A tool to assess the capacity for storage of carbon dioxide in deep saline aquifers

SCADSA v1.0 – User Guide

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Summary

This user guide explains how to use the SCADSA tool. SCADSA stands for Storage Capacity Assessment for Deep Saline Aquifers. The software computes the theoretical CO_2 storage capacity of a deep saline aquifer based on thirteen input parameters. It provides both deterministic and probabilistic CO_2 storage capacities. The probabilistic calculations are derived from Monte Carlo simulations, utilizing these parameters.

Contents

1 Introduction

The SCADSA tool has been developed to assess the capacity for storage of carbon dioxide (CO_2) in deep saline sandstone aquifer complexes and utilizes the Microsoft Excel platform. SCADSA stands for Storage Capacity Assessment for Deep Saline Aquifers. The scientific principles and calculations that form the foundation of this tool are detailed in Reference 1. With version 1.0 of the tool, it becomes possible to calculate the theoretical storage capacity of closed system sandstone aquifer complexes. This capacity represents the maximum amount of CO_2 that can be stored within the aquifer under ideal conditions. Future versions of the tool will focus on calculating the effective storage capacity of closed-system sandstone aquifer complexes. The user-guide aims to provide clear instructions for achieving user-friendly interaction, efficient data input, and accurate calculation results.

2 Installation and set up

Version 1.0 of the SCADSA tool is developed for the Excel platform: Microsoft® Excel® for Microsoft 365 MSO (Version 2308 Build 16.0.16731.20542) 64-bit or later.

Working Memory: Advised working memory: 4 GB or more.

Use System Separators (Excel Options, Advanced): Decimal separator: . [dot]; Thousands separator: , [comma].

Start the tool by Opening your Excel program, Choose File, Open and select the SCADSA workbook. If you receive a notification that macros are being used, enable the content by clicking the ‘Enable Content’ button.”

3 Layout and features

The SCADSA tool consists of seven worksheets (see Figure 1) with a) The capacity calculations (worksheet “Probabilistic Capacity”), b) calculations and graphics display supporting worksheets (Tabs 2–6) and c) a hydrostatic gradient calculator (worksheet “Hydrostatic”). The capacity calculations worksheet “Probabilistic Capacity” serves as the user interface for the tool. In this worksheet, users can input their parameters and subsequently view the calculated results. Tabs 2-6 are hidden for the user. When adjustments are made in these tabs TNO cannot guarantee correctness of the outcome of the tool.

3.1 Probabilistic capacity worksheet

The Probabilistic Capacity calculations worksheet is divided into five distinct sections, each with its own unique features (as shown in Figure 1). In this section a short overview is given of each section, followed by detailed, step-by-step walkthroughs in section 4.

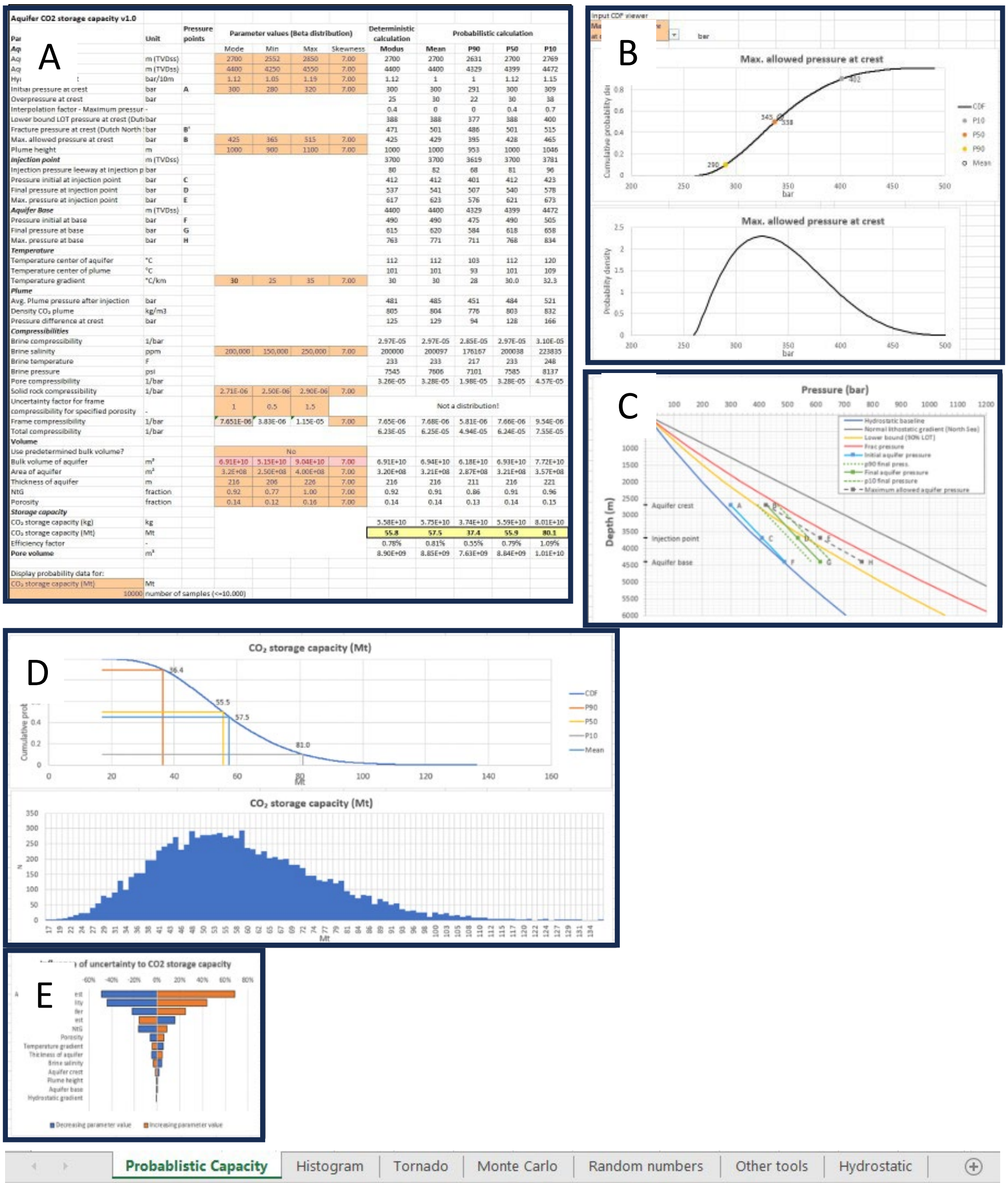

Figure 1 – Overview of the Probabilistic Capacity worksheet with indicated sections and the SCADSA tool worksheet tabs. Only the Probabilistic Capacity and the Hydrostatic worksheets are visible for the user. The other worksheets are hidden from view.

3.1.1 Section A

In section A (Figure 2) of the probabilistic capacity worksheet, users can input relevant data for calculations and then view the results.

Aquifer CO2 storage capacity v1.0											
Parameter name	**Unit**	**Pressure points**	**Parameter values (Beta distribution)**				**Deterministic calculation**	**Probabilistic calculation**			
Aquifer			Mode	Min	Max	Skewness	**Modus**	**Mean**	**P90**	**P50**	**P10**
Aquifer crest	m (TVDss)		2700	2552	2850	7.00	2700	2700	2631	2700	2769
Aquifer base	m (TVDss)		4400	4250	4550	7.00	4400	4400	4329	4399	4472
Hydrostatic gradient	bar/10m		1.12	1.05	1.19	7.00	1.12	1	1	1.12	1.15
Initial pressure at crest	bar	**A**	300	280	320	7.00	300	300	291	300	309
Overpressure at crest	bar						25	30	22	30	38
Interpolation factor - Maximum pressur	-						0.4	0	0	0.4	0.7
Lower bound LOT pressure at crest (Dut	bar						388	388	377	388	400
Fracture pressure at crest (Dutch North :	bar	**B'**					471	501	486	501	515
Max. allowed pressure at crest	bar	**B**	425	365	515	7.00	425	429	395	428	465
Plume height	m		1000	900	1100	7.00	1000	1000	953	1000	1046
Injection point	m (TVDss)						3700	3700	3619	3700	3781
Injection pressure leeway at injection p	bar						80	82	68	81	96
Pressure initial at injection point	bar	**C**					412	412	401	412	423
Final pressure at injection point	bar	**D**					537	541	507	540	578
Max. pressure at injection point	bar	**E**					617	623	576	621	673
Aquifer Base	m (TVDss)						4400	4400	4329	4399	4472
Pressure initial at base	bar	**F**					490	490	475	490	505
Final pressure at base	bar	**G**					615	620	584	618	658
Max. pressure at base	bar	**H**					763	771	711	768	834
Temperature											
Temperature center of aquifer	°C						112	112	103	112	120
Temperature center of plume	°C						101	101	93	101	109
Temperature gradient	°C/km		30	25	35	7.00	30	30	28	30.0	32.3
Plume											
Avg. Plume pressure after injection	bar						481	485	451	484	521
Density CO_2 plume	kg/m3						805	804	776	803	832
Pressure difference at crest	bar						125	129	94	128	166
Compressibilities											
Brine compressibility	1/bar						2.97E-05	2.97E-05	2.85E-05	2.97E-05	3.10E-05
Brine salinity	ppm		200,000	150,000	250,000	7.00	200000	200097	176167	200038	223835
Brine temperature	F						233	233	217	233	248
Brine pressure	psi						7545	7606	7101	7585	8137
Pore compressibility	1/bar						3.26E-05	3.28E-05	1.98E-05	3.28E-05	4.57E-05
Solid rock compressibility	1/bar		2.71E-06	2.50E-06	2.90E-06	7.00					
Uncertainty factor for frame compressibility for specified porosity	-		1	0.5	1.5		Not a distribution!				
Frame compressibility	1/bar		7.651E-06	3.83E-06	1.15E-05	7.00	7.65E-06	7.68E-06	5.81E-06	7.66E-06	9.54E-06
Total compressibility	1/bar						6.23E-05	6.25E-05	4.94E-05	6.24E-05	7.55E-05
Volume											
Use predetermined bulk volume?			No								
Bulk volume of aquifer	m³		6.91E+10	5.15E+10	9.04E+10	7.00	6.91E+10	6.94E+10	6.18E+10	6.93E+10	7.72E+10
Area of aquifer	m²		3.2E+08	2.50E+08	4.00E+08	7.00	3.20E+08	3.21E+08	2.87E+08	3.21E+08	3.57E+08
Thickness of aquifer	m		216	206	226	7.00	216	216	211	216	221
NtG	fraction		0.92	0.77	1.00	7.00	0.92	0.91	0.86	0.91	0.96
Porosity	fraction		0.14	0.12	0.16	7.00	0.14	0.14	0.13	0.14	0.15
Storage capacity											
CO_2 storage capacity (kg)	kg						5.58E+10	5.75E+10	3.74E+10	5.59E+10	8.01E+10
CO_2 storage capacity (Mt)	Mt						**55.8**	**57.5**	**37.4**	**55.9**	**80.1**
Efficiency factor	-						0.78%	0.81%	0.55%	0.79%	1.09%
Pore volume	m³						8.90E+09	8.85E+09	7.63E+09	8.84E+09	1.01E+10
Display probability data for:											
CO_2 storage capacity (Mt)	Mt										
10000	number of samples (<=10.000)										

Figure 2 – Overview of Section A of the Probabilistic Capacity worksheet: The input and output table.

Section A comprises a spreadsheet area with 12 columns and 52 rows:

Column A (Parameter name): The first column contains the names of parameters relevant for the calculations (input-, calculations- and output parameters).
Column B (Unit): The second column specifies the units of each parameter.
Column C (Pressure points): The third column illustrates the labels of the aquifer, as depicted in Figure 4.
Column D-G (Parameter values, Beta distribution): Input parameters for the calculations can be entered in the fourth to seventh column. The stochastic input variables are modeled using a 4-parameter Beta distribution (see Reference 1).
Column H (Deterministic calculation): The eighth column shows results of the deterministic capacity calculation, which is derived from the values in the column “Modus”. The formulas to come to these results can be inspected by the user in these cells.

Column I-L (Probabilistic calculation): Columns nine through twelve display the results obtained from Monte Carlo sampling of the thirteen input parameters. Rows 49 through 51 represent the outcomes of the Monte Carlo simulation based on these parameters.

3.1.2 Section B

In Section B of the Probabilistic Capacity worksheet (referred to as the Input CDF viewer), users can evaluate the inherent variability and uncertainty associated with each input parameter using both a probability density function (PDF) and a corresponding cumulative distribution function (CDF) plot (Figure 3).

Users can choose and display any of the thirteen input parameters from the dropdown menu in cell N4.

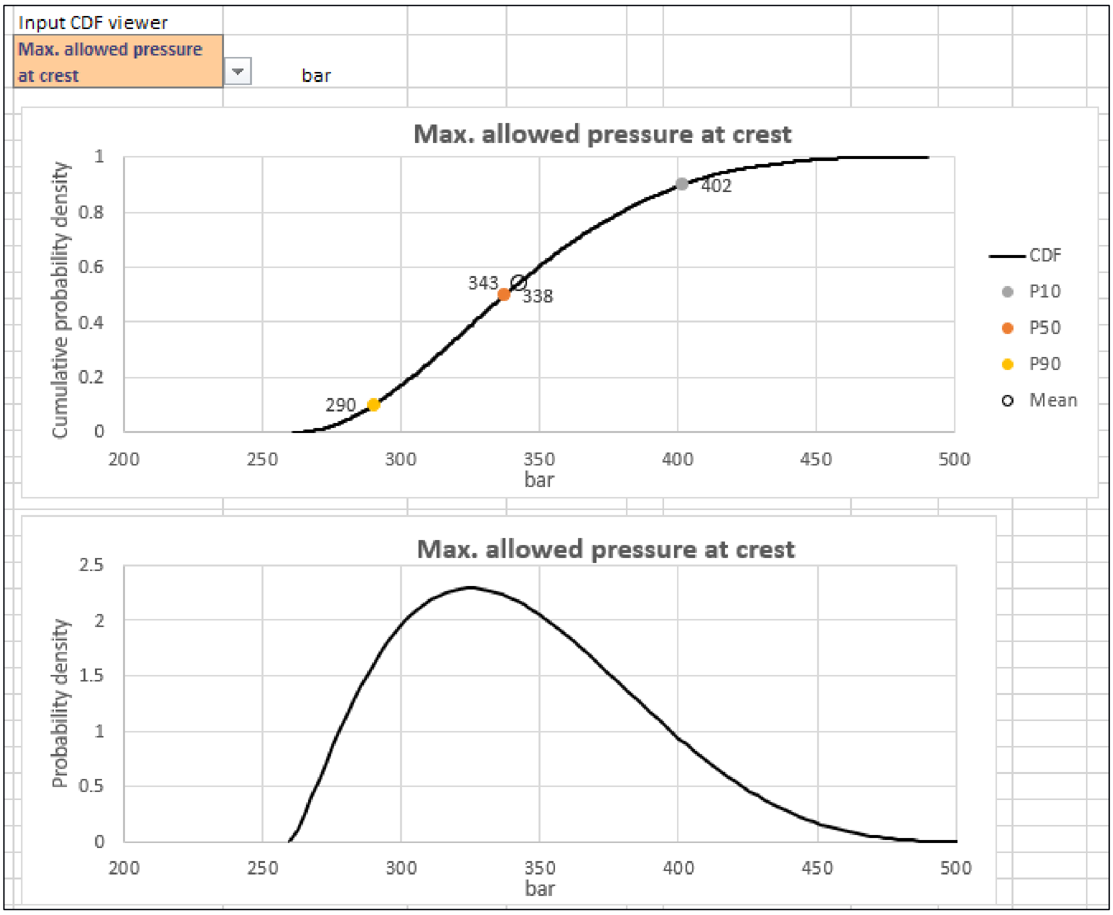

Figure 3 – Overview of Section B of the Probabilistic Capacity worksheet: The Input CDF viewer.

3.1.3 Section C

In Section C of the probabilistic capacity worksheet is a graphical representation of the pressure profile of an aquifer over depth. The labeled lines represent the pressure over depth before (Initial aquifer pressure line A-C-F) and after (see Final aquifer pressure line B-D-G) injection of CO_2. The additional lines and points shown in this graph are further explained in Reference 1.

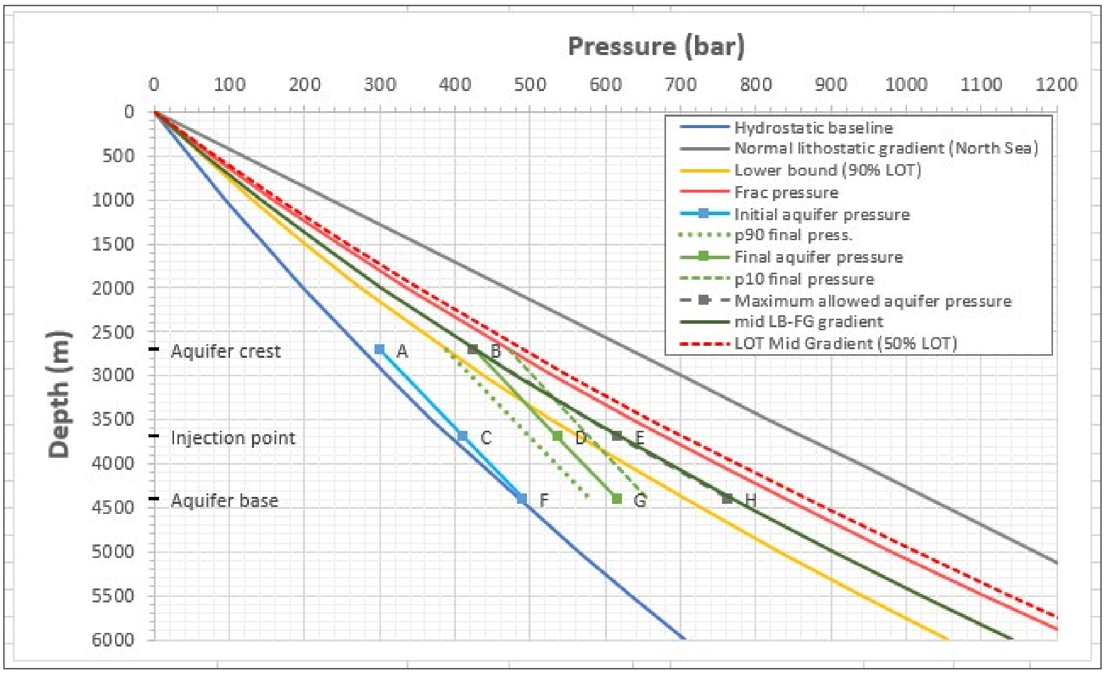

Figure 4 - Overview of Section C of the Probabilistic Capacity worksheet: The Aquifer storage complex pressures graph.

3.1.4 Section D

Section D of the probabilistic capacity worksheet visualizes the cumulative density and frequency distribution of the calculated CO_2 storage capacity.

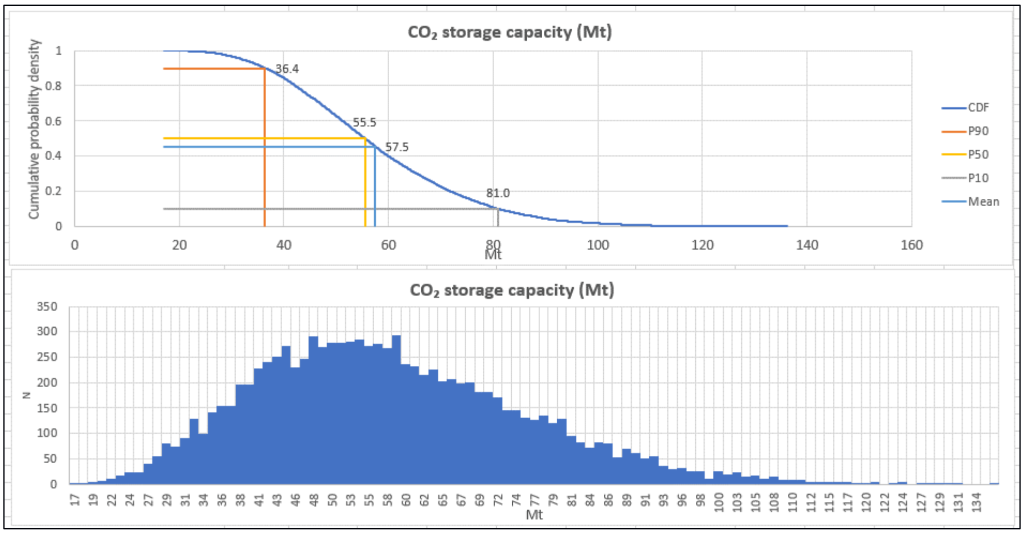

Figure 5 – Overview of Section D of the Probabilistic Capacity worksheet: The Output viewer.

3.1.5 Section E

Section E of the probabilistic capacity worksheet features the tornado diagram. The tornado diagram can be used to determine the relative importance of input variables.

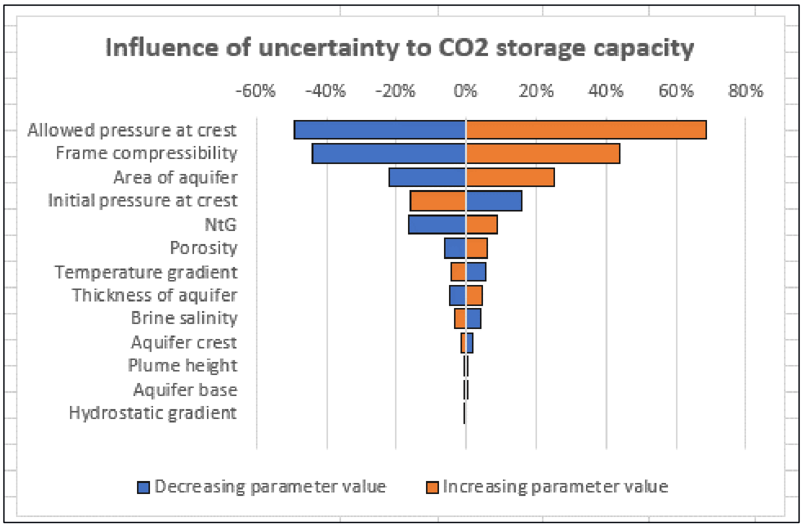

Figure 6 – Overview of Section E of the Probabilistic Capacity worksheet: The Tornado chart.

4 Instructions

4.1 Automatic calculation

When using the SCADSA tool, make sure that Excel's automatic calculation option is enabled. You can find this option in Excel's menu under **Formulas** > **Calculation Options** > **Automatic**. When this functionality causes slow functioning of the sheet, you can disable it using **Formulas** > **Calculation Options** > **Manual** and perform the calculations using **Formulas** > **Calculate Now**.

4.2 Sample frequency

In cell A56 of section A the user can adjust the number of samples used in the Monte Carlo simulation. This value should be an integer higher than 0 and lower or equal to 10.000.

The Monte Carlo simulations involves random sampling and repeated calculations. As a result, it demands significant computational resources. Please ensure that your system has sufficient processing power and memory to handle the simulation effectively.

If you encounter unacceptable delays during usage of the tool, consider:

- lowering the sample frequency of the Monte Carlo simulations. This adjustment will expedite calculations during data input, with the drawback of a lower resolution frequency plot in section D. After entering all relevant data, it is recommended to increase the sample frequency back to the program's maximum of 10,000 samples. A larger sample size ensures a precise and reliable assessment of the CO_2 storage capacity of your storage complex.
  OR:
- disable Automatic calculation using **Formulas** > **Calculation Options** > **Manual** and perform the calculations using **Formulas** > **Calculate Now**.

	A	B	C	D
55	CO_2 storage capacity (Mt)	Mt		
56	1000	number of samples (<=10.000)		

Figure 7 – Sample frequency for Monte Carlo simulation.

4.3 Input entry

This section covers general considerations for entering input. More detailed and parameter specific considerations will be discussed in section 4.3.

The brown colored cells within the probabilistic capacity worksheet, Section A (see 3.1.1) correspond to input fields. To assess the storage capacity of your investigated storage complex, it is essential to provide relevant data in all input fields.

The input fields consist of four parameter values (Figure 8).

Parameter values (Beta distribution)			
Mode	Min	Max	Kurtosis
2700	2552	2850	7.00

Figure 8 – Parameter input fields for Monte Carlo simulation.
The parameter values define the shape and range of parameter distributions. The distribution is used to sample from in the Monte Carlo simulation. The shape and range of the distribution is according the 4-parmater Beta distribution. These four parameters are: mode, minimum, maximum and kurtosis. Mode, minimum and max can be any real number. Minimum must be lower than mode, and mode must be lower than maximum. Minimum and maximum determine the range of the distribution. The kurtosis determines the shape of the distribution. Values from 0 to 2 will create distributions which sample more frequently from the extremes. 2 can be seen as a uniform distribution. From 2 to 3 the kurtosis will move to a spherical distribution at 3. Higher than 3 will approximate a normal distribution, where higher kurtosis indicates a lower standard deviation. By default, the kurtosis parameter is set to 7.

In Section B of the Probabilistic Capacity Worksheet (paragraph 3.1.2), users can select and display density for which input parameter to display the PDF and CDF. To do this, click on cell N3 and on the small arrow which will appear in cell O3. From there, click on the arrow, and a dropdown menu will appear. From this menu, the user can select the desired parameter by clicking on it (Figure 9).

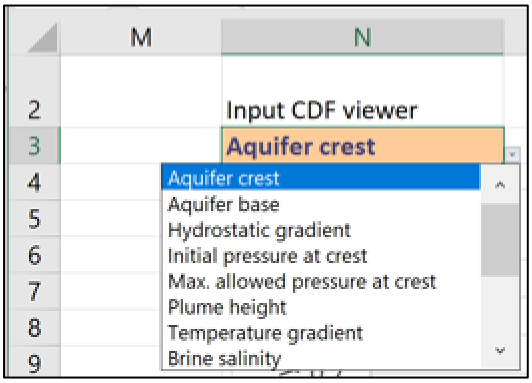

Figure 9 - Input CDF viewer dropdown menu

4.4 Input Parameters

In columns D-G of the Probabilistic capacity worksheet, users can define the thirteen input parameters used to calculate the CO_2 storage capacity of the aquifer. The brown-colored cells within the worksheet correspond to these input fields. Please refrain from modifying worksheet cells that are not colored.

4.4.1 Aquifer crest

In row 4 (Figure 10) can enter the input (columns D-G) for the distribution for the depth of the aquifer crest. The input range for mode, min and max are between 0 and 10.000 (indicating a reservoir crest below the sea surface) in meter True Vertical Depth subsea (mTVDss). There should be no overlap in the range of these values and that of the aquifer base and this input range should always be lower than that of the aquifer base.

3	*Aquifer*			Mode	Min	Max	Kurtosis
4	Aquifer crest	m (TVDss)		2700	2552	2850	7.00

Figure 10 – Parameter entry fields for depth of the aquifer crest.

The aquifer crest corresponds to the depth of the highest (shallowest) point within the aquifer. The user can locate this point on your Top Reservoir Depth Map of the aquifer. Values higher than 0 will indicate a depth of the aquifer crest above the sea surface.

4.4.2 Aquifer base

In row 5 (Figure 11) the user can enter the input (columns D-G) for the distribution for the depth of the aquifer base. The input range for mode, min and max must be between 0 and 10.000 (indicating a reservoir crest below the sea surface) in the unit mTVDss. There should be no overlap in the range of these values and that of the aquifer crest and this input range should always be higher than that of the aquifer crest.

5	Aquifer base	m (TVDss)		4400	4250	4550	7.00

Figure 11 - Parameter entry fields for depth of the aquifer base.

The aquifer base corresponds to the depth of the lowest (deepest) point within the aquifer. The user can locate this point on your Base Reservoir Depth Map of the aquifer.

4.4.3 Hydrostatic gradient

In row 6 (Figure 12) the user can enter the input (columns D-G) for the distribution for the hydrostatic gradient. The input range for mode, min and max is generally between 0.95 and 1.9 in the unit bar per 10 m.

6	Hydrostatic gradient	bar/10m		1.12	1.05	1.19	7.00

Figure 12 - Parameter entry fields for hydrostatic pressure gradient.

The hydrostatic pressure gradient refers to the rate of change in formation fluid pressure with depth. Users can assess this gradient by analyzing formation pressure data, such as data obtained from Repeat Formation Tests (RFTs) or from wells within and around the relevant aquifer. In situations where reliable fluid pressure data is unavailable, the SCADSA tool offers users three theoretical alternatives within the Hydrostatic worksheet (Figure 13) to calculate a hydrostatic pressure gradient.

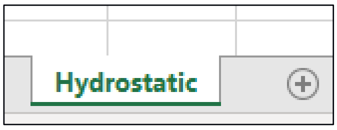

Figure 13 – Tab label Hydrostatic gradient calculator

The worksheet does not require additional data entry. The salt, temperature, and pressure input parameters (cells D4, D5, D6) are automatically populated from the Probabilistic Capacity worksheet. Users can find the Hydrostatic gradients, referred to as the 'Brine pressure gradient,' in this worksheet at cells D12, D25, and D48.

4.4.4 Initial pressure at crest

In row 7 (Figure 14) the user can enter the input (columns D-G) for the distribution for the initial pressure at aquifer crest. The input range for mode, min and max must be between 0 and 1200 bar.

7	Initial pressure at crest	bar	A	300	280	320	7.00

Figure 14 - Parameter entry fields for initial pressure at the crest.

The term 'Initial pressure at crest' refers to the formation water pressure at the aquifer's highest point before CO_2 injection takes place. Users can assess this pressure by analyzing formation pressure data, such as data obtained from Repeat Formation Tests (RFTs), conducted in wells within the relevant aquifer. After inputting the 'Initial pressure at crest' value and specifying the height of the CO_2 plume, the SCADSA tool will automatically compute the initial pressure of the aquifer at both the injection point and the base of the aquifer (see Figure 15 and column C from the Probabilistic Capacity worksheet).

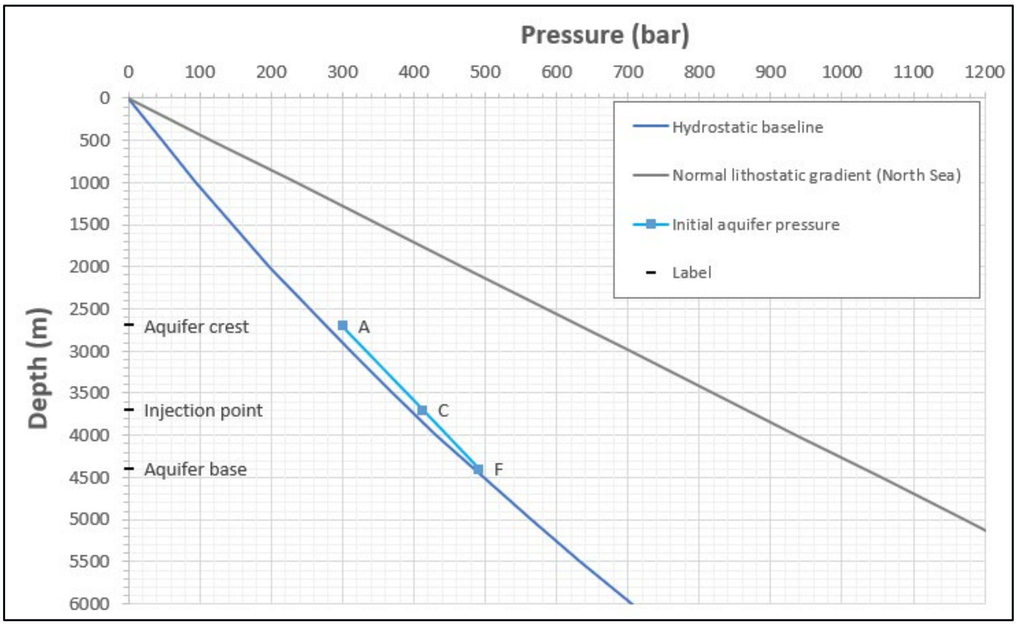

Figure 15 – Pressure over depth profile with the indicated hydrostatic and lithostatic profiles. Labeled initial aquifer pressures are A) at the aquifer crest, C) at the injection point and F) at the aquifer base.

4.4.5 Maximum allowed pressure at crest

In row 12 (Figure 14) the user can enter the input (columns D-G) for the distribution for the maximum allowed pressure at aquifer crest. The input range for mode, min and max must be between 0 and 1200 bar.

12	Max. allowed pressure at crest	bar	B	425	365	515	7.00

Figure 16 - Parameter entry fields for maximum allowed pressure at the crest.

The term ‘Max. allowed pressure at crest’ refers to the maximum allowed pressure of the aquifer. This allowed pressure can be the pressure before the caprock is fractured and leakage of CO_2 occurs, or other reasons to cap the pressure. After inputting the ‘Max. allowed pressure at crest’ value (= final aquifer pressure at crest) the SCADSA tool will automatically compute the aquifer’s final pressure at both the injection point and the base of the aquifer (see Figure 17 and column C from the Probabilistic Capacity worksheet).

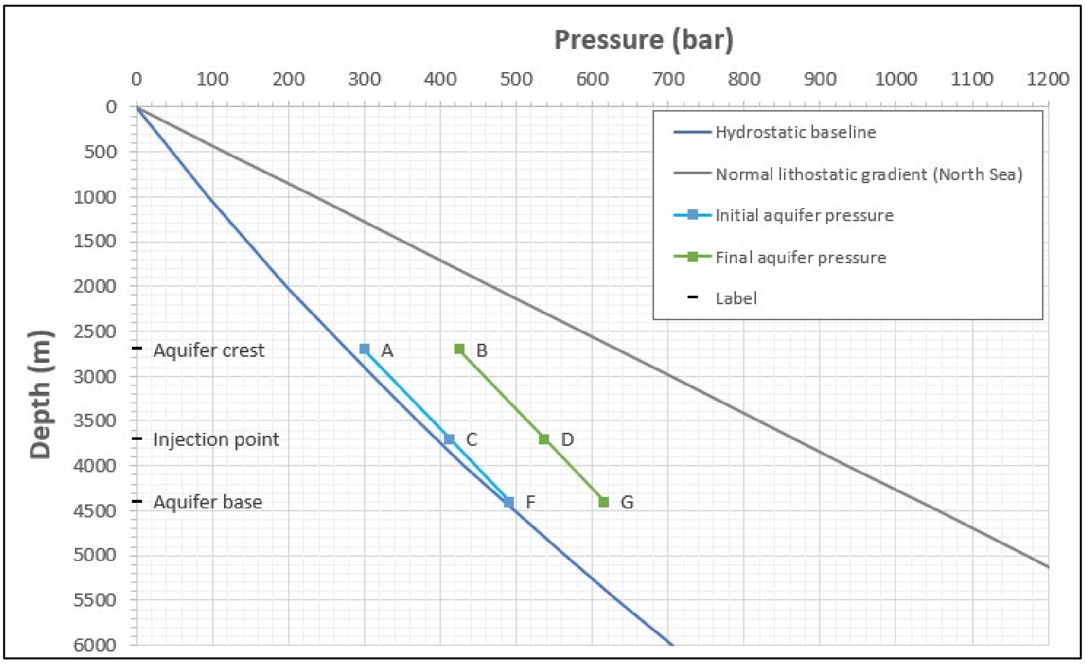

Figure 17 - Pressure over depth profile with the indicated hydrostatic and lithostatic profiles and the initial aquifer pressures (described in Figure 15). Additionally, the final aquifer pressures are indicated at B) the aquifer crest, D) the injection point and G) the aquifer base.

4.4.6 Plume height

In row 13 (Figure 18) the user can enter the input (columns D-G) for the distribution for the plume height. The input range for mode, min and max must be between 0 and 10.000 in meter.

13	Plume height	m		1000	900	1100	7.00

Figure 18 - Parameter entry fields for plume height.

The plume height refers to the vertical extent of the CO_2 plume formed when CO_2 is injected into an aquifer. As the buoyant CO_2 migrates upward, it displaces water or brine, within the aquifer. In the SCADSA tool, the plume height is defined as the vertical distance in m from the CO_2 injection point to the crest of the aquifer. Therefore, the injection point depth is computed by adding the depth of the aquifer's crest to the plume height.

4.4.7 Temperature gradient

In row 26 (Figure 19) the user can enter the input (columns D-G) for the distribution of the temperature gradient over depth. The input range for mode, min and max must be between 0 and 100 in °C/km.

26	Temperature gradient	°C/km		30	25	35	7.00

Figure 19 - Parameter entry fields for temperature gradient.

The temperature gradient can be assessed from temperature measurements in wells within and around the relevant aquifer.

4.4.8 Brine salinity

In row 33 (Figure 20) the user can enter the input (columns D-G) for the distribution of the salinity of the aquifer fluid. The input range for mode, min and max must be between 0 and 500.000 in the unit parts per million (ppm).

33	Brine salinity	ppm		200,000	150,000	250,000	7.00

Figure 20 - Parameter entry fields for brine salinity.

The brine salinity can be assessed from analyzed formation water samples taken from wells within and around the relevant aquifer.

4.4.9 Solid rock compressibility

In row 37 (columns D-G) the user can enter the input the value for solid rock compressibility of the grains. The input range for mode, min and max must be between 0 and 1 in the unit 1/bar (bar^{-1}).

37	Solid rock compressibility	1/bar		2.71E-06	2.50E-06	3.00E-06	7.00E+00

Figure 21 - Parameter entry fields for solid rock compressibility.

The term solid rock compressibility refers to the relative volume change of a non-porous rock in response to pressure variations. In the SCADSA tool, this change is specified in compressibility per bar (1/bar) of pressure increase. Solid rock compressibility is influenced by the mineral composition of the aquifer rock. By default, the solid rock compressibility is set to 2.71E-6 per bar of pressure increase. This value is typical for quartz.

4.4.10 Frame compressibility

In row 38 and row 39 (Figure 22), users can input values (columns D and G) for the frame compressibility distribution. Notably, this parameter is divided into two rows. The values in row 39 represent a function based on porosity, as frame compressibility is dependent on porosity. In cell D39, a formula is entered like any other Excel formula. When this formula references cell D47 (the mode of porosity), it is considered in the Monte Carlo analysis, where frame compressibility is linked to porosity according to this formula. Notably, the Monte Carlo analysis uses randomly drawn porosity values, rather than the mode of porosity. The parameters in row 38 act as multipliers. The formula calculates a single frame compressibility value. However, since frame compressibility can be uncertain for a specific porosity, these multipliers adjust the result of the formula to determine the minimum and maximum values for the Beta distribution.

	A	B	C	D	E	F	G
38	Uncertainty factor for frame compressibility for specified porosity	-		1	0.5	1.5	
39	Frame compressibility	1/bar		7.651E-06	3.83E-06	1.15E-05	7.00

Figure 22 - Parameter entry fields for frame compressibility.

The input range for mode, min and max in row 39 must be between 0 and 1 in the unit bar^{-1}. The input range for row 39 is between 0 and 1.

The term frame compressibility refers to the relative volume change of a grain supported porous material, grain/pore structure of the aquifer rock, in response to pressure variations. By default, the frame compressibility is a typical relationship between porosity and frame compressibility for the Rotliegend fluvio-aeolian sandstone reservoir. The uncertainty factors have been based on the data can be adjusted based on available data from TNO (2013). The relationship between porosity, and the uncertainty, can be adjusted when knowledge of these parameters exist from, for instance, geomechanical lab tests or field observations.

Note that the plots in section B will show the distribution for the frame compressibility at the porosity specified in D47.

4.4.11 Use predefined bulk volume?

In row 42 (Figure 23) of the SCADSA tool, users can specify whether the aquifer's pore volume calculation should be based on 'Bulk volume' or 'Area x Thickness'. A drop-down menu for this choice will appear when selecting cell D42.

42	Use predetermined bulk volume?			Yes
43	Bulk volume of aquifer	m^3		Yes No

Figure 23 – Dropdown menu to toggle between calculating bulk volume from area and thickness, or to set the bulk volume manually.

If 'Yes' is selected, users can enter the assessed aquifer's bulk volume and its uncertainty range in cells D43 through F43. In the SCADSA tool, the bulk volume of the aquifer must be specified in cubic meters (m^3). These values must be higher than 0.

42	Use predetermined bulk volume?			Yes			
43	Bulk volume of aquifer	m^3		6.91E+10	5.15E+10	9.04E+10	7.00
44	Area of aquifer	m^2		3.2E+08	2.50E+08	4.00E+08	7.00
45	Thickness of aquifer	m		216	206	226	7.00

Figure 24 – View of input fields in row 42-45 when D42 is set to "Yes".

If 'No' is selected, users can enter the assessed aquifer's area and its thickness in rows 44 and 45. In the SCADSA tool, the area of the aquifer must be specified in square meters (m²), whereas the thickness of the aquifer must be specified in meter (m). These values must be higher than 0.

42	Use predetermined bulk volume?			No			
43	Bulk volume of aquifer	m³		6.91E+10	5.15E+10	9.04E+10	7.00
44	Area of aquifer	m²		3.2E+08	2.50E+08	4.00E+08	7.00
45	Thickness of aquifer	m		216	206	226	7.00

Figure 25 – View of input fields in row 42-45 when D42 is set to "No".

4.4.12 NtG

In row 46 (Figure 26) the user can enter the input (columns D-G) the value for the net to gross ratio (NtG). The values for mode, min and max must be between 0 and 1 and have no unit.

46	NtG	fraction		0.92	0.77	1.00	7.00

Figure 26 - Parameter entry fields for net-to-gross ratio.

The net-to-gross ratio of the aquifer's reservoir sandstone can be determined through petrophysical evaluations conducted in wells both within and around the relevant aquifer.

4.4.13 Porosity

In row 47 (Figure 27) the user can enter the input (columns D-G) the value for porosity. The values for mode, min and max must be between 0 and 1 and have no unit.

47	Porosity	fraction		0.14	0.12	0.16	7.00

Figure 27 - Parameter entry fields for porosity.

The porosity of the aquifer's reservoir sandstone can be determined through petrophysical evaluations conducted in wells both within and around the relevant aquifer.

5 Output

The SCADSA tool output (see Figure 28) includes the CO_2 storage capacity of the aquifer, expressed in kilograms (row 49) and megatons (row 50), as well as the (pore space) efficiency factor (row 51). The efficiency factor represents the proportion of additional pore space resulting from increase pressures in the aquifer due to CO_2 injection, compared to the initial pore space before CO_2 injection.

	A	B	H	I	J	K	L
2	**Parameter name**	**Unit**	**Deterministic calculation**	**Probabilistic calculation**			
3	***Aquifer***		**Modus**	**Mean**	**P90**	**P50**	**P10**
49	CO_2 storage capacity (kg)	kg	5.58E+10	5.78E+10	3.67E+10	5.63E+10	8.08E+10
50	CO_2 storage capacity (Mt)	Mt	**55.8**	**57.8**	**36.7**	**56.3**	**80.8**
51	Efficiency factor	-	0.78%	0.81%	0.53%	0.78%	1.12%

Figure 28 – SCADSA Output

The deterministic storage capacities and efficiency factor outputs, located in cells H49, H50, and H51 of the Storage Capacity worksheet, are calculated based on the ‘mode’ input values from parameters entered in column D.

The probabilistic storage capacities and efficiency factor outputs, located in cells I49 through I51, are based on the mode, min, max and kurtosis input values from parameters entered in columns D, E, F and G. The probabilistic output is based on Monte Carlo simulations.

The summary statistics from the Monte Carlo simulation are explained as follows:
Mean (Average): This represents the average value of the calculated estimates from the Monte Carlo simulation.
P90 (Proved): The lowest figure. It indicates that 90% of the calculated estimates will be equal to or exceed the P90 estimate.
P50 (Median): This represents the median value. It signifies the point where 50% of the outcomes are greater, and the other 50% are less than this value.
P10 (Possible): The highest figure. It means that 10% of the calculated estimates will be equal to or exceed the P10 estimate.

References

1. Ravestein, T., Davids, B., van Buggenum, J. 2025. SCADSA - Storage Capacity Assessment for Deep Saline Aquifers - A tool to assess the capacity for storage of carbon dioxide in deep saline aquifers – TNO public report-TNO2025 R10218

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Glossary

CO_2: Carbon dioxide

mTVDss: meter True Vertical Depth subsea, It represents the vertical distance from a specific point of interest in a wellbore to the sea level.

Mt: Megaton, 1 million ton or 1 billion kg

NtG: net-to-gross

p10-p50-p90: Probability estimates. P10=high; p50=median; p90=low

ppm: Parts per million

RFT: Repeat Formation Test, formation pressure test

SCADSA: Storage Capacity Assessment of Deep Saline Aquifers

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