field.
Field ident	field_ident	An identifier assigned by the author for his/her own use.
Designation	designation	A designation for the soil horizon from Soil Survey Method.
FAO Designation	fao_designation	A designation for the soil horizon from the FAO handbook.
New Zealand Designation	new_zealand_designation	A designation for the soil horizon from the New Zealand Soil Classification.
Top	top	The depth to the top of the soil horizon.
Base	base	The depth to the base of the soil horizon.
Thickness	thickness	The depth to the bottom of the soil horizon minus the depth to the top of the soil horizon.
Depth	depth (cm)	The depths to the top and bottom of the soil sample or horizon.
Moisture	moisture	An indication of how moist the soil horizon is.
Matrix colour code	matrix_colour_code	The code for the colour of the soil matrix.
Matrix colour	matrix_colour	The colour of the soil matrix.
Secondary matrix col code	secondary_matrix_col_code	The colour code for the secondary soil matrix.
Secondary matrix colour	secondary_matrix_colour	The colour of the secondary soil matrix.
Ped face colour code	ped_face_colour_code	The colour code for the ped face.
Ped face colour	ped_face_colour	The colour for the ped face.
Rubbed colour code	rubbed_colour_code	The colour code for the rubbed soil.
Rubbed colour	rubbed_colour	The colour of the rubbed soil.
Mottle abundance	mottle_abundance	An estimation of the primary mottle abundance.
Mottle size	mottle_size	An estimation of the primary mottle size.
Mottle contrast	mottle_contrast	An estimation of the primary mottle contrast.
Mottle colour code	mottle_colour_code	A code for the primary mottle colour.
Mottle colour	mottle_colour	The primary mottle colour.
Secondary mottle abund	secondary_mottle_abund	An estimation of the secondary mottle abundance.
Secondary mottle size	secondary_mottle_size	An estimation of the secondary mottle size.
Secondary mottle contrast	secondary_mottle_contrast	An estimation of the secondary mottle contrast.
Secondary mottle colour	secondary_mottle_colour	The secondary mottle colour.
Texture modifier	texture_modifier	A modifier for the soil texture.
Texture	texture	The texture of the top soil horizon.
Primary structure grade	primary_structure_grade	An estimation of the primary soil structure grade.
Primary structure size	primary_structure_size	An estimation of the primary soil structure size.
Primary structure type	primary_structure_type	An estimation of the primary soil structure type.
Structure link	structure_link	A link between primary and secondary structure.
Secondary structure grade	secondary_structure_grade	An estimation of the secondary soil structure grade.
Secondary structure size	secondary_structure_size	An estimation of the secondary soil structure size.
Secondary structure type	secondary_structure_type	An estimation of the secondary soil structure type.
Stickiness	stickiness	An estimation of soil stickiness.
Plasticity	plasticity	An estimation of soil plasticity.
Soil strength	soil_strength	An estimation of soil strength.
Ped strength	ped_strength	An estimation of ped strength.

Failure	failure	An estimation of soil failure.
Cementation	cementation	An estimation of soil cementation.
Penetration resistance	penetration_resistance	An estimation of penetration resistance.
Coatings abundance	coatings_abundance	An estimation of coatings abundance.
Coatings distinctness	coatings_distinctness	An estimation of coatings distinctness.
Coatings type	coatings_type	An estimation of coatings type.
Coatings colour code	coatings_colour_code	A code for the colour of coatings.
Coatings colour	coatings_colour	The colour of coatings.
Pan continuity	pan_continuity	A description of pan continuity.
Pan kind	pan_kind	A description for the type of pan.
Live roots abundance	live_roots_abundance	An estimate of the abundance of live roots.
Live roots size	live_roots_size	An estimate of live root size.
Stone abundance	stone_abundance	An estimate of stone abundance.
Stone weathering	stone_weathering	A description of the stone weathering.
Stone rounding	stone_rounding	A description of the stone shape.
Stone size	stone_size	An estimation of the stone size.
Stone parent rock	stone_parent_rock	The parent rock of the stones.
Boundary distinctness	boundary_distinctness	A description of boundary distinctness.
Boundary shape	boundary_shape	A description of boundary shape.
Horizon Notes	horizon_notes	Notes pertaining to the horizon.
Secondary mottle colour code	secondary_mottle_col_code	The secondary mottle colour code.
Stone parent rock modifier	stone_parent_rk_modifier	A stone parent rock modifier.
Description	VIRTUAL	Structured text description of a Horizon

Table A2 The fields and their descriptions in the *horizons* table in the NSD.

### Moisture

Here is where one may find the bulk density, total available water information and COLE. Identifiers are *moisture\_uid* and *horizon\_uid*. The *moisture\_uid* is not linked anywhere.

fullname	fieldname	units	description
Ident	ident		A unique identifier for the soil profile assigned in the laboratory.
Fabno	fabno		A unique identifier for the soil sample for moisture analysis assigned in the laboratory.
Moist top	moist_top	cm	The top depth of the moisture sample.
Moist base	moist_base	cm	The bottom depth of the moisture sample.
Moist thickness	moist_thickness	cm	The bottom depth of the moisture sample less the top depth.
Moist depth	moist_depth	cm	The top depth and the bottom depth of the moisture sample.
Whole soil method	whole_soil_method		The sampling method used for the whole soil.
Fine earth method	fine_earth_method		The sampling method used for the fine earth fraction.
Water content	water_content	%	The water content of the whole soil.
Stones over 2mm	stones_over_2mm	v/v %	A value for the stones > 2 mm in diameter.
Dry bulk density	dry_bulk_density	t/m3	A measurement of dry bulk density on the whole soil.
Fine earth dry BD	fine_earth_dry_bd	t/m3	A measurement of dry bulk density on the fine earth fraction
Particle density	particle_density	t/m3	A measurement of particle density on the fine earth fraction.
Total porosity	total_porosity	%	A measurement of total porosity on the fine earth fraction.
Macro porosity	macro_porosity	%	A measurement of macro porosity on the fine earth fraction.
COLE	cole		A ????

1 bar	1_bar	v/v %	A measurement of water retention on the fine earth fraction at 100 kPa or 1 bar on a volume basis.
15 bar	15_bar	v/v %	A measurement of water retention on the fine earth fraction at 1500 kPa or 15 bar on a volume basis.
Field moist water	field_moist_water	v/v %	The field moist water at 1500 kPa or 15 bar on a weight basis.
0.025 bar	0.025_bar	v/v %	A measurement of water retention on the fine earth fraction at 2.5 kPa or .025 bar on a volume basis.
0.05 bar	0.05_bar	v/v %	A measurement of water retention on the fine earth fraction at 5 kPa or .05 bar on a volume basis.
0.1 bar	0.1_bar	v/v %	A measurement of water retention on the fine earth fraction at 10 kPa or 0.1 bar on a volume basis.
0.2 bar	0.2_bar	v/v %	A measurement of water retention on the fine earth fraction at 20 kPa or .2 bar on a volume basis.
0.4 bar	0.4_bar	v/v %	A measurement of water retention on the fine earth fraction at 40 kPa or .4 bar on a volume basis.
Read avail water	read_avail_water	v/v%	Readily available water (10-100 kPa) of the soil sample.
Total avail water	total_avail_water	v/v %	Total available water (1500-10 kPa) of the sample.
DBD (PTF)	ALIAS		Dry Bulk Density from Pedotransfer function

Table A3 The fields and their descriptions in the *moisture* table in the NSD.

#### nzmethod

This table is good for reference to see what experimental methods have been used to measure relevant data.

fullname	fieldname	description
P acid soluble method	p_acid_soluble_method	
P organic method	p_organic_method	
P inorganic method	p_inorganic_method	
P total method	p_total_method	
P retention method	p_retention_method	
CEC method	cec_method	
Bases method	bases_method	
Base saturation method	base_saturation_method	
Exchange bases method	exchange_bases_method	
KCl extractable Al method	kcl_extractable_al_method	
Titrateable acidity method	titrateable_acidity_method	
Mgr method	mgr_method	
Kc method	kc_method	
S phosphate ext method	s_phosphate_ext_method	
SO4 phosphate ext method	so4_phosphate_ext_method	
Pyrophosphate method	pyrophosphate_method	
Acid oxalate method	acid_oxalate_method	
Dithionite citrate method	dithionite_citrate_method	
Moisture factor method	moisture_factor_method	
Soluble salts SO4 method	soluble_salts_so4_method	
Soluble salts Cl method	soluble_salts_cl_method	
K25 method	k25_method	
CaCO3 method	caco3_method	

Chemical extraction	chemical_extraction	
Major element method	major_element_method	
Trace element method	trace element method	
Ident	ident	A unique identifier for the soil profile assigned in the laboratory.
Collectors	collectors	The initials of the collectors of the soil samples.
Collection date	collection_date	The date the soil samples were collected.
Chemistry analysts	chemistry_analysts	The initials of the chemical analysts of the soil samples.
Chemistry date	chemistry_date	The date of chemical analyses.
Particle analysts	particle_analysts	The initials of the particle size analysts.
Particle date	particle_date	The date of the particle size analyses.
Fabric analysts	fabric_analysts	The initials of the soil moisture analysts.
Fabric date	fabric_date	The date of the moisture analyses.
Mineralogy analysts	mineralogy_analysts	The initials of the mineralogical analysts.
Mineralogy date	mineralogy_date	The date of the mineralogical analyses.
XRF analysts	xrf_analysts	The initials of the X-ray fluorescence analysts
XRF date	xrf_date	The date of X-ray fluorescence analyses.
P available method	p_available_method	The method code for available phosphorus measurements.
Ca removal	ca_removal	An indication of a pretreatment of calcium removal before mineralogical analysis.
H2O2	h2o2	An indication of hydrogen peroxide pretreatment before mineralogical analysis.
CDB	cdb	An indication of CBD pretreatment before mineralogical analysis.
Ultrasound	ultrasound	An indication of ultrasound pretreatment before mineralogical analysis.
Grinding	grinding	An indication of grinding pretreatment before mineralogical analysis.
Size fractionation	size_fractionation	An indication of size fractionation pretreatment before mineralogical analysis.
HM Density separation	hm_density_separation	An indication of heavy mineral density separation pretreatment before mineralogical analysis.
VG Density separation	vg_density_separation	An indication of volcanic glass density separation pretreatment before mineralogical analysis.
XRD whole soil	xrd_whole_soil	An indication that X-ray diffraction was used for whole soil analysis.
DTA whole soil	dta_whole_soil	An indication that DTA was used for whole soil analysis.
IR whole soil	ir_whole_soil	An indication that IR was used for whole soil analysis.
Optical whole soil	optical_whole_soil	An indication that an optical microscope was used for whole soil analysis.
Chem ext whole soil	chem_ext_whole_soil	An indication that chemical extraction was used for whole soil analysis.
Electron mic whole soil	electron_mic_whole_soil	An indication that electron microscopy was used for whole soil analysis.
Moess whole soil	moess_whole_soil	An indication that Moessbauer was used for whole soil analysis.
XRD clay	xrd_clay	An indication that X-ray diffraction was used for clay analysis.
DTA clay	dta_clay	An indication that DTA was used for clay analysis.
IR clay	ir_clay	An indication that IR was used for clay analysis.
Optical clay	optical_clay	An indication that an optical microscope was used for clay analysis.
Chem ext clay	chem_ext_clay	An indication that chemical extraction was used for clay analysis.
Electron mic clay	electron_mic_clay	An indication that electron microscopy was used for clay analysis.
Moess clay	moess_clay	An indication that Moessbauer was used for clay analysis.
XRD sand	xrd_sand	An indication that X-ray diffraction was used for sand analysis.
DTA sand	dta_sand	An indication that DTA was used for sand analysis.
IR sand	ir_sand	An indication that IR was used for sand analysis.
Optical sand	optical_sand	An indication that an optical microscope was used for sand analysis.

Chem ext sand	chem_ext_sand	An indication that chemical extraction was used for sand analysis.
Electron mic sand	electron mic sand	An indication that electron microscopy was used for sand analysis.
Moess sand	moess_sand	An indication that Moessbauer was used for sand analysis.
XRD heavy minerals	xrd heavy minerals	An indication that X-ray diffraction was used for heavy minerals analysis.
DTA heavy minerals	dta heavy minerals	An indication that DTA was used for heavy mineral analysis.
IR heavy minerals	ir_heavy_minerals	An indication that IR was used for heavy mineral analysis.
Optical heavy minerals	optical heavy minerals	An indication that an optical microscope was used for heavy mineral analysis.
Chem ext heavy minerals	chem_ext heavy minerals	An indication that chemical extraction was used for heavy minerals analysis.
Electron mic heavy mins	electron mic heavy mins	An indication that electron microscopy was used for heavy minerals analysis.
Moess heavy minerals	moess_heavy_minerals	An indication that Moessbauer was used for heavy minerals analysis.
XRD silt	xrd_silt	An indication that X-ray diffraction was used for silt analysis.
DTA silt	dta_silt	An indication that DTA was used for silt analysis.
IR silt	ir_silt	An indication that IR was used for silt analysis.
Optical silt	optical_silt	An indication that an optical microscope was used for silt analysis.
Electron mic silt	electron mic_silt	An indication that electron microscopy was used for silt analysis.
Chem ext silt	chem_ext_silt	An indication that chemical extraction was used for silt analysis.
Moess silt	moess_silt	An indication that Moessbauer was used for silt analysis.
Mg whole soil	mg_whole_soil	An indication that the XRD method used magnesium treatment for the whole soil and glass slides.
Mg glycerol whole soil	mg_glycerol whole soil	An indication that the XRD method used magnesium/glycerol treatment for the whole soil and glass slides.
Mg heat whole soil	mg_heat whole soil	An indication that the XRD method used magnesium/heat treatment for the whole soil and glass slides.
K whole soil	k_whole_soil	An indication that the XRD method used potassium treatment for the whole soil and glass slides.
K heat whole soil	k_heat whole soil	An indication that the XRD method used potassium/heat treatment for the whole soil and glass slides.
Acetone whole soil	acetone whole soil	An indication that the XRD method used acetone treatment for the whole soil and glass slides.
Powder whole soil	powder whole soil	An indication that the XRD method used powder for the whole soil.
Tile formamide whole soil	tile_formamide whole soil	An indication that the XRD method used formamide/tile for the whole soil.
Mg clay	mg_clay	An indication that the XRD method used magnesium treatment for the clay and glass slides.
Mg glycerol clay	mg_glycerol clay	An indication that the XRD method used magnesium/glycerol treatment for the clay and glass slides.
Mg heat clay	mg_heat clay	An indication that the XRD method used magnesium/heat treatment for the clay and glass slides.
K clay	k_clay	An indication that the XRD method used potassium treatment for the clay and glass slides.
K heat clay	k_heat clay	An indication that the XRD method used potassium/heat treatment for the clay and glass slides.
Acetone clay	acetone_clay	An indication that the XRD method used acetone treatment for the clay and glass slides.
Powder clay	powder_clay	An indication that the XRD method used powder for the clay.
Tile formamide clay	tile_formamide_clay	An indication that the XRD method used formamide/tile for the clay.
Mg sand	mg_sand	An indication that the XRD method used magnesium treatment for the sand and glass slides.
Mg glycerol sand	mg_glycerol sand	An indication that the XRD method used magnesium/glycerol treatment for the sand and glass slides.
Mg heat sand	mg_heat sand	An indication that the XRD method used magnesium/heat treatment for the sand and glass slides.

K sand	k_sand	An indication that the XRD method used potassium treatment for the sand and glass slides.
K heat sand	k heat sand	An indication that the XRD method used potassium/heat treatment for the sand and glass slides.
Acetone sand	acetone sand	An indication that the XRD method used acetone treatment for the sand and glass slides.
Powder sand	powder_sand	An indication that the XRD method used powder for the sand.
Tile formamide sand	tile_formamide_sand	An indication that the XRD method used formamide/tile for the sand.
Mg heavy minerals	mg_heavy_minerals	An indication that the XRD method used magnesium treatment for the heavy minerals and glass slides.
Mg glycerol heavy mineral	mg glycerol heavy mineral	An indication that the XRD method used magnesium/glycerol treatment for the heavy minerals and glass slides.
Mg heat heavy minerals	mg_heat_heavy_minerals	An indication that the XRD method used magnesium/heat treatment for the heavy minerals and glass slides.
K heavy minerals	k_heavy_minerals	An indication that the XRD method used potassium treatment for the heavy minerals and glass slides.
K heat heavy minerals	k heat heavy minerals	An indication that the XRD method used potassium/heat treatment for the heavy minerals and glass slides.
Acetone heavy minerals	acetone heavy minerals	An indication that the XRD method used acetone treatment for the heavy minerals and glass slides.
Powder heavy minerals	powder heavy minerals	An indication that the XRD method used powder for the heavy minerals.
Tile formamide heavy mins	tile_formamide_heavy_mins	An indication that the XRD method used formamide/tile for the heavy minerals.
Mg silt	mg_silt	An indication that the XRD method used magnesium treatment for the silt and glass slides.
Mg glycerol silt	mg glycerol silt	An indication that the XRD method used magnesium/glycerol treatment for the silt and glass slides.
Mg heat silt	mg heat silt	An indication that the XRD method used magnesium/heat treatment for the silt and glass slides.
K silt	k_silt	An indication that the XRD method used potassium treatment for the silt and glass slides.
K heat silt	k_heat_silt	An indication that the XRD method used potassium/heat treatment for the silt and glass slides.
Acetone silt	acetone_silt	An indication that the XRD method used acetone treatment for the silt and glass slides.
Powder silt	powder_silt	An indication that the XRD method used powder for the silt.
Tile formamide silt	tile_formamide_silt	An indication that the XRD method used formamide/tile for the silt.
PHH2O method	phh2o_method	The method code for pH H2O.
PHKCl method	phkcl_method	The method code for pH KCl.
PHNaF method	phnaf_method	The method code for pH in sodium fluoride.
PHCaCl method	phcacl_method	The method code for pH in calcium chloride.
Carbon method	carbon method	The units for the carbon measurement value.
Nitrogen method	nitrogen method	The units for nitrogen measurements.
Soluble basic cations met	soluble basic cations met	The method code for soluble basic cations measurements.
Li green Kelly whole soil	li green kelly whole soil	An indication that the XRD method used the lithium Greene-Kelly treatment for the whole soil and glass slides.
Li green Kelly clay	li_green_kelly_clay	An indication that the XRD method used lithium Greene-Kelly treatment for the clay and glass slides.
Li green Kelly sand	li_green_kelly_sand	An indication that the XRD method used lithium Greene-Kelly treatment for the sand and glass slides.
Li green Kelly heavy mins	li green kelly heavy mins	An indication that the XRD method used lithium Greene-Kelly treatment for the heavy minerals and glass slides.
Li green Kelly silt	li green kelly silt	An indication that the XRD method used lithium Greene-Kelly treatment for the silt and glass slides.

**Table A4** The fields and their descriptions in the *nzmmethods* table in the NSD.

#### Particle size

This table is useful to find sand, clay, silt, and stone percentages.

Fullname	fieldname	units	description
Ident	ident		
Fine earth fraction	fine_earth_fraction	%	
Small particle method	small_particle_method		
Fine Total	fine_total		
Fine clay	fine_clay	%	
WS3P35	ws3p35	%	
WS4P75	ws4p75	%	
WS6P7	ws6p7	%	
WS9P5	ws9p5	%	
WS13P2	ws13p2	%	
WS19	ws19	%	
WS38	ws38	%	
WS76	ws76	%	
Sample id	sample_id		A unique identifier for the analytical soil sample assigned by the laboratory.
Coarse sand	coarse_sand	%	A measurement of the coarse sand fraction of the soil (2-0.6 mm).
Medium sand	medium_sand	%	A measurement of the medium sand fraction of the soil (0.6-0.2 mm).
Fine sand	fine_sand	%	A measurement of the fine sand fraction of the soil 0.2(2-0.06 mm).
Sand	sand	%	A measurement of sand fraction of the soil (2-0.06 mm).
Silt	silt	%	A measurement of the silt fraction of the soil (0.06--0.002 mm).
FE 2	fe_2	%	Clay, the fine earth fraction with particle size less than 0.002 mm.
FE 5	fe_5	%	A measurement of of the whole soil fraction less than 0.005 mm.
FE 6	fe_6	%	A measurement of of the whole soil fraction less than 0.006 mm.
FE 10	fe_10	%	A measurement of of the whole soil fraction less than 0.01 mm.
FE 20	fe_20	%	A measurement of of the whole soil fraction less than 0.02 mm.
FE 40	fe_40	%	A measurement of of the whole soil fraction less than 0.04 mm.
FE 50	fe_50	%	A measurement of of the whole soil fraction less than 0.05 mm.
FE 60	fe_60	%	A measurement of of the whole soil fraction less than 0.06 mm.
FE 63	fe_63	%	A measurement of of the whole soil fraction less than 0.063 mm.
FE 100	fe_100	%	A measurement of of the whole soil fraction less than 0.1 mm.
FE 125	fe_125	%	A measurement of of the whole soil fraction less than 0.125 mm.
FE 200	fe_200	%	A measurement of of the whole soil fraction less than 0.2 mm.
FE 250	fe_250	%	A measurement of of the whole soil fraction less than 0.25 mm.
FE 500	fe_500	%	A measurement of of the whole soil fraction less than 0.5 mm.
FE 600	fe_600	%	A measurement of of the whole soil fraction less than 0.6 mm.
FE 1000	fe_1000	%	A measurement of of the whole soil fraction less than 1.0 mm.
Derived	derived		An indication of the method used to obtain the < 2.0 mm figure.
WS2	ws2	%	Fine Earth, fraction of the whole soil with particle size less than 2 mm.
Sample dry mass	sample_dry_mass	kg	A measurement of sample dry mass.
Maximum stone size	maximum_stone_size	mm	A measurement of maximum stone size.
AD 15 bar water	ad_15_bar_water	w/w %	A measurement of air dried water retention at 1500 kPa.
FM 15 bar water	fm_15_bar_water	%	A measurement of field moist water retention at 1500 kPa.
FE 5-6	fe_5-6	%	A measurement of of the whole soil fraction less than 0.005-0.006 mm???
Clay	ALIAS	%	A measurement of of the whole soil fraction less than 0.002 mm.

Table A5 The fields and their descriptions in the *particle size* table in the NSD.

### Chemistry

This table has the carbon (%) and CEC.

Fullname	Fieldname	Units	description
----------	-----------	-------	-------------

Ident	ident		
ODOE	odoe		
Fe Dithionite citrate	fe_dithionite_citrate	%	Dithionite-citrate extractable iron.
K25 Saturation	k25_saturation	mS/cm	
Calcium carbonate	calcium_carbonate	%	A measurement of soil total carbon in air-dried soil.
Soluble salts K25	soluble_salts_k25	%	A measurement of water-soluble potassium on a water extract of air-dried soil.
Sample id	sample_id		A unique identifier for the analytical soil sample assigned by the laboratory.
PH H2O	ph_h2o		A measurement of soil pH in a water suspension using air-dried soil.
PH KCl	ph_kcl		A measurement of soil pH in a potassium chloride solution using air-dried soil.
PH NaF	ph_naf		A measurement of soil pH in a sodium fluoride solution using air-dried soil.
PH Moist	ph_moist		A measurement of soil pH in a water suspension using moist soil.
PH CaCl	ph_cacl		A measurement of soil pH in a calcium chloride suspension using air-dried soil.
Carbon	carbon	%	A measurement of soil total carbon in air-dried soil. (g/100g)
Nitrogen	nitrogen	%	A measurement of soil total nitrogen in air-dried soil.
P Truog Available	p_truog_available	mg/kg	A measurement of available phosphorus based on Truogs method..
P Olsen Available	p_olsen_available	mg/kg	A measurement of available phosphorus based on Olsens method.
P Bray Available	p_bray_available	mg/kg	A measurement of available phosphorus based on Brays method.
P acid soluble	p_acid_soluble	mg/kg	A measurement of inorganic unfixed phosphorus.
P inorganic	p_inorganic	mg/kg	This value is the total phosphorus value less the organic phosphorus value.
P organic	p_organic	mg/kg	A measurement of organic phosphorus.
P Total	p_total	mg/kg	A measurement of total phosphorus.
P retention	p_retention	%	A measurement of phosphate retention which shows the degree to which soil removes phosphorus from solution.
CEC	cec	cmol(+)/kg	A measurement of cation exchange capacity which shows the amount of cation that a soil can hold when a salt solution is leached through it.
Sum bases	sum_bases	cmol(+)/kg	This value is the sum of the individual exchangeable cations Calcium, Magnesium, Potassium and Sodium.
Base saturation	base_saturation	%	This value is the sum of the cations divided by the cation exchange capacity as a percentage.
Exchange Ca	exchange_ca	cmol(+)/kg	A measurement of exchangeable calcium.
Exchange Mg	exchange_mg	cmol(+)/kg	A measurement of exchangeable magnesium.
Exchange K	exchange_k	cmol(+)/kg	A measurement of exchangeable potassium.
Exchange Na	exchange_na	cmol(+)/kg	A measurement of exchangeable sodium.
KCl extractable Al	kcl_extractable_al	cmol(+)/kg	A measurement of potassium chloride extractable aluminium.
Titrateable acidity	titrateable_acidity	cmol(+)/kg	Cation exchange capacity at pH 8.2.
Kc	kc	cmol(+)/kg	A measurement of the reserve potassium or long-term potassium-supplying power of soil.
S Total	s_total	mg/kg	A measurement of total sulphur in soil.
S Phosphate extr	s_phosphate_extr	mg/kg	A measurement of soil phosphate extractable sulphur.
SO4 Phosphate extr	so4_phosphate_extr	mg/kg	A measurement of soil phosphate extractable sulphate.
C Pyrophosphate	c_pyrophosphate	%	A measurement of soil pyrophosphate extractable carbon.
Fe Pyrophosphate	fe_pyrophosphate	%	Soil pyrophosphate extractable iron.
Al Pyrophosphate	al_pyrophosphate	%	Soil pyrophosphate extractable aluminium.
Fe Acid oxalate	fe_acid_oxalate	%	Soil acid oxalate extractable iron.
Al Acid oxalate	al_acid_oxalate	%	Soil acid oxalate-extractable aluminium.
Si Acid oxalate	si_acid_oxalate	%	Soil acid oxalate-extractable silicon.
Mn Acid oxalate	mn_acid_oxalate	%	Soil acid oxalate-extractable manganese.
Al Dithionite citrate	al_dithionite_citrate	%	Dithionite-citrate extractable aluminium.
Stones air dry	stones_air_dry	%	A measurement of stones in the air dried soil > 2 mm.
Stones	stones	%	A measurement of stones in the field sample.

Moisture factor	moisture_factor		A factor to convert analyses on an air-dried basis to an oven-dried basis.
Loss on ignition 500	loss_on_ignition_500	%	A measurement of the loss of weight on igniting a sample high in organic matter (litters and peats i.e. > 80% loss on ignition) at 500 C.
Soluble salts Tot	soluble_salts_tot	cmol(+)/kg	A measurement of total soluble salts on a water extract from air-dried soils.
Soluble salts Ca	soluble_salts_ca	cmol(+)/kg	A measurement of water-soluble calcium on a water extract of air-dried soil.
Soluble salts Mg	soluble_salts_mg	cmol(+)/kg	A measurement of water-soluble magnesium on a water extract of air-dried soil.
Soluble salts Na	soluble_salts_na	cmol(+)/kg	A measurement of water-soluble sodium on a water extract of air-dried soil.
Soluble salts K	soluble_salts_k	cmol(+)/kg	A measurement of water-soluble potassium on a water extract of air-dried soil.
Soluble salts SO4	soluble_salts_so4	cmol(+)/kg	A measurement of water-soluble sulphate on a water extract of air-dried soil.
Soluble salts Cl	soluble_salts_cl	cmol(+)/kg	A measurement of water-soluble chloride on a water extract of air-dried soil.
Carbon/Nitrogen	carbon/nitrogen		The total carbon value divided by the total nitrogen value.
Mgr	mgr	cmol(+)/kg	A measurement of acid-soluble reserve magnesium.
K25 1T05	k25_1t05	mS/cm	A measurement of soluble salts by conductivity in 1:5 soil to water ratio extract at 25 degrees C.

Table A6 The fields and their descriptions in the *chemistry* table in the NSD

#### *nznote*

This table contains general notes about the data and classification

fullname	fieldname	description
Ident	ident	A unique identifier for the soil profile assigned in the laboratory.
Field ident	field_ident	An identifier assigned by the author for his/her own use.
Chem note	chem_note	Notes about chemical analyses.
Chem2 note	chem2_note	More notes about chemical analyses.
Part note	part_note	Notes about particle size analyses.
Fab note	fab_note	Notes about moisture analyses.
Min note	min_note	Notes about mineralogical analyses.
Min note2	min_note2	More notes about mineralogical analyses.
XRF note	xrf_note	Notes about X-ray fluorescence analyses.
US Taxonomy class	us_taxonomy_class	US Soil Taxonomy classification for mineralogy.
NZB CM14 Class S	nzsb_cm14_class	New Zealand mineralogy class.

Table A7. The fields and their descriptions in the *nznote* table in the NSD.

#### *site*

This table contains general notes about classification

fullname	fieldname	description
NZ Revised Soil class	nz_revised_soil_class	
NZ Revised extra	nz_revised_extra	
Order root	order_root	
Suborder5	suborder5	

Suborder	suborder	
Greatgroup5	greatgroup5	
Great group	great_group	
Subgroup	subgroup	
Family qualifier	family_qualifier	
Family	family	
Control section	control_section	
Topdress	topdress	
NZ Revised order	nz_revised_order	A code for the classification of New Zealand revised order.
NZ Revised group	nz_revised_group	A code for the classification of New Zealand revised group.
NZ Revised subgroup	nz_revised_subgroup	A code for the classification of New Zealand revised subgroup.
Date observed	date_observed	The date when the profile was described.
Author	author	The initials of the people who described the soil in the field.
Survey code	survey_code	A code to identify the soil survey.
Survey	survey	The name of the soil survey in full.
Survey free	survey_free	Additional information about the soil survey
Region	region	The region where the describe soil is.
Map series	map_series	The map series used for the grid reference.
Map number	map_number	The number of the map in the map series for the grid reference
East	east (m)	The NZMG easting of the grid reference.
North	north (m)	The NZMG northing of the grid reference.
Locality	locality	A description of the locality of the sample in relation to road names, fence lines etc.
Annual rain	annual_rain	The annual rainfall at the site.
Mean annual temp	mean_annual_temp	The annual temperature at the site.
Mean temp warm month	mean_temp_warm_month	The mean temperature at the site for the warmest month
Mean temp cold month	mean_temp_cold_month	The mean temperature at the site for the coldest month.
Altitude	altitude	Altitude of the site.
Element	element	The element of the position in the landscape of the soil profile..
Landform	landform	The landform of the position in the landscape of the soil profile.
Landscape	landscape	The landscape in which the profile is described.
Landform genesis	landform_genesis	The landform genesis of the of the site of the soil profile.
Micro relief	micro_relief	A description of the microrelief at the site.
Slope shape	slope_shape	a description of the slope shape.
Slope face	slope_facet	A description of the slope facet.
Slope angle	slope_angle	The angle of the slope at the site.
Slope length	slope_length	The length of the slope at the site.
Slope aspect	slope_aspect	The aspect of the slope at the site.
Rock outcrops	rock_outcrops	The quantity of rock outcrop at the site.
Stone cover	stone_cover	A measurement of the soil surface covered by stones at the site..
Surface stone size	surface_stone_size	A measurement of the soil surface stone size.
Surface stone kind	surface_stone_kind	The kind of surface stones.
Oversown	oversown	Has the site been oversown?
Fertilised	fertilised	Has the site been fertilised?
Ploughed	ploughed	Has the site been ploughed?
Irrigated	irrigated	Is the site irrigated?
Drained	drained	Has the site been drained?
Subsoiled	subsoiled	Has the site been subsoiled?
Erosion control wind	erosion_control_wind	Is there any wind erosion control at the site?
Erosion control water	erosion_control_water	Is there any water erosion control at the site?
Slope movement area	slope_movement_area	An estimate of the area affected by slope movement at the site.

Slope movement type	slope_movement_type	The type of slope movement at the site.
Soil erosion topsoil loss	soil_erosion_topsoil_loss	An estimate of soil erosion topsoil loss.
Flooding	flooding	The frequency at which flooding occurs.
Profile Drainage	profile_drainage	An estimate of profile drainage.
Land use	land_use	A land use classification for the site.
site_id	ident	A unique identifier for the soil profile assigned in the laboratory.
Field ident	field_ident	An identifier assigned by the author for his/her own use.
Series name	series_name	Soil series name.
Type qualifier	type_qualifier	A textural name, colour or other distinguishing feature.
Correlation status	correlation_status	This indicates whether or not the soil has been correlated.
NZG	nzg	A New Zealand genetic group code.
NZ Genetic	nz_genetic	The New Zealand genetic group in full text.
NZ Class free	nz_class_free	Other features for the New Zealand genetic classification.
Leached	leached	Indication of the degree of leaching.
Gleyed	gleyed	Indication of the degree of gleying.
Vegetation type	vegetation_type	A classification of vegetation type at the site.
Vegetation species	vegetation_species	A list of vegetation species at the site in no particular order.
Parent material weather	parent_material_weather	An estimation of the degree of weathering of the parent material.
Parent material consist	parent_material_consist	An estimate of the in situ parent material consistence.
Parent material cement	parent_material_cement	Description of the parent material cementation.
Parent material joint	parent_material_joint	Description of the parent material jointing.
Parent rock modifier	parent_rock_modifier	A modifier for the parent rock.
Parent rock	parent_rock	Parent rock.
Parent rock free format	parent_rock_free_format	Other important features for parent rock.
Site Notes	site_notes	Notes about the site that are not covered elsewhere.
Elite	elite	Whether or not the soil is described as elite.
VCMNZ Veg class	vcmnz	Vegetation Cover Map mappings
NZSC	ALIAS	New Zealand Soil Classification (A.E.Hewitt, ed.2 1998)
East (NZMG)	ALIAS	Easting in NZMG Projection (Datum NZGD1949)
North (NZMG)	ALIAS	Northing in NZMG Projection (Datum NZGD1949)
East (NZTM)	ALIAS	Easting in NZTM Projection (Datum NZGD2000)
North (NZTM)	ALIAS	Northing in NZTM Projection (Datum NZGD2000)

Table A8. The fields and their descriptions in the *particle size* table in the NSD.

### Sample

This is the table where one may find the soil SB identifier.

fullname	fieldname	description
Sample note	sample_note	Notes about the soil sample.
Sample id	sample_id	A unique identifier for the analytical soil sample assigned by the laboratory.
Ident	ident	A unique identifier for the soil profile assigned in the laboratory.
Lab letter	lab_letter	A letter indicating a separate analytical sample, assigned in the laboratory.
Sample top	sample_top (cm)	The depth to the top of the soil sample.
Sample base	sample_base (cm)	The depth to the base of the soil sample.
Sample depth	sample_depth (cm)	The soil sample depth from top to base.
Sample thickness	sample_thickness (cm)	The thickness of the soil sample i.e. base - top.

Table A9. The fields and their descriptions in the *sample* table in the NSD.

### Site

This is the table one may find texture information and the NS Soil class and the location of sample sites and a description of those sites.

fullname	fieldname	description
NZ Revised Soil class	nz revised soil class	
NZ Revised extra	nz revised extra	
Order root	order root	
Suborder5	suborder5	
Suborder	suborder	
Greatgroup5	greatgroup5	
Great group	great group	
Subgroup	subgroup	
Family qualifier	family qualifier	
Family	family	
Control section	control section	
Topdress	topdress	
NZ Revised order	nz revised order	A code for the classification of New Zealand revised order.
NZ Revised group	nz revised group	A code for the classification of New Zealand revised group.
NZ Revised subgroup	nz revised subgroup	A code for the classification of New Zealand revised subgroup.
Date observed	date observed	The date when the profile was described.
Author	author	The initials of the people who described the soil in the field.
Survey code	survey code	A code to identify the soil survey
Survey	survey	The name of the soil survey in full.
Survey free	survey_free	Additional information about the soil survey.
Region	region	The region where the describe soil is.
Map series	map_series	The map series used for the grid reference.
Map number	map_number	The number of the map in the map series for the grid reference
East	east (m)	The NZMG easting of the grid reference.
North	north (m)	The NZMG northing of the grid reference.
Locality	locality	A description of the locality of the sample in relation to road names, fence lines etc.
Annual rain	annual_rain	The annual rainfall at the site.
Mean annual temp	mean_annual_temp	The annual temperature at the site.
Mean temp warm month	mean_temp_warm_month	The mean temperature at the site for the warmest month.
Mean temp cold month	mean_temp_cold_month	The mean temperature at the site for the coldest month.
Altitude	altitude	Altitude of the site.
Element	element	The element of the position in the landscape of the soil profile..
Landform	landform	The landform of the position in the landscape of the soil profile.
Landscape	landscape	The landscape in which the profile is described.
Landform genesis	landform_genesis	The landform genesis of the of the site of the soil profile.
Micro relief	micro_relief	A description of the microrelief at the site.
Slope shape	slope_shape	a description of the slope shape.
Slope acet	slope_facet	A description of the slope facet.
Slope angle	slope_angle	The angle of the slope at the site.
Slope length	slope_length	The length of the slope at the site.
Slope aspect	slope_aspect	The aspect of the slope at the site.
Rock outcrops	rock_outcrops	The quantity of rock outcrop at the site.
Stone cover	stone_cover	A measurement of the soil surface covered by stones at the site..
Surface stone size	surface_stone_size	A measurement of the soil surface stone size.
Surface stone kind	surface_stone_kind	The kind of surface stones.
Oversown	oversown	Has the site been oversown?
Fertilised	fertilised	Has the site been fertilised?
Ploughed	ploughed	Has the site been ploughed?

Irrigated	irrigated	Is the site irrigated?
Drained	drained	Has the site been drained?
Subsoiled	subsoiled	Has the site been subsoiled?
Erosion control wind	erosion_control_wind	Is there any wind erosion control at the site?
Erosion control water	erosion_control_water	Is there any water erosion control at the site?
Slope movement area	slope_movement_area	An estimate of the area affected by slope movement at the site.
Slope movement type	slope_movement_type	The type of slope movement at the site.
Soil erosion topsoil loss	soil_erosion_topsoil_loss	An estimate of soil erosion topsoil loss.
Flooding	flooding	The frequency at which flooding occurs.
Profile Drainage	profile_drainage	An estimate of profile drainage.
Land use	land_use	A land use classification for the site.
site id	ident	A unique identifier for the soil profile assigned in the laboratory.
Field ident	field_ident	An identifier assigned by the author for his/her own use.
Series name	series_name	Soil series name.
Type qualifier	type_qualifier	A textural name, colour or other distinguishing feature.
Correlation status	correlation_status	This indicates whether or not the soil has been correlated.
NZG	nzg	A New Zealand genetic group code.
NZ Genetic	nz_genetic	The New Zealand genetic group in full text.
NZ Class free	nz_class_free	Other features for the New Zealand genetic classification.
Leached	leached	Indication of the degree of leaching.
Gleyed	gleyed	Indication of the degree of gleying.
Vegetation type	vegetation_type	A classification of vegetation type at the site.
Vegetation species	vegetation_species	A list of vegetation species at the site in no particular order.
Parent material weather	parent_material_weather	An estimation of the degree of weathering of the parent material.
Parent material consist	parent_material_consist	An estimate of the in situ parent material consistence.
Parent material cement	parent_material_cement	Description of the parent material cementation.
Parent material joint	parent_material_joint	Description of the parent material jointing.
Parent rock modifier	parent_rock_modifier	A modifier for the parent rock.
Parent rock	parent_rock	Parent rock.
Parent rock free format	parent_rock_free_format	Other important features for parent rock.
Site Notes	site_notes	Notes about the site that are not covered elsewhere.
Elite	elite	Whether or not the soil is described as elite.
VCMNZ Veg class	vcmnz	Vegetation Cover Map mappings
NZSC	ALIAS	New Zealand Soil Classification (A.E.Hewitt, ed.2 1998)
East (NZMG)	ALIAS	Easting in NZMG Projection (Datum NZGD1949)
North (NZMG)	ALIAS	Northing in NZMG Projection (Datum NZGD1949)
East (NZTM)	ALIAS	Easting in NZTM Projection (Datum NZGD2000)
North (NZTM)	ALIAS	Northing in NZTM Projection (Datum NZGD2000)

**Table A10. The fields and their descriptions in the *Site* table in the NSD.**