Programme Area: Carbon Capture and Storage

Project: Storage Appraisal

Title: User Guide for the Web-enabled Database and Geographical Information System

Abstract:

This deliverable is the user guide for accessing the Web-enabled Database and Geographical Information System (WDG). The guide includes; Logging on; Primary menus; Retrieving database information on storage units; and Map (Geographic Information System).

Context:

This £4m project produced the UK's first carbon dioxide storage appraisal database enabling more informed decisions on the economics of CO2 storage opportunities. It was delivered by a consortium of partners from across academia and industry - LR Senergy Limited, BGS, the Scottish Centre for Carbon Storage (University of Edinburgh, Heriot-Watt University), Durham University, GeoPressure Technology Ltd, Geospatial Research Ltd, Imperial College London, RPS Energy and Element Energy Ltd. The outputs were licensed to The Crown Estate and the British Geological Survey (BGS) who have hosted and further developed an online database of mapped UK offshore carbon dioxide storage capacity. This is publically available under the name CO2 Stored. It can be accessed via www.co2stored.co.uk.

UKSAP

The UK Storage Appraisal Project

Conducted for

The Energy Technologies Institute

User Guide for the Web-enabled Database and Geographical Information System (WDG)

Contents

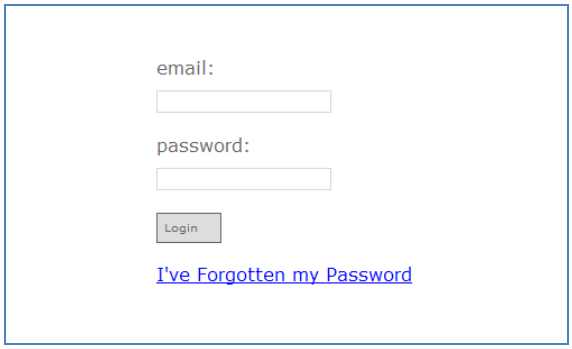
1 Login to Carbonstore

The UK Storage Appraisal Project (UKSAP) Web-enabled Database and GIS (WDG) is accessed via the following url:

http://www.carbonstore.org.uk/

Entry into the system requires a registered Username (e-mail address) and Password, issued by the database administrator:

Note: This user guide covers both User and Admin rights. Not all users will see everything in the guide, e.g. downloading rights are restricted to Admin.



2 Primary Menus

The following sections give guidance to use of top-level tabs, visible from the Carbonstore 'Home' page, and the options directly associated with them. The top-level tabs comprise:

Storage Units The principal point of entry into the UKSAP database, from which new storage units can be created, and information on existing units may be viewed and edited.

Overall Capacity Summed storage capacity of storage units in the database, and/ or matching any search criteria entered on the 'Search Units' page.

Map Entry to the Geographical Information System, or GIS.

Admin Access to various database administration functions.

Help Placeholder for future Help files etc: currently summarises a selection of computed parameters, and the input (or dependent) parameters that require to be entered in order for the computed parameter to be displayed.

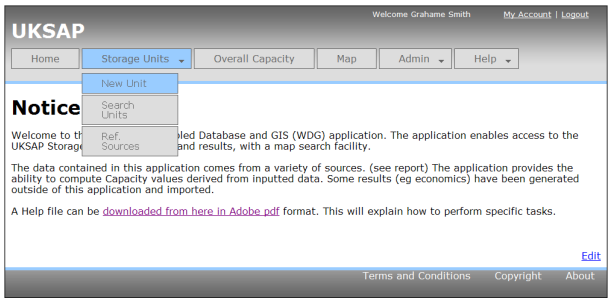
2.1 Storage Units

The 'Storage Units' tab provides the principal route into the UKSAP database, for creating new storage units and entering/ amending information stored on existing units.

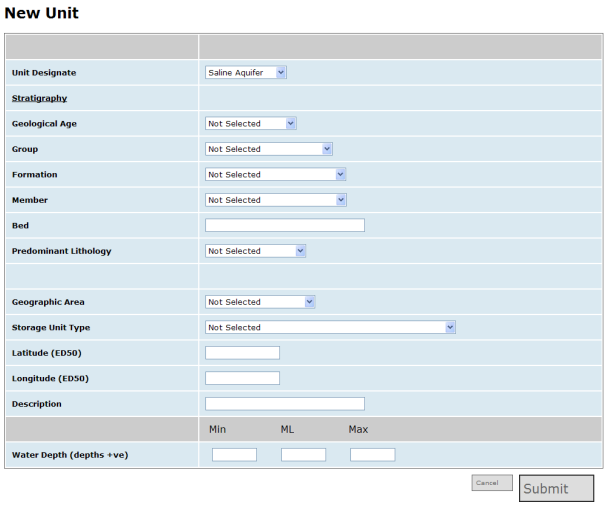
2.1.1 Create a Storage Unit

User requires database 'write' privileges (only available to users involved in project work to update the WDG).

On the home page click the 'Storage Units' tab. From the drop down menu select 'New Unit':

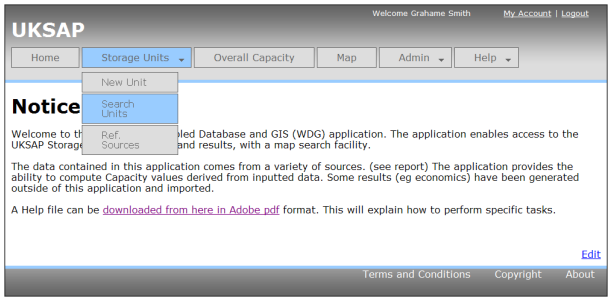


The 'New Unit' page appears. Select from the drop down menus or type in the text fields to enter information about the storage unit. To save, click 'Submit' in the bottom right corner. Certain parameters require an entry before the page will save.

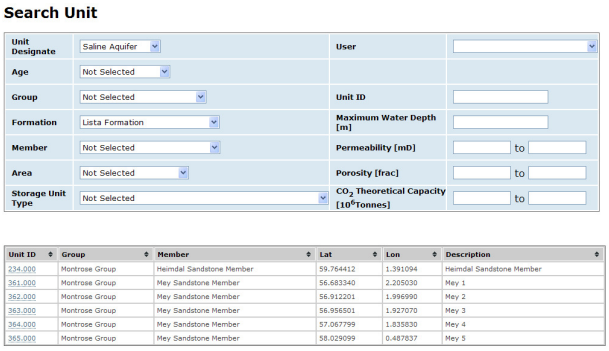


2.1.2 Search for a Storage Unit

On the home page click the 'Storage Units' tab. From the drop down menu select 'Search Unit':



The 'Search Unit' page appears. If required, filter for matching storage units using the available parameters (Unit Designate, Age, Group, Formation, Unit ID etc). In the example shown, all Saline Aquifer stores in the Lista Formation have been selected:



From the list of matching units at the base of the page, click on the desired 'Unit ID' to enter the database pages containing information specific to that unit.

The unique ID is a number allocated to each storage unit as it is created within the database. An integer ID indicates a parent unit; daughters retain the corresponding integer part of the ID number, and the decimal part is used to distinguish between individual daughters of the same parent. The parent might, for example, be one part of an extensive formation, which has been identified as a separate storage unit because it has a representative reservoir pressure that is distinct from other parts of that formation. The daughters might then be each of the identified hydrocarbon fields associated with that parent. Thus

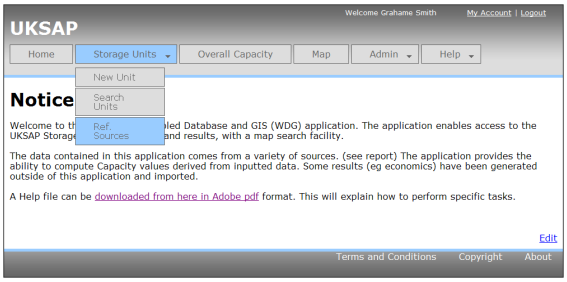
Unit ID 166.000	Tarbert_211_23 (part of the Tarbert Formation) [Parent]
Unit ID 166.002	Alwyn North oil field [Daughter of Unit 166.000]
Unit ID 166.003	Thistle oil field [Daughter of Unit 166.000]
.....	
Unit ID 167.000	Tarbert_003_02 (also part of the Tarbert Formation, but distinct to Tarbert_211_23) [Parent]

The ID number itself has no significance other than to provide a means of cross-referencing information within the relational database. They are not necessarily continuous, nor should anything be inferred about the geographical location of units with either similar, or very different, storage unit IDs.

Further guidance on navigation through the database pages specific to a unit are given in section 3

2.1.3 Reference Sources

On the home page click the 'Storage Units' tab. From the drop down menu select 'Ref. Sources':

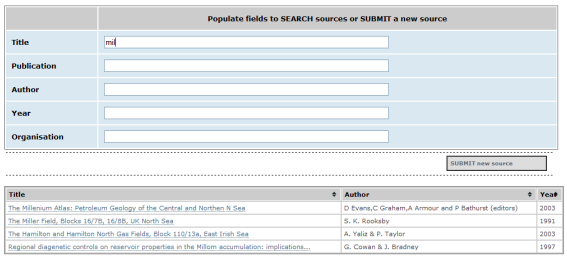


The 'Reference Sources' page appears. Reference sources are listed at the base of the page. As information is entered in the Title, Publication, Author boxes etc, the list of matching reference

sources reduces in accordance with the search criteria entered.

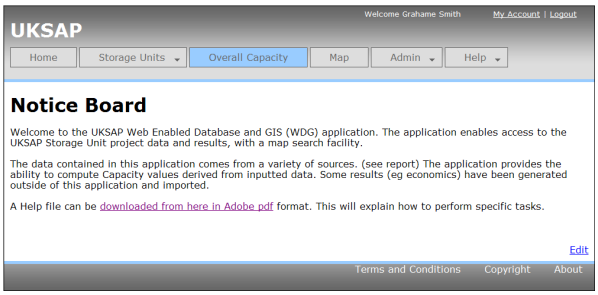
Details of a new reference source can be entered and saved by clicking the 'SUBMIT new source' button.

Reference Sources



2.2 Overall Capacity

On the home page click the 'Overall Capacity' tab:



The 'Overall Theoretical Capacity' is displayed, this being the summed theoretical storage capacity (P_{90}, P_{50}, P_{10}) of all units in the database. For further information on Theoretical Capacity, refer to section 3.2.5.

If search criteria have been entered on the 'Search Units' page, the summed capacity of all matching units is also displayed.

The maximum number of matching units is currently limited to 50 to prevent time-out errors as database queries are run across the internet connection.

Overall Theoretical Capacity

Total Number of Storage Units		574
Number of Storage Units With Results		505
Overall Theoretical Capacity (P90)	[10^6 Tonnes]	62845
Overall Theoretical Capacity (P50)	[10^6 Tonnes]	69172
Overall Theoretical Capacity (P10)	[10^6 Tonnes]	75499

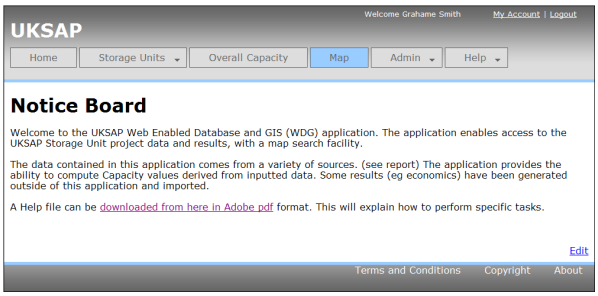
Searched units only

Total Number of Storage Units		6
Number of Storage Units With Results		6
Preliminary Overall Theoretical Capacity (P90)	[10^6 Tonnes]	3795
Preliminary Overall Theoretical Capacity (P50)	[10^6 Tonnes]	7189
Preliminary Overall Theoretical Capacity (P10)	[10^6 Tonnes]	10583

The summed P_{90}, P_{50}, P_{10} capacities of searched units is calculated on the assumption that the sum of many distributions, irrespective of their individual skewness, approximates a normal distribution. However, the lower the number of combined distributions, the greater the degree of this approximation. Summed capacities are hence described as preliminary; if individual storage unit capacity distributions were exported from the database and combined rigorously (for example using Monte Carlo simulation), more accurate estimates of the overall P_{90} and P_{10} capacity would be achieved.

2.3 Map (GIS)

On the home page click the 'Map' tab to enter the Geographical Information System (GIS) interface:



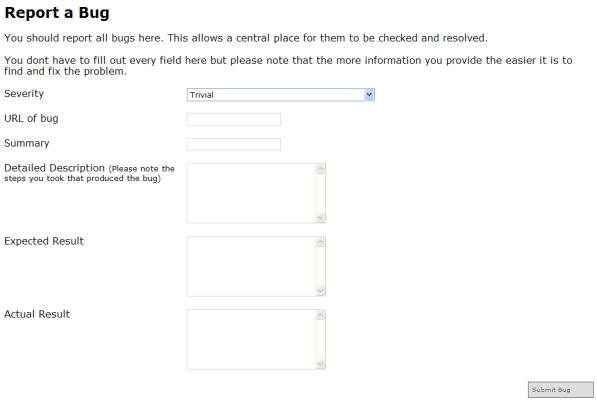
More information on use of the GIS is provided in section 4.

2.4 Admin

The 'Admin' tab provides access to a range of database administration tasks, dependent on the database access privileges assigned to the user.

2.4.1 Report a Bug

If a software bug is suspected, it may be reported to the database administrator by completing details on the 'Report a Bug' page:



2.4.2 Request a Feature

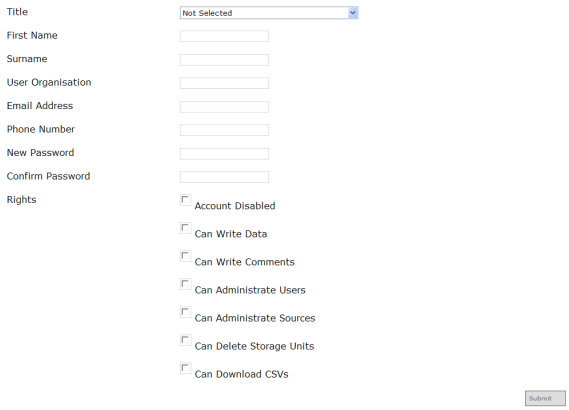
A new feature may be requested through the 'Request a Feature' page:

Fill in the text fields with required information and click 'Submit'. The feature report will be sent to the site administrator by email.

2.4.3 Administrate Users

This feature is for database administrators only. It allows user details to be edited, access privileges set, and new users to be added.

To add a new user and set privileges, select Admin\ Administrate Users, and click on the '**New User**' link:



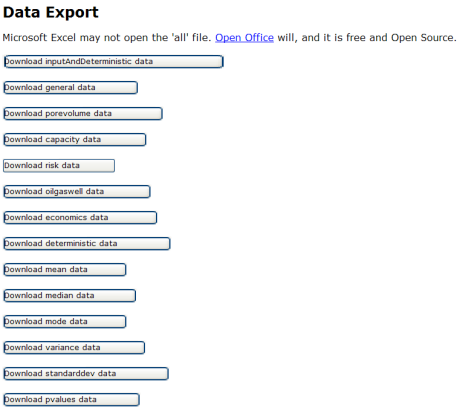
2.4.4 Email Users

This feature is for database administrators only. It allows the database administrator to e-mail all registered users with information about updates to the system, server maintenance periods etc

2.4.5 Download All Units

Allows database content to be downloaded to Comma Separated Variable (CSV) files, for subsequent import to other software applications (such as spreadsheets, statistical analysis software, presentations etc):

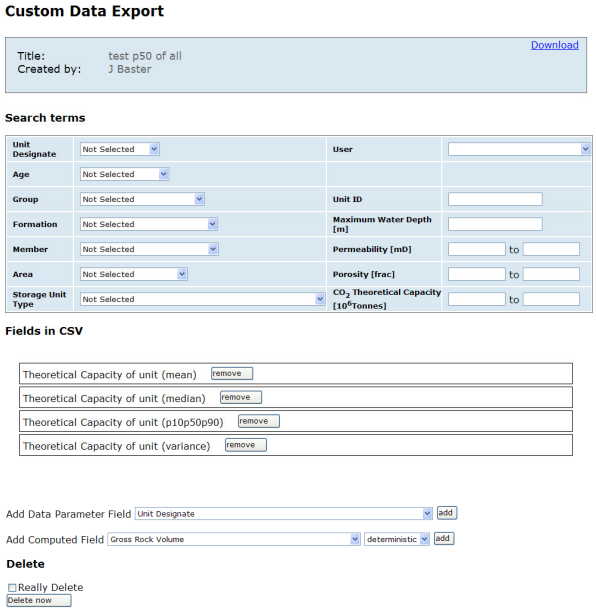
The database is too large to download as one file, hence a number of pre-defined database sections have been made available. These may be subsequently cross-referenced by use of the unique storage unit ID number, written to each CSV file.



2.4.6 Custom Data Exports

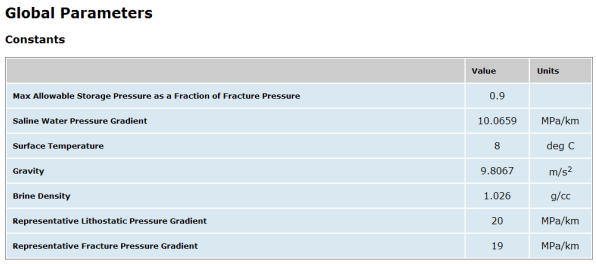
This feature is only available to users with specific privileges. If the standard database download CSV files are insufficient, custom downloads may be compiled:

Select Admin\ Custom Data Exports. Choose a previously compiled download specification from the list, or enter the name of a new CSV file and click 'create'. Search criteria may be applied to limit the storage units included in the download, and the required database fields can be specified by the 'Add Data Parameter' and 'Add Computed' fields. Once completed, click the '**Download**' link at the top right of the page.



2.4.7 Global Parameters

A number of calculations embedded within the WDG use default values or constants which may require future revision. For convenience, the 'global constants' used by the calculations may be viewed here:



	Value	Units
Max Allowable Storage Pressure as a Fraction of Fracture Pressure	0.9	
Saline Water Pressure Gradient	10.0659	MPa/km
Surface Temperature	8	deg C
Gravity	9.8067	m/s^2
Brine Density	1.026	g/cc
Representative Lithostatic Pressure Gradient	20	MPa/km
Representative Fracture Pressure Gradient	19	MPa/km

2.5 Help

Placeholder for future Help files etc: currently summarises a selection of computed parameters, and the input (or dependent) parameters that require to be entered in order for the computed parameter to be displayed.

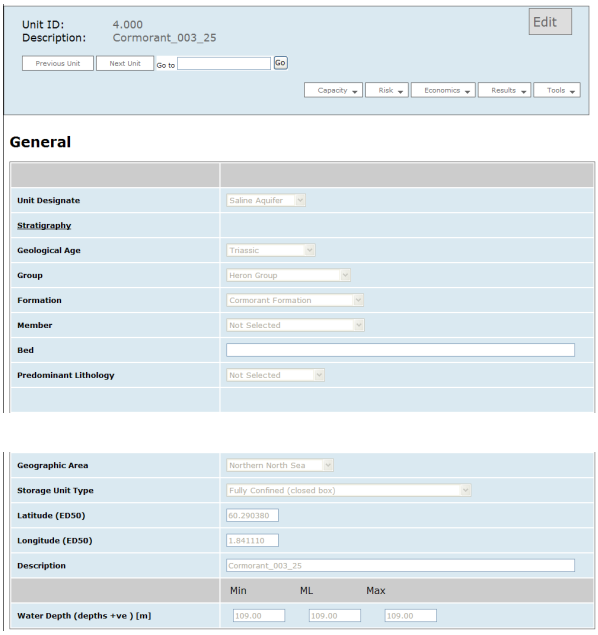
3 Retrieving Database Information on Storage Units

The following sections give guidance to accessing, viewing and editing information related to specific storage units. The pages containing this information are accessed via the 'Storage Units\ Search Units' selection, as described in section 2.1.

The colour-code convention used throughout is that light blue areas contain input data; the green areas contain calculated values, derived from the input data in accordance with the algorithms embedded within the WDG. In order for a computed result to be displayed, **all** its associated input parameters must have been entered.

3.1 Storage Unit 'General' page

From the 'Storage Units' tab select 'Search Units'. Apply search criteria and then click on the 'Unit ID' of the required storage unit. The storage unit 'General' page is displayed:



Users with 'write' privileges may amend data by clicking the 'Edit' button at the top right. To save or discard changes, click the 'Submit' or 'Cancel' buttons at the foot of the page.

If required, comments may be added at the foot of the page.

The 'Previous Unit', 'Next Unit' and 'Go' buttons may be used to move from one storage unit to another. If search criteria have been entered on the 'Search Units' page, 'Previous' and 'Next' storage unit buttons refer to storage units in the filtered list rather than entire database. The storage unit ID number should be entered to 'Go' directly to a specific unit.

To the right of the Unit ID navigation buttons in the uppermost blue banner, are the tabs and dropdown menus that allow access to the other data pages associated with each storage unit. The precise pages that are visible are dependent on the 'Unit Designate': data-entry pages for saline aquifer stores are different from those associated with (depleted) hydrocarbon fields. Hovering the mouse over each tab reveals the pages that are accessible for the current unit. The tabs are:

Capacity access to storage unit information used to calculate the CO_2 storage capacity of each unit

Risk Risk assessment data (saline aquifer stores only)

Economics Results of economic analysis derived for each unit externally of the WDG, and then uploaded to the database

Results Summary of Monte Carlo simulation results

Tools Various tools to assist in the creation and management of storage units within the database

3.2 Capacity (Saline Aquifer Storage Units)

For saline aquifer storage units, data pages available via the 'Capacity' tab are as follows:

3.2.1 General

Hovering the mouse over the 'Capacity' tab and selecting 'General' from the dropdown menu allows direct return to the General page from any of the other storage unit information pages.

3.2.2 Pore Volume

The Pore Volume page contains information about the storage unit's areal extent, thickness, porosity and net-to-gross (NTG) ratio. For most parameters a triangular distribution has been entered to allow Monte Carlo simulation of uncertainty in the computed result.

The deterministic Gross Rock Volume (GRV) and Pore Volume (PV) are displayed, based on the Most Likely input parameter values.

Pore Volume

		Min	Most Likely	Max	Source	Confidence (L,M,H)
Area	[km²]	350.91	389.90	428.89	ARC GIS UNIT Shape F	medium
Average Gross Thickness	[m]	143.42	182.80	222.18	IHS Database	low
Estimated Relief	[m]		1951.00		IHS Database	low
Shape Factor			1.000			
Average Areal Net Sand	[frac]	1.00	1.00	1.00	BGS Shapefiles	medium
Average Vertical NTG	[frac]	0.58	0.64	0.70	Triassic, Permian &	medium
Average Porosity	[frac]	0.12	0.16	0.20	The Cormorant Field,	medium
Gross Rock Volume	[10⁹m³]		71274			
Pore Volume	[10⁶m³]		7298			
Aspect Ratio						
Thickness : Area	[10⁻⁶m⁻¹]		0.4688			

3.2.3 Static Capacity

Computed PV is carried forward from the previous page, and augmented by other input data in order to enable a preliminary estimate of storage capacity to be made.

The method of calculation depends on the 'Storage Unit Type' (see 'General' page). For saline aquifer storage units, this may be either 'Pressure Capacity', 'PV x storage factor' or 'Buoyant Trapping Capacity'; n/a is displayed for those methods inapplicable to the current 'Storage Unit Type'.

Static Capacity

		Min	Most Likely	Max	Source	Confidence (L,M,H)
Pore Volume	[10⁶m³]		4930			
Does Unit extend above 800 mTVDSS?			No			
% PV occupied by stored CO_2 ('open' Units)	%	0.10	2.00	6.00		
Shallowest Depth (at which there is closure)	[m TVDSS]	2953.00	3275.00	3278.00	IHS Database	medium
Depth to centroid of Storage Unit	[m TVDSS]	4662.24	5221.97	5781.70	IHS Database	low
Formation Temp at Shallowest Depth	[Deg C]	96.43	102.90	109.50	The Millenium Atlas:	medium
Pressures						
Expected Pore Pressure at Shallowest Depth and Start of CO_2 Injection	[MPa]	73.08	75.58	78.08		
Lithostatic Pressure at Shallowest Depth	[MPa]	69.48	71.26	73.04		
Fracture Pressure (of Primary Seal) at Shallowest Depth	[MPa]	71.04	74.00	76.96		
Stress field data available			Not Selected			
Pressures					GPT Pressure Cells	high
Rock Compressibility	[MPa⁻¹]				not set.	unknown
Formation Water Salinity	[ppm]		30082.18		Judgement/Analogue	medium
Volumetric Sweep Efficiency	[frac]	0.12	0.33	0.65		
Formation Water Compressibility (Cw)	[MPa⁻¹]		0.000473			
Aquifer Seal Capacity	[MPa]		0.00			
Rock Compressibility (Computed)	[MPa⁻¹]	0.000359	0.000585	0.000995		
CO_2 Density at centroid depth and final storage conditions	Tonnes/m³		0.8273			
CO_2 Viscosity at centroid depth	[cP]		0.0947			
Normal Hydrostatic Pressure at Shallowest Depth	[MPa]		33.0658			
CO_2 Column Height	[m]		0.00			
Static Capacity Estimate						
Pressure capacity ('closed' units)	[10⁶Tonnes]	0	0	0		
PV x storage factor	[10⁶Tonnes]		n/a			
Buoyant Trapping Capacity	[10⁶ tonnes]		n/a			

3.2.4 Injectivity

The injectivity page consists of three sections. The first contains additional data required for the injectivity calculations:

Injectivity

		Min	Most Likely	Max	Source	Confidence (L,M,H)
Storage Formation Permeability	[mD]	0.00	40.00	600.00	The Beryl Field, Blo	low
Irreducible Water Saturation	[frac]	0.200	0.423	0.650		
CO_2 End-Point Relative Permeability	[frac]	0.100	0.237	0.900		
Brine Viscosity at reservoir conditions	[cP]		0.21			

Three tables (P_{10}, P_{50}, P_{90}) follow, containing estimated numbers of wells required to satisfy each injection scenario within the matrix. Down the left-hand column are CO_2 injection rates from 2 to 60 million tonnes per year; along the top are injection durations from 10 to 100 years. In the illustration, 9 injection wells are required to inject 15 Mt/ yr for 20 years in the P_{50} case (300 Mt CO_2 stored). The largest amount of CO_2 stored is 500 Mt, which can be achieved in two ways. For this storage unit, there is no valid scenario > 500 Mt.

Number of Wells (P50)

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)									
	10	20	30	40	50	60	70	80	90	100
2	1	2	2	2	2	2	2	2	2	2
5	3	3	3	3	3	3	3	3	4	7
10	6	6	6	6	13					
15	8	9	12							
20	11	12								
40	24									
60										

Finally, there are a further three tables, displaying the predicted bottom-hole injection pressure (in MPa) required for each scenario

Bottom-hole Injection Pressure (P50)

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)									
	10	20	30	40	50	60	70	80	90	100
2	24.2	24.4	24.6	24.9	25.1	25.4	25.7	26.1	26.4	26.8
5	25	25.9	26.9	28	29	30.1	30.9	31.5	32	32.6
10	26	27.9	30	31.5	32.6					
15	27.2	30	32.1							
20	28.1	31.5								
40	31.6									
60										

3.2.5 Theoretical Capacity

This page displays various intermediate calculated results along with other key input parameters, to enable final estimates of storage capacity to be made.

'Theoretical Capacity' gives the final predicted range of CO_2 storage capacity for the unit, taking into account its static capacity and dynamic effects as appropriate.

'Dynamic Utilisation' is the largest volume stored under the various injection scenarios described above; it must always be less than or equal to 'Theoretical Capacity'.

Theoretical Capacity

		P90	P50	P10
Pore Volume	[$10^6 m^3$]	47798	66777	88439
Aquifer Seal Capacity	[MPa]		12.37	
Total Compressibility (Cw + Cf)	[MPa^{-1}]	0	0	0
Irreducible Water Saturation	[frac]	0.200	0.423	0.650
Volumetric Sweep Efficiency	[frac]	0.12	0.33	0.65
CO_2 Density at centroid depth and final storage conditions	[Tonnes/m^3]	0.73	0.75	0.77
CO_2 Viscosity at centroid depth and final storage conditions	[cP]	0.06	0.07	0.07
Storage Formation Permeability	[mD]	0.20	5.00	125.00
Dip	[Degrees]		1.20	
Predicted Migration Velocity	[m / year]			
Pore Space Utilisation ('open' units)	[%]			
Theoretical Capacity of unit	[10^6 Tonnes]	417	601	862
Theoretical Capacity of Parent Unit and Daughters	[10^6 Tonnes]	417	601	862
Injection Scenarios				
Dynamic Utilisation	[10^6Tonnes]	400	500	800
Dynamic Utilisation of Parent and Daughters	[10^6Tonnes]		500	

If predicted injection rates are low, 'Dynamic Utilisation' could be considerably less than 'Theoretical Capacity'; it would take an inordinate length of time to inject the amount of CO_2 implied by the theoretical capacity. Alternatively however, the difference might be due merely to the fact that only a finite number of injection scenarios have been considered. Thus, if theoretical capacity is 430 Mt, the maximum utilization that could be reported within the WDG is 400 Mt (eg. 10 Mt pa for 40 years, 20 Mt pa for 20 years etc); the next 'increment' (eg. 5 Mt pa for 90 years or 15 Mt pa for 30 years) gives 450 Mt, which exceeds the theoretical capacity.

For units with daughters, the total capacity and utilization of the parent and daughters is quoted. Because of interaction between parent and daughters, the total mean capacity may not equal the sum of the individual mean capacities. In addition, the overall P_{90} and P_{10} capacities will not be the sum of the individual P_{90}'s and P_{10}'s, because of the statistical method employed to estimate overall P_{90} and P_{10} capacity (see section 2.2).

3.3 Capacity (Hydrocarbon Fields)

For hydrocarbon fields, data pages available via the 'Capacity' tab are as follows:

3.3.1 General

As with saline aquifer storage units, hovering the mouse over the 'Capacity' tab and selecting 'General' from the dropdown menu allows direct return to the General page from any of the other storage unit information pages.

3.3.2 Fluid PVT

The potential CO_2 storage capacity of hydrocarbon fields is calculated on a fluid replacement basis ie. the net reservoir volume of fluids expected to be extracted during hydrocarbon production, is equated to the reservoir volume of CO_2 that may subsequently be stored. The fluid PVT page contains data used in converting fluid volumes at surface conditions of temperature and pressure, to the volumes they occupy at the temperature and pressure of the reservoir. The pages are slightly different for oil, gas and gas condensate reservoirs.

Fluid PVT

		Data	Source	Confidence (L,M,H)
Reference Depth	[m TVDSS]	3980.00		
Virgin Reservoir Pressure @ Reference Depth	[MPa]	50.00		
Virgin Reservoir Temperature @ Reference Depth	[Deg C]	121.00		
CO2 Density at Ref. Depth and Virgin Reservoir Conditions	[tonne/m³]	0.7614		
CO2 Viscosity at Ref. Depth and Virgin Reservoir Conditions	[cP]	0.0758		
Gas Compressibility (Z) Factor @ P, T	[]	0.68		
Gas Formation Volume Factor	[Res m³/scm]	0.0019		
Oil Formation Volume Factor	[Res m³/scm]	1.97		
Oil Viscosity at Reservoir Conditions	[cP]	0.6567		
Water Formation Volume Factor	[Res m³/scm]	1.02		
Solution Gas Oil Ratio at Virgin Reservoir Conditions	[scm/ scm]	314.00		
Fluid PVT Source	[n/a]		The Miller Field, Bl	high

3.3.3 HC Field Volumes

This page contains data for the expected cumulative volume of produced oil, water and gas to be entered, together with cumulative volumes of water and/ or gas injected. Other information such as initial fluids in place (STOIIP, GIIP) may be recorded for information.

HC Field Volumes

		Data	Source	Confidence (L,M,H)
STOIIP	[10^6 scm]	129.30		
GIIP (Gas Cap)	[10^6 scm]			
Cumulative Oil Production	[10^6 scm]	63.80		
Cumulative Sales Gas	[10^6 scm]	8500.00		
Cumulative Fuel+Flare Gas	[10^6 scm]	0.00		
Cumulative Gas Production	[10^6 scm]	8500.0		
Cumulative Water Production	[10^6 scm]	229.00		
Cumulative Gas Injection	[10^6 scm]	0.00		
Cumulative water Injection	[10^6 scm]	241.50		
Hydrocarbon Volumes Source	[n/a]		Full Production Extr	medium
Expected Cessation of Production	[n/a]			
Expected Cessation of Production Source	[n/a]		not set.	unknown
Theoretical Capacity of unit (Hydrocarbons)	[10^6 tonnes]	57.4		

3.3.4 Injectivity

The injectivity page for hydrocarbon fields displays the same information as for saline aquifer storage units: see section 3.2.3

3.3.5 Theoretical Capacity

The theoretical capacity page for hydrocarbon fields displays the same information as for saline aquifer storage units: see section 3.2.4

3.4 Risk

The risk assessment pages are applicable only to saline aquifer storage units, and hence are not available if the current storage unit has a Unit Designate other than Saline Aquifer (see 'General' page).

For saline aquifer storage units, data pages available via the 'Risk' tab are as follows:

Seal Mechanisms related to the nature of the primary seal (the impermeable lithology that directly overlies the storage formation) that may influence long-term security of CO_2 storage

Faults Mechanisms related to the presence of faults that may influence long-term security of CO_2 storage

Lateral Migration Factors that may allow injected CO_2 to migrate over considerable distance in the subsurface

Wells The number and vintage of wells that have been drilled in the vicinity of the storage unit, and which could compromise long-term security of CO_2 storage

Formation Damage Mechanisms that could impair ability to inject CO2 during the operational phase of storage

Connectivity The degree to which the storage unit might be compartmentalized, again potentially impacting ability to inject the expected amount of CO_2

An example from the Risk input pages is shown, displaying mechanisms related to faults that could compromise containment integrity. Hovering the mouse over each input box (in this case 'Throw and Fault Seal') reveals a list of definitions to guide the user in consistent assessment of the relevant risk mechanism.

Containment Risk - Faults

	Likelihood	Source	Confidence (L,M,H)	Severity - Capacity	Severity - Cost
Leakage Containment					
Density	medium	Interpreted Horizons	medium	High	High
Throw and fault seal	medium	Interpreted Horizons	low	High	High
Fault vertical extent	medium	Interpreted Horizons	medium	High	High

Likelihood Of Failure	Low	Medium	High	Very High
Throw and Fault seal	none (comment on resolution based on data source)	estimated offset less than caprock/inter-reservoir shale thickness (note timing of faulting versus expected consildation)	estimated offset greater than caprock thickness/potential for clay smear (cf. published work on UKCS fault seal)	undefined

Risk Profiles

A summary of all assessments made under the preceding six categories. Mechanisms associated with the first four categories are related to security of containment, and are displayed on the Boston Square in plain font; those associated with the last two are related to operational risks, and are displayed in *italics*. Two Boston Squares are presented for each saline aquifer storage unit: the first summarises likelihood and severity of impact on project cost, the second the impact on assessed storage capacity. An example matrix is illustrated below

Severity of Impact		low	medium	high
	Low			Seal chemical reactivity
	Medium	Fracture pressure capacity	Well vintage *Stratigraphic compartmentalization horizontal*	Well density *Mineralogy of grains and cements* *Diagenesis*
	High	Rugosity Hydrodynamics Transnational migration	Seal degradation Density Throw and fault seal Fault vertical extent Structural trend Dip *Stratigraphic compartmentalization vertical*	Depositional/diagenetic fabric Pressure sinks in storage unit *Structural/fault compartmentalization*
		Likelihood		

3.5 Economics

Economic analyses for UKSAP were conducted by Element Energy Ltd, using a techno-economic model that is held externally to the WDG. Amending data input parameters within the WDG thus requires the economic model to be re-run with the new information, and results re-imported to the WDG.

The economic results consist of seven tables:

Storage CAPEX [£millions]

Storage capex/ £millions

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	270	297	325	352
5	505	560	642	697
10	809	946	1146	1283
15	1266	1458	1802	2056
20	1570	1969	2492	NC
40	3341	NC	NC	NC
60	4121	NC	NC	NC

Transmission CAPEX [£millions]

Transmission capex/ £millions

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	818	818	818	818
5	973	973	973	973
10	1209	1209	1209	1209
15	1373	1373	1373	1373
20	1536	1536	1536	NC
40	1978	NC	NC	NC
60	2347	NC	NC	NC

Storage OPEX [£millions/ yr]

Storage opex/ £millions/year

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	12	12	12	12
5	25	25	25	25
10	41	41	45	45
15	66	66	74	78
20	82	90	107	NC
40	181	NC	NC	NC
60	188	NC	NC	NC

Transmission OPEX [£millions/ yr]

Transmission opex/ £millions/year

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	13	13	13	13
5	19	19	19	19
10	27	28	28	28
15	35	35	35	35
20	41	41	42	NC
40	65	NC	NC	NC
60	87	NC	NC	NC

Undiscounted Lifetime Cost of Storage [£/ t]

Undiscounted lifetime cost of storage ï¿½/tCO2 stored

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	£19.73	£13.67	£11.65	£10.64
5	£15.03	£10.53	£9.21	£8.42
10	£12.20	£8.84	£8.34	£7.73
15	£12.82	£9.24	£8.94	£8.63
20	£11.96	£9.44	£9.50	NC
40	£12.88	NC	NC	NC
60	£10.00	NC	NC	NC

Undiscounted Lifetime Cost of Transmission and Storage [£/ t]

Undiscounted lifetime cost of transmission and storage £/tCO2 transported and stored

CO_2 Injection Rate [10^6 Tonnes/yr]	Injection Duration (yr)			
	10	20	30	40
2	£67.21	£40.71	£31.88	£27.47
5	£38.28	£24.06	£19.51	£17.11
10	£27.03	£17.65	£15.13	£13.53
15	£24.27	£16.15	£14.32	£13.27
20	£21.70	£15.36	£14.14	NC
40	£19.44	NC	NC	NC
60	£15.36	NC	NC	NC

Summary: the lowest (undiscounted) cost of the largest achievable utilization scenario is reported.

Summary

Capacity used in marginal cost curve/ Mt	Undiscounted lifetime cost of storage in marginal cost curve at this capacity/ £/tCO2	Undiscounted lifetime cost of transmission and storage in marginal cost curve at this capacity/ £/t CO2	Assumed shoreline hub (for transmission cost)
600.00	8.63	13.27	0.00

3.6 Results

The results tab displays a summary of Monte Carlo Simulation results for the selected storage unit.

A table of mean computed results is displayed:

		Mean
Gross Rock Volume	[$10^9 m^3$]	87153
Thickness : Area	[$10^{-4} m^{-1}$]	0.1353
Pore Volume	[$10^6 m^3$]	9900
Normal Hydrostatic Pressure at Shallowest Depth	[MPa]	34.8148
Initial Pore Pressure at Centroid Depth	[MPa]	67.8691
Final (Max Allowable) Pore Pressure at Shallowest Depth	[MPa]	66.5634
Final Pore Pressure at Centroid Depth	[MPa]	82.9179
Average Pore Pressure at Centroid Depth	[MPa]	75.3935
Aquifer Seal Capacity	[MPa]	15.05
Temperature Gradient	[Deg C/km]	39.58
Formation Temperature at Centroid Depth	[Deg C]	208.8405
CO_2 Density at centroid depth and final storage conditions	[Tonnes/m^3]	0.7412
CO_2 Pressure Gradient at storage conditions	[MPa/km]	7.2683
CO_2 Viscosity at centroid depth and final storage conditions	[cP]	0.0682
CO_2 Column Height	[m]	5409.56
Formation Water Compressibility (Cw)	[MPa^{-1}]	0.000543
Brine Viscosity at reservoir conditions	[cP]	0.19
Pressure capacity ('closed' units)	[10^6Tonnes]	129
PV x storage factor	[10^6Tonnes]	n/a
Buoyant Trapping Capacity	[10^6 tonnes]	n/a

Along with a summary of decile storage capacity and related statistics:

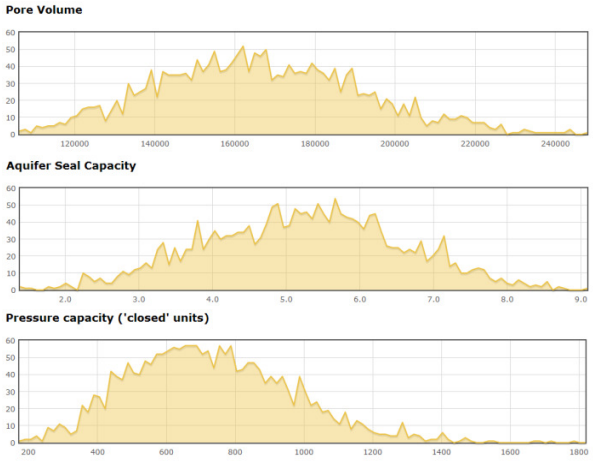
Storage Capacity Probability

	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}
Pressure capacity ('closed' units)	1042	929	846	776	711	654	590	522	441

Statistics

	Pressure capacity ('closed' units)
No of iterations (trials)	2000
Mean	732
Median	711
Mode	911
Standard Deviation	240
Variance	57634

Various graphical output from the Monte Carlo Simulation is also displayed, a selection from which is illustrated:

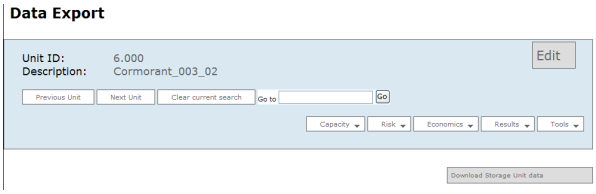


3.7 Tools

The Tools dropdown menu allows the following options, dependent on the level of privileges available to the user:

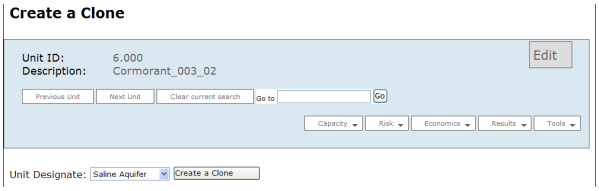
3.7.1 Data Export

Data associated with the selected storage unit may be downloaded to a Comma Separated Variable (CSV) file for subsequent import to other software applications (such as spreadsheets, statistical analysis software, presentations etc). Users will require specific privileges to be able to use this facility.



3.7.2 Create a Clone (WDG Developer only)

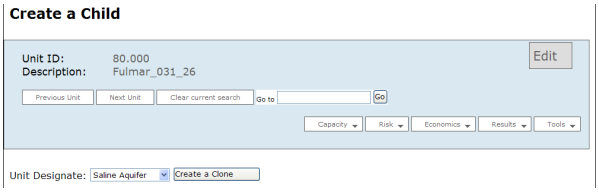
This feature is intended only for creating and facilitating data population of multiple storage units that are similar to each other (for example, where a formation has been compartmentalized into many isolated fault blocks, and each block is to be treated as a separate storage unit).



In such circumstances, many input parameters (Geological Age, Group, Formation etc) are common to all, and only specific parameters (depth, porosity, permeability etc) require editing from one to the other.

The 'Create a Clone' facility allows one storage unit to be duplicated, and the clone then edited as required to reflect the properties of the second storage unit.

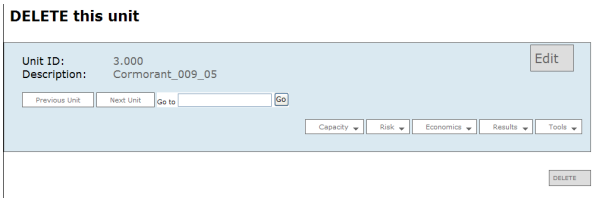
3.7.3 Create a Child (WDG Developer only)



It is sometimes convenient to subdivide a hydraulically connected volume of porous and permeable rock into distinct but related storage units; one such instance is when a closure of significant size has been mapped (for example oil and gas fields). This facility allows the 'parent' storage unit (for example, extensive aquifer) to be created, and then the 'child' (or children) oil/ gas field(s) to be associated with it.

Parent storage units are identified by the fact that their storage unit ID numbers are integers (eg. 80.000); their children are identified by the decimal part of the ID number (eg. 80.001, 80.002, 80.003 …)

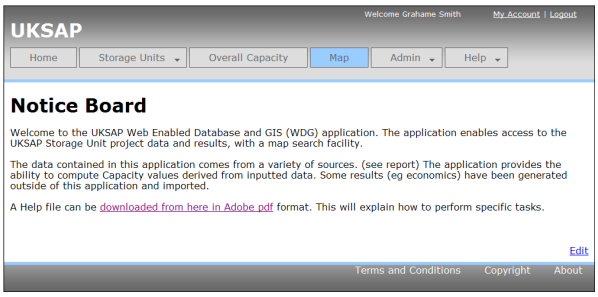
3.7.4 Delete (WDG Developer only)



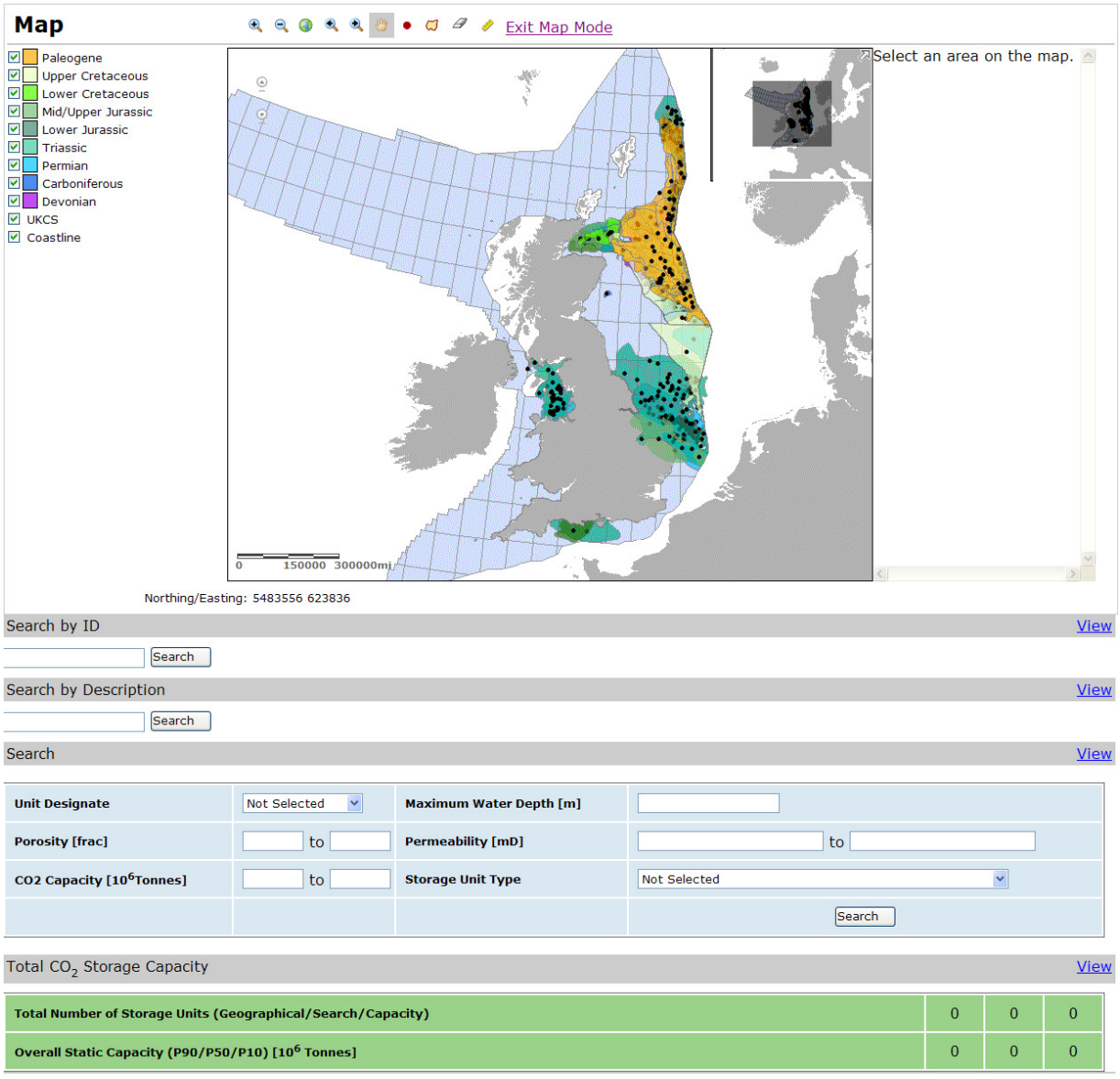
Allows 'deletion' of a storage unit from the database. In order to preserve database integrity, the unit is not in fact completely removed from the system, but is made invisible to the database pages and GIS

4 Map (Geographical Information System)

The Geographical Information System is entered by clicking on the 'Map' tab of the primary menu bar. It may be entered directly from any page where the 'Map' tab is visible.



The default view of the GIS is as follows:



4.1 GIS Tools and Commands

For each tool, first select the appropriate icon (located above the map) by clicking on it; hovering over the tool will reveal a brief description of its function in a pop-up. Once selected, the active tool will be highlighted by a grey square. Then perform the action as described:

	**Zoom In:** click and drag on map to define zoom area. Repeat as required
	**Zoom Out:** click and drag on map to define zoom area. Repeat as required
	**Full Extent:** return to the default view
	**Previous Extent:** with 'Next Extent', allows toggling back and forth between zoom levels for example
	**Next Extent:** with 'Previous Extent', allows toggling back and forth between zoom levels for example
	**Click and Drag:** allows map to be moved within the map window
	**Point tool:** click on the map to reveal all storage units whose shapefiles are intersected by the location of the point. The list of intersected storage units will appear in the panel at the right-hand side of the map. To select another point, re-select the tool icon and repeat.
	**Click and Drag:** with repeated mouse clicks, draw a simple polygon around the search area; a final double-click closes the polygon. All storage units whose centroid (indicated by a black dot) lies within the described polygon will be returned in the right-hand panel.
	**Clear Selection:** removes current point or polygon.
	**Measure:** click 'start' and 'end' of line on the map, and distance between the two points will be displayed at the base of the map.
	**Active Tool:** indicated by a grey square over the appropriate icon.

Layers

The map has different layers for each geological age, as described by the colour-key in the left-hand panel. Individual layers may be turned off (made invisible), or back, on by checking/ unchecking the appropriate selection box.

4.2 Accessing Database Pages from the GIS

Once a selection has been made on the map (for example using the polygon tool), the list of matching storage units is displayed in the right-hand panel: the storage unit ID is shown along with the storage unit description. Two icons also appear with each: hovering the mouse over them reveals a description of their function in a pop-up:

	**Show Storage Unit Data:** opens a new window at the 'General' page of the respective storage unit. The user may then navigate to other pages within the database as normal. Remember to close, hide or minimize the newly opened window in order to return to the map in the original window; if the 'Map' tab is selected from within the new window, a fresh session of the GIS will be started and it will not reflect the previously made selection.
	**Highlight Storage Unit:** click on this icon to reveal the shapefile describing the plan view of the respective storage unit.

Note that due to the time taken to perform database queries of the internet, and to prevent time-out errors, a maximum of 50 matching units only is permissible; if more than 50 units are returned, the search area must be reduced.

4.3 Summed Capacities and Second-Level Searches

Once a selection of storage units has been made, their summed storage capacity is displayed at the foot of the map view page.

The list of selected units can also be refined further, by defining secondary search filters in the blue boxes beneath the map.