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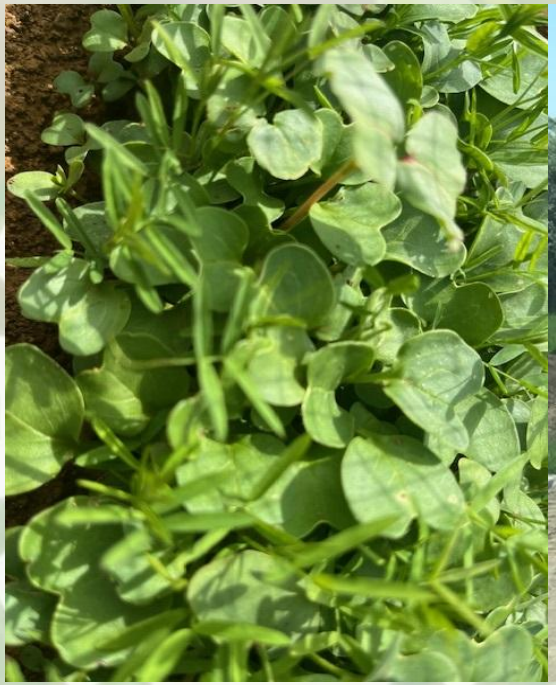
Soil Stabilisation Decommissioning

Haul Road Whole Life Cycle



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All regenerative systems start by measuring and understanding the existing soil conditions.

Soil knowledge leads to the correct remedial activity, resulting in a fully functional soil.

The measurements taken will cover aspects of the Physical, Chemical and Biological functionality of the soil and interpreting these aspects to find out the limiting factor to soil functionality. These principles are used in the following Decommission strategy.

The more we know about the subsoil before we start the better, therefore we should test the soil and then try and balance it back post treatments.

Understanding the effect of the stabilisation process on soils through the Pulverisation, Binder addition and Compaction is essential for compiling the Decommissioning Strategy DECOMSTRAT.

The Decomstrat will require a full suite of tests to be carried out prior and post soil stabilisation. Allowing for correct reinstatement.

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Soil testing pre-construction work

- TerraMap scanned and Gold soil tested, soil scanner detects 4 isotopes which informs the sampler where to collect soil samples for wet chemical testing.
- Scan and test results uploaded onto digital, interactive mapping platform Omnia, generate reports digitally or physical printouts.
- This will show the state and functionality of the soil, so there is a target to aim for when soil is reinstated.

Construction of Haul Roads

- Roadways are put in by normal practice after soil has been baseline assessed.
- Test the roadway again, once stabilised by hydrated lime and cement.
- Compare it to the original soil, allowing regenerative reinstatement plans to be made before roadway removal is considered.

Regenerative reinstatement plan

- Will cover physical, chemical and biological aspects of the soil, how to balance these to maximise soil functionality post-reinstatement and bring them as close (or better in some cases) to the original.
- Parameters include pH, organic matter, bulk density, microbial populations and diversity. Actions include chemical amendments, growing plants to stabilise soil and additions of native microbial consortiums.
- A clear, ordered programme of work will be issued, including a timeline, before reinstatement. Will include nutrients, seed rates, plant species and biological inoculants to be applied. This will allow for successful development of plants and microbial communities over time (minimum of 6 weeks post application).

Soil inspections post-reinstatement

- Carry out physical inspection of the soil profile and visual soil assessment.
- This is to ensure the regenerative reinstatement plan is working and the soils natural functionality has been either restored or further enhanced.

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Soil Tests: using the TerraMap Gold test

Tests are required to be carried out at each stage of the Decommissioning Process.

- Testing of the Natural Untreated Soil
- Testing of the Binder Treated Soil
- Testing of the Regenerated Soil

TerraMap Gold Analysis

An examination of the chemical, biological and physical aspects of the soil.

Extensive understanding of how and why the soil performs.

Presented on digital maps and paper reports.

The 42 parameters TerraMap Gold test includes amongst others:

- Active (water) pH
- Buffer pH
- Soil texture
- Organic matter
- Organic carbon

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TerraMap Scanning

TerraMap is the best soil mapping service with the most detailed soil analysis, all results are uploaded onto the best digital precision farming platform. No comparable service is available elsewhere on the UK market.

Onsite TerraMap Scanning

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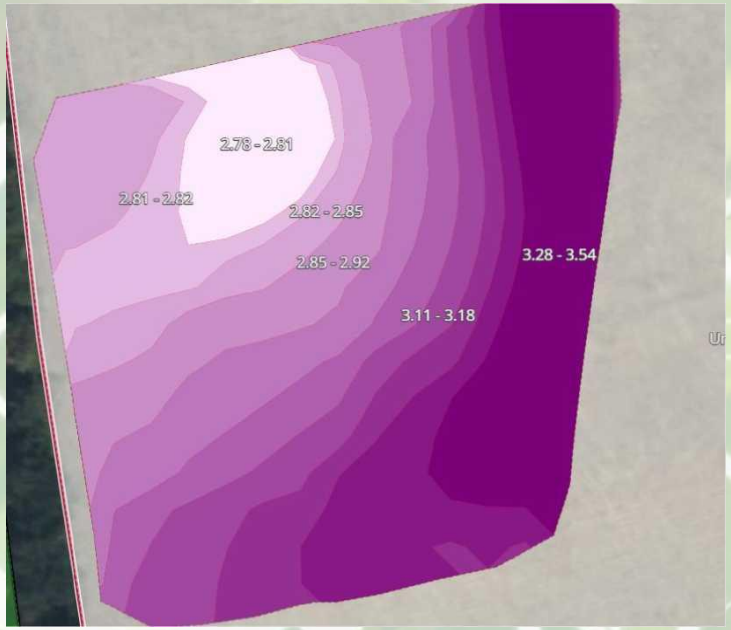
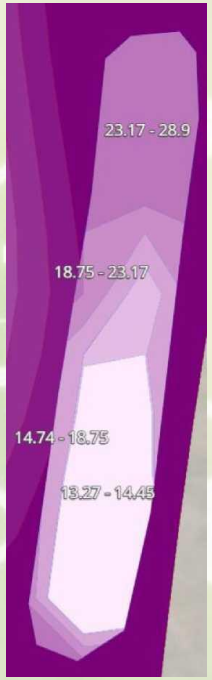
TerraMap Scan Data

The Ca:**Mag** ratio is very different in topsoil and subsoil: topsoil more free draining than subsoil due to a chemical imbalance in Calcium and Magnesium in the subsoil.

Whole Field Analysis of Ca:**Mag**



Haul Road Strip Analysis of Ca:**Mag**



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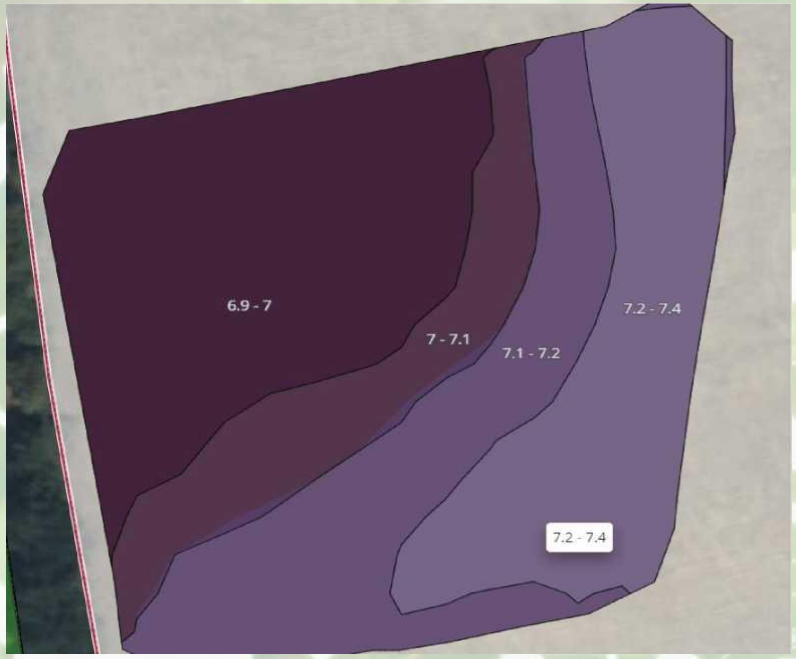
Soil pH

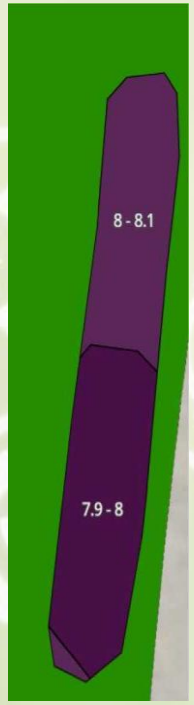
The Stabilisation has increased the pH because of the Ca in the cement.

Remedial Action required

Natural State pH range 7.2 – 7.4



Cement Treated State pH elevated 7.9 – 8.1



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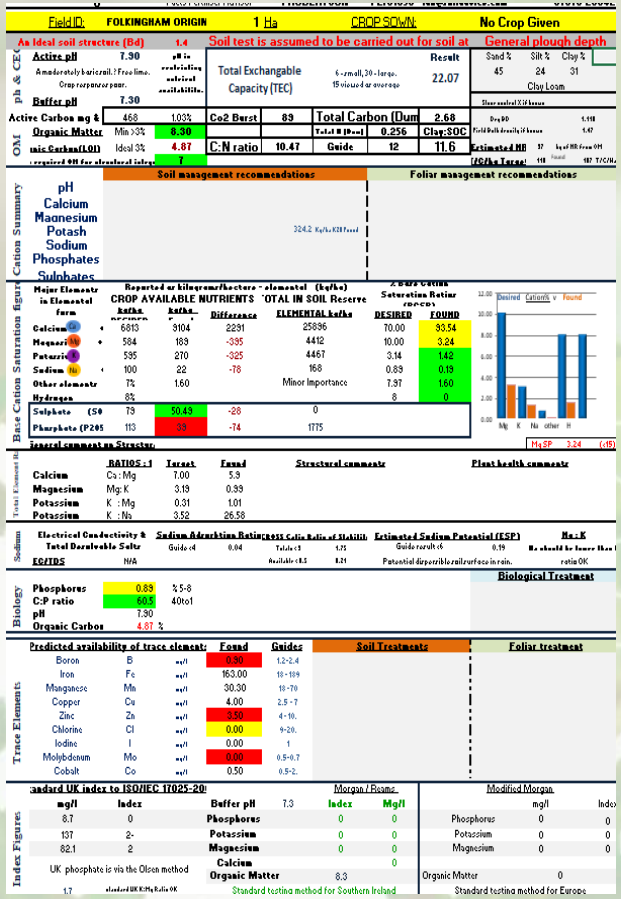
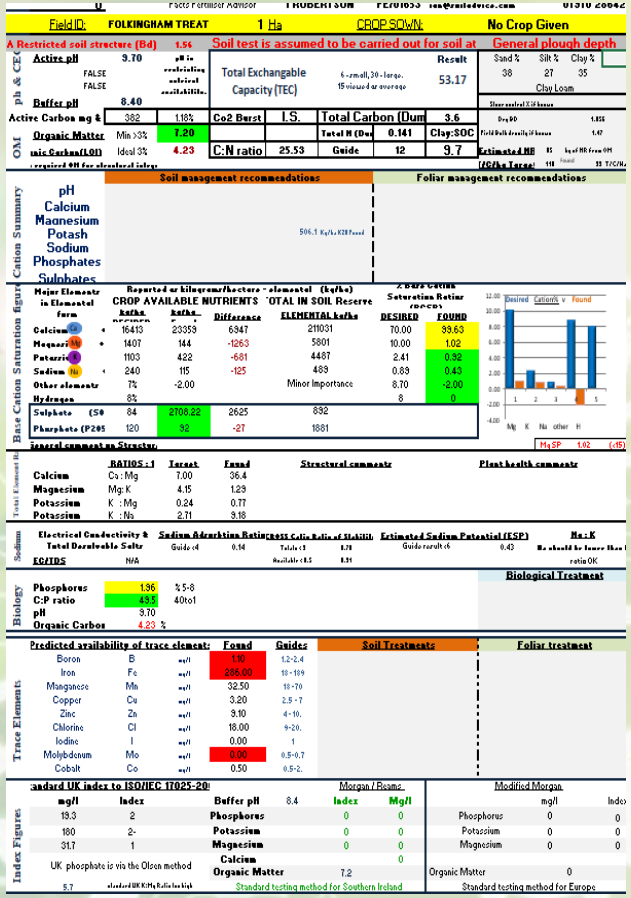
Gold Soil Reports - Gold Soil Analysis

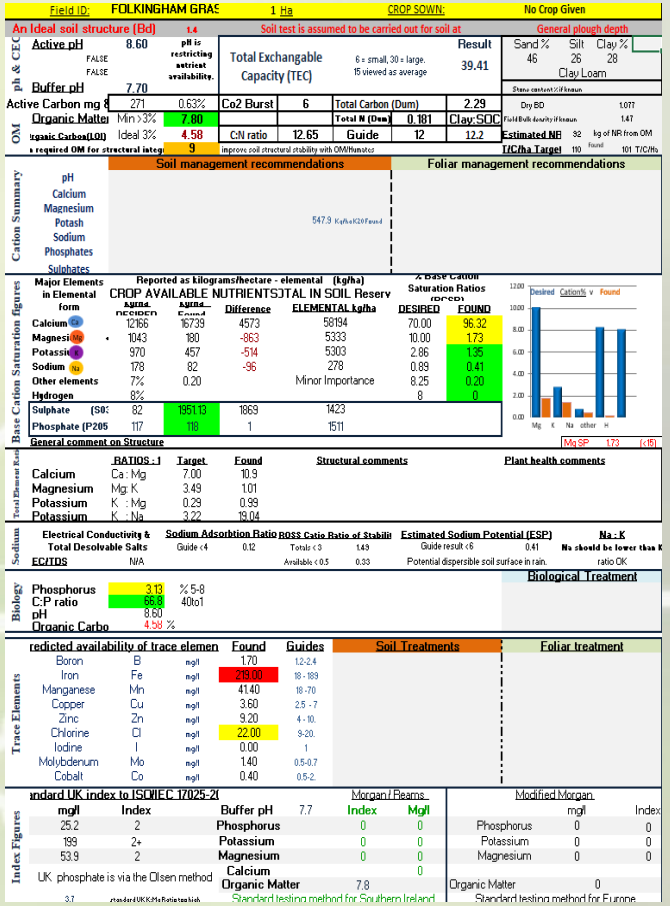
Gold Soil Analysis - Natural State Untreated



Gold Soil Analysis – Cement Stabilised



Gold Soil Analysis – Decommissioned



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Organic Matter and pH

The cement stabilisation has oxidised the organic matter seen by a reduction from 8.3 to 7.2 and an increase in Active Carbon %, the big rise in **pH** will increase bacterial content and Co2 release.
The 3rd result here shows the soil 5 weeks post treatment showing that the pH is dropping back to the original **pH** 7.9 , and the organic matter has also increased showing that we are moving in the right direction. (5 weeks post treatment is not long for remedial action to work)

Field ID:	FOLKINGHAM ORIGINAL	
An Ideal soil structure (Bd)		1.4
Active pH	7.90	pH is restricting nutrient availability.
	A moderately basic soil. ? Free lime. Crop responses poor.	
Buffer pH	7.30	
Active Carbon mg & %	468	1.03%
Organic Matter	Min >3%	8.30
Organic Carbon(LOI)	Ideal 3%	4.87

Field ID:	FOLKINGHAM TREATED	
A Restricted soil structure (Bd)		1.56
Active pH	9.70	pH is restricting nutrient availability.
	FALSE	
	FALSE	
Buffer pH	8.40	
Active Carbon mg & %	382	1.18%
Organic Matter	Min >3%	7.20
Organic Carbon(LOI)	Ideal 3%	4.23

Field ID:	FOLKINGHAM GRASS	
An Ideal soil structure (Bd)		1.4
Active pH	8.60	pH is restricting nutrient availability.
	FALSE	
	FALSE	
Buffer pH	7.70	
Active Carbon mg & %	271	0.63%
Organic Matter	Min >3%	7.80
Organic Carbon(LOI)	Ideal 3%	4.58

This soil test was taken 5 weeks after the remedial action and we can see a good direction in travel.
The pH is dropping the organic matter is rising, the C:N ratio is stabilizing. Sulphur is still elevated but this will drop as the pH drops.
Other nutrients are good which will encourage good plant growth and rooting throughout the profile.

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Testing the soil biology: PLFA analysis

Phospho**l**ipid **F**atty **A**cid analysis. PLFAs are an essential structural component of all microbial cellular membranes. PLFA analysis is a technique widely used for estimation of the total biomass and to observe broad changes in the community composition of the living microbiota of soil and aqueous environments.

Soil biological testing gives a representation of living soil microbial biomass, allowing us to identify the presence or absence of various functional groups of interest through known PLFA biomarker

PLFA test measures microbial activity in the soil, ground stabilisation has a very negative effect on soil biology:

Results	Unit	Result	low	rather low	average	rather high	high
Biological							
Microbial biomass	mg PLFA/kg	25					
Total bacteria	mg PLFA/kg	22					
Gram positive	mg PLFA/kg	10					
Actinomycetes	mg PLFA/kg	2,9					
Gram negative	mg PLFA/kg	13					
Total fungi	mg PLFA/kg	2,6					
Arbuscular Mycorrhiza	mg PLFA/kg	1,4					
Other fungi	mg PLFA/kg	1,2					
Protozoa	mg PLFA/kg	0,16					
Shannon Wiener Index		1,28					
Fungal/bacterial ratio		0,8					
Gram(+)/Gram(-) ratio		0,8					
Physical							
Acidity (pH)		7,0					
C-organic	%	2,68					
Organic matter	%	4,5					
SOC/SOM ratio		0,60					
Clay (<2 pm)	%	49					

Organic matter Figure: Quality of the organic matter

Organic carbon held in micro-organisms		mg C/kg
Microbial biomass		529

Results	Unit	Result	low	rather low	average	rather high	high
Biological							
Microbial biomass	mg PLFA/kg	< 0,6					
Total bacteria	mg PLFA/kg	< 0,6					
Gram positive	mg PLFA/kg	< 0,3					
Actinomycetes	mg PLFA/kg	< 0,2					
Gram negative	mg PLFA/kg	< 0,3					
Total fungi	mg PLFA/kg	< 0,2					
Arbuscular Mycorrhiza	mg PLFA/kg	< 0,1					
Other fungi	mg PLFA/kg	< 0,1					
Protozoa	mg PLFA/kg	<0,03					
Shannon Wiener Index		< 1,60					
Fungal/bacterial ratio		<1,2					
Gram(+)/Gram(-) ratio		<1,0					
Physical							
Acidity (pH)		10,5					
C-organic	%	2,02					
Organic matter	%	5,2					
SOC/SOM ratio		0,39					
Clay (<2 pm)	%	45					

Organic matter Figure: Quality of the organic matter

Organic carbon held in micro-organisms		mg C/kg
Microbial biomass		< 18

Here we can see the reduction in biological activity following soil treatment.

If no biological remedial work is undertaken, soil functionality will be compromised.

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Microbial Activity

The cement stabilisation has caused a major decrease in microbial activity and change in C:N ratios due to the death of the microbes. The Cement Stabilisation has effectively killed all biology in the soil.

Natural State subsoil prior to Stabilisation

Co2 Burst	35	Total Carbon (Dum)		3.58
		Total N (Dum)	0.13	SOC/Clay
C:N ratio	27.54	Guide	12	11.5

Cement Stabilised subsoil

Co2 Burst	4	Total Carbon (Dum)		2.6
		Total N (Dum)	0.12	SOC/Clay
C:N ratio	21.67	Guide	12	11.2

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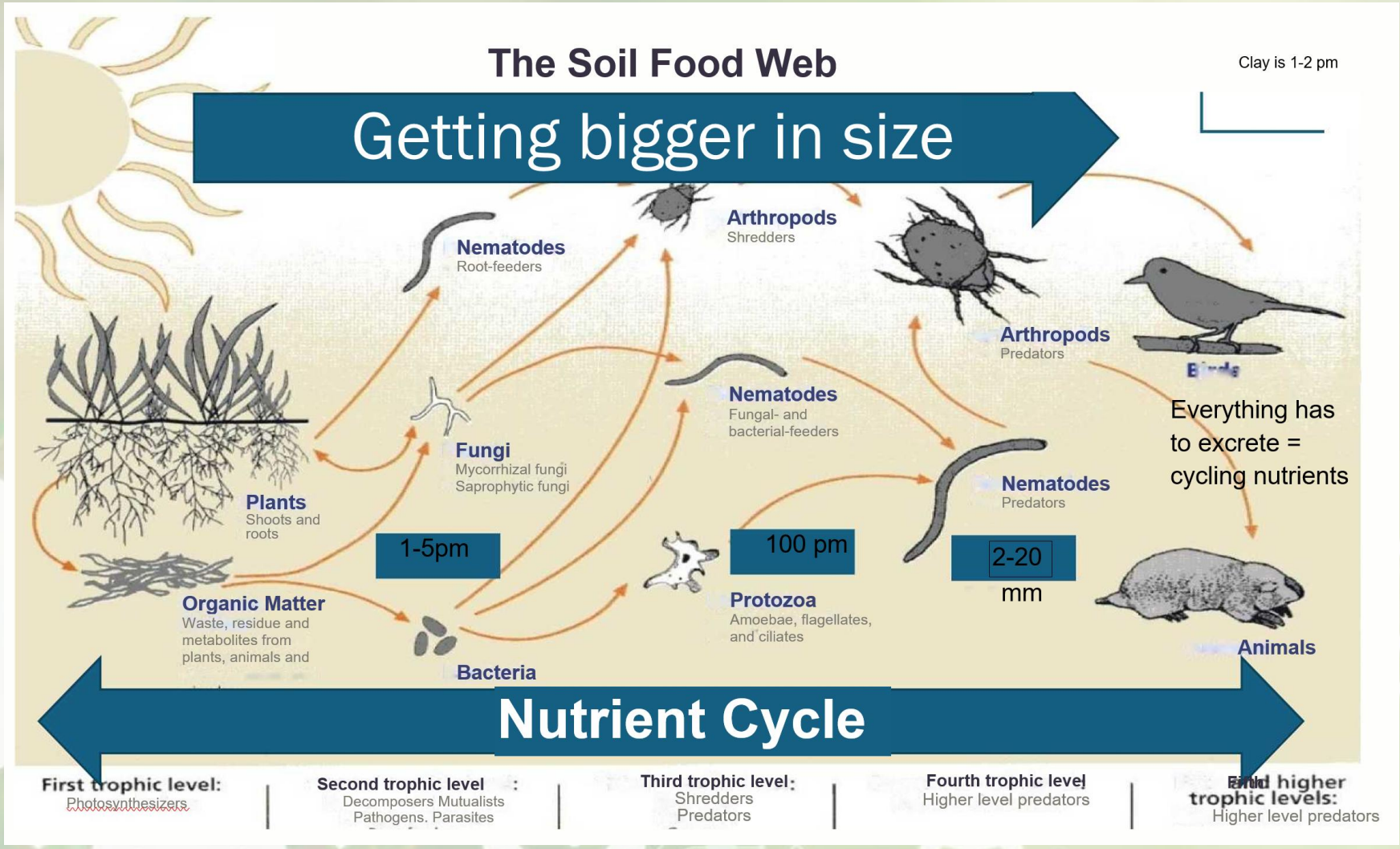

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Treatment Plan - DECOMSTRAT

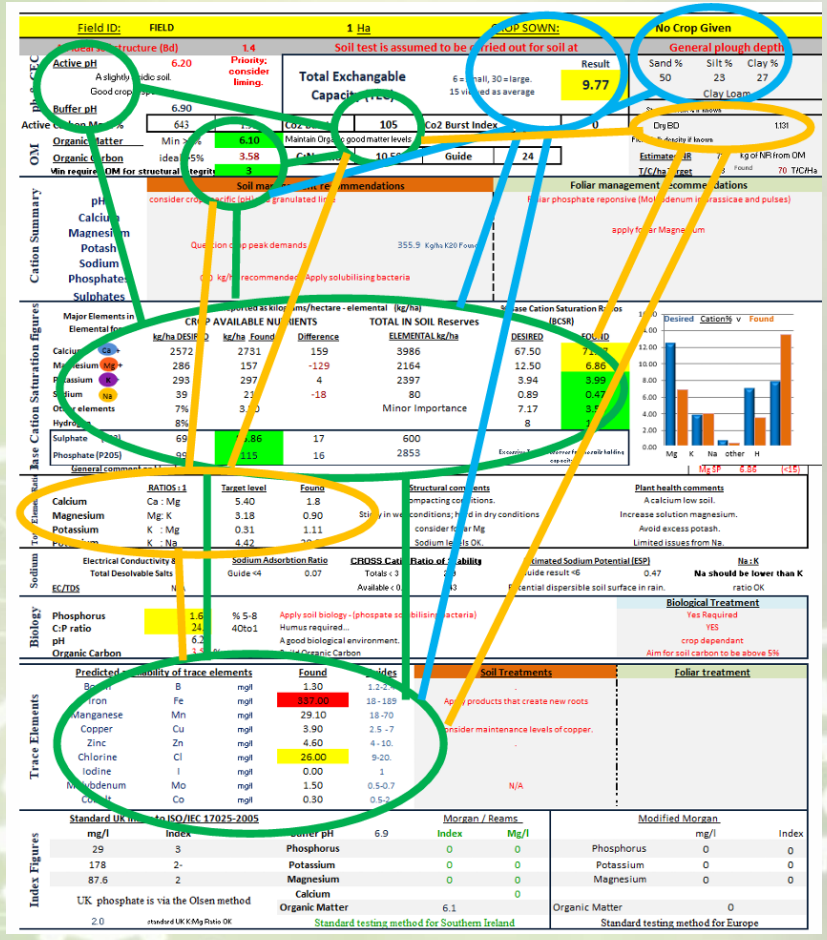
Effects of Cement Stabilisation on Subsoil:

Raises pH
Reduces Organic Matter
Reduces Microbial Activity
De-structures the Soil

Actions Required:

Reduce pH to buffer level
Increase Organic Matter in the soil
Introduce Microbiology
Re-structure the soil

All actions in the DECONSTRAT
are determined by the TerraMap GOLD Test Analysis



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Stabilisation of Haul Road Track with 3% CEMI

Haul Road Compaction to >30% CBR

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Pulverisation using Stabilisation Mixer to re-structure the stabilised

Samples taken for Gold Testing

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Re-Balancing pH and Nutrients

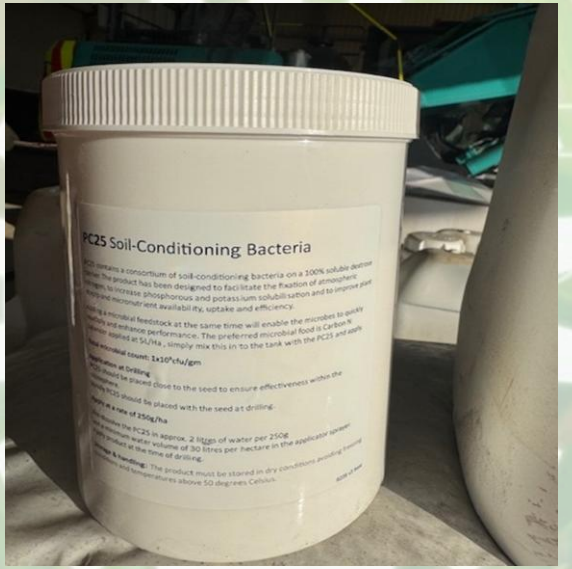
Ammonium Sulphate and Elemental Boron and Sulphur are applied to stabilise the pH levels in the subsoil.

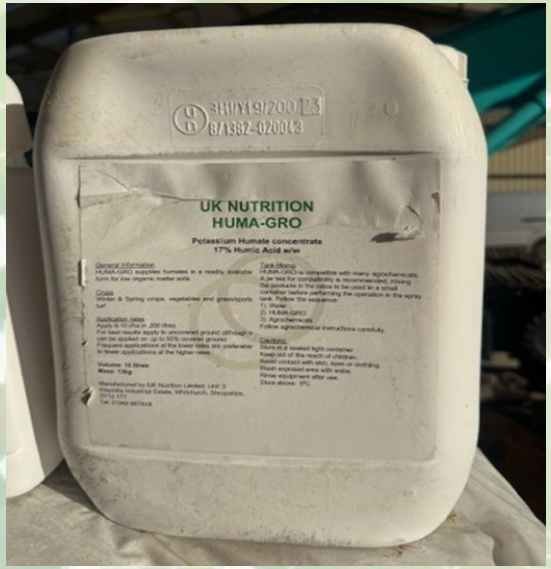
Soil Conditioning Bacteria and Huma-Grow are applied to redress the nutrient loss during the stabilisation

Nutrients can leach through the soil profile and enhance the soil fertility

Good topsoil management is the key to successful decommissioning of stabilised works.

All the nutrients and structure will allow successful crop growth to take place within the topsoil.





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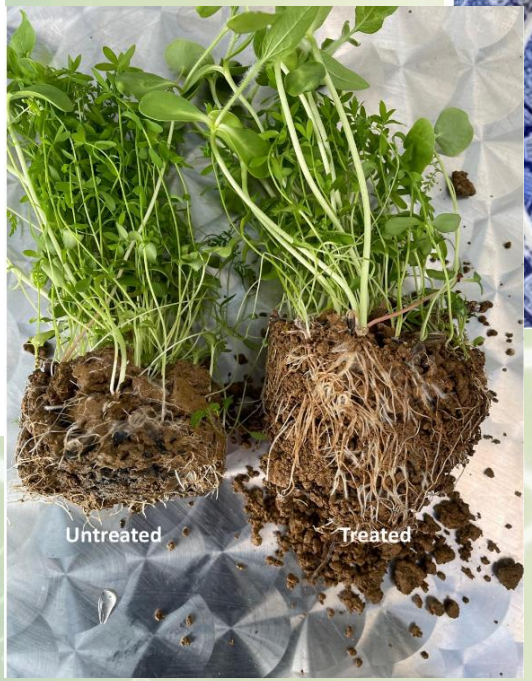
Cover Crop Seeding

Early seeding trials in dishes showed very promising results in the Cement Stabilised soil with early establishment of seed growth.

Untreated subsoil



Cement Stabilised subsoil

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Regenerative Process

Seeding was carried out on the pulverised soil to introduce organic matter and in turn reintroduce microbial activity

Seed mix contained **Linseed, Buckwheat, Phacelia, Radish, Mustard, Hairy Vetch and Clover.**

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Six week established growth in the pH balanced pulverised subsoil.
Fully established root systems and increased organic matter in the pulverised subsoil.

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In summary:
The soil is measured to ascertain its physical, chemical and biological status, all reinstatement works are designed to return this soil back to its native state.

These treatments include:

Chemical intervention - pH and humic acids,
Physical - Pulverisation
Biological - Plant roots and biological inoculants.
Organical - Wild Flower Planting

All targeted via Terra map digital mapping system, Gold Standard Analysis and PLFA Analysis.

Haul Road Decommissioned and topsoil fully reinstated after six weeks