



**Department of Environmental Protection
Water and Rivers Commission**
Amalgamating to form the Department of
Environment, Water and Catchment Protection

Acid Sulfate Soils Guideline Series

Treatment and management of disturbed acid sulfate soils and acidic ground and surface waters

1.0 Introduction

The disturbance of acid sulfate soils (ASS) by excavation, drainage or dewatering can cause severe environmental problems unless managed correctly. Several management techniques used to manage disturbed acid sulfate soils may also cause environmental risk unless they are implemented correctly. Before any of the following management strategies are used, a proponent should provide a risk assessment and documented scientific justification to the Department of Environment and Catchment Protection (DEWCP) that the process will not impact on the values of the receiving environment or pose a risk to public health.

2.0 Purpose of the Guidelines

The purpose of these guidelines is to provide information on:

- the management of ASS stockpiles and defining the level of treatment that is necessary to neutralise existing acidity plus potential acidity associated with the disturbance of ASS; and
- the levels of management and reporting that are expected for these treatment methods.

3.0 Stockpiling acid sulfate soils

The risks of stockpiling large volumes of untreated ASS may be very high even over the short-term. Stockpiling small volumes of untreated ASS should **only** be undertaken as a **short-term** activity. For example:

- part of a day's extraction of clay and peat may be stockpiled over a weekend before strategic reburial;
- due to weather conditions that may prohibit treatment or problems with obtaining laboratory results; or
- required land areas for soil neutralising treatment may not be available as quickly as was anticipated in earthworks strategies, leading to the creation of small stockpiles before changes can be made to earthworks programs.

After soils have been excavated and moved, the soil profile will be mixed. It then becomes difficult to correlate laboratory results with soil profile horizons to identify the specific liming rates needed for those horizons, and consequently, matching the soil horizons with their respective liming rates may become difficult. Impact to the environment may occur if incorrect liming rates are used.

Significant quantities of acid can build up, especially in porous sandy stockpiles, if left in oxidising conditions for even short periods of time. Large stockpiles are difficult to neutralise, primarily due to the earthmoving required. In addition, when determining the treatment options it is important that by-products of oxidation, such as jarosite, are properly characterised and that representative sampling of the stockpile is performed. Sampling rates for stockpiles may need to be double or triple that of an undisturbed profile. Costs of representative sampling of stockpiles are much cheaper if sampling is performed as the stockpile is being created.

4.0 Management considerations

Stockpiling untreated ASS should be minimised by preparing a detailed earthworks strategy that documents the timing of soil volumes to be moved, treatment locations and capacity of those areas to receive the stockpile materials. Stockpiling may mean double-handling and increased earthmoving costs. It is important to account for risk from wet weather and plan for other contingencies.

4.1 Short-term stockpiles

The recommended maximum time period for which soils can be temporarily stockpiled without treatment is detailed in Table 1.

Table 1 – indicative maximum periods for short-term stockpiling of untreated ASS

Type of material		Duration of stockpiling	
Texture range (McDonald <i>et al.</i> 1990)	Approx clay content (%)	Days	Hours
Coarse texture Sands to loamy sands	≤5	Overnight	18 hours
Medium texture Sandy loams to light clays	5-40	2½ days	70 hours
Fine texture Medium to heavy clays & silty clays	≥40	2½ days	70 hours

At some sites these figures may be too conservative, and in some circumstances not conservative enough (eg. during hot weather some sands may begin to oxidise within a matter of hours whereas complete oxidation of peat may be longer). Appropriate operational delay times should be determined well before the creation of the stockpile for the specific circumstances. The use of a guard layer under the stockpiles may be warranted in certain circumstances.

The total volume of material that is placed in short-term stockpiles should not exceed 20% of a day's total extraction.

Note: These timeframes do not apply to monosulfidic black ooze. These ooze or sediments should not be stockpiled without a risk assessment, and the implementation of strict environmental management protocols.

4.2 Medium-term stockpiles

Situations where it is necessary to stockpile untreated ASS for moderate periods will need to be justified to the DEWCP. Management to reduce the oxidation of sulfides and the collection and treatment of all leachate and runoff water will need to be implemented during the entire

stockpiling period. The maximum time period for which soils can be temporarily stockpiled in the medium-term is listed in Table 2.

Table 2 – indicative maximum periods for medium-term stockpiling of untreated ASS

Type of material		Duration of stockpiling	
Texture range (McDonald <i>et al.</i> 1990)	Approx clay content (%)	Days	Weeks
<i>Coarse texture</i> Sands to loamy sands	≤5	14 days	2 weeks
<i>Medium texture</i> Sandy loams to light clays	5-40	21 days	3 weeks
<i>Fine texture</i> Medium to heavy clays & silty clays	≥40	28 days	4 weeks

Depending on site specific requirements, a risk assessment should be undertaken if soils are to be stockpiled for longer periods than those listed in Table 2. Neutralisation of the stockpiled materials may be necessary if it cannot be demonstrated there is minimal risk of acidic leachate being generated by the stockpiles. Stockpiling in the medium term should be a contingency measure rather than standard practice.

A guard layer of a suitable neutralising agent **MUST** be placed under all medium-term stockpiles. In addition, the following management strategies may need to be implemented to manage risk:

- the volume stockpiled should not exceed more than 1 week’s volume of extraction;
- all stockpiles will need to be bunded and diversion banks installed upslope to prevent the ingress of surface runoff into the stockpiles. Bunds and diversion banks should not be constructed out of untreated ASS or other materials that may be a source of contaminants to the environment. The bund materials used should have an appropriately low permeability to avoid infiltration;
- leachate collection and treatment systems should be installed;
- the surface area of the stockpile should be minimised to reduce exposure to atmospheric oxygen. This may involve shaping the stockpile, and/or capping or lining it with a material that will minimise drying by wind and sun and prevent rainfall entering the stockpile. The cap or liner will need to cover the sides of the stockpile as well as the top;
- keeping the surface of the material moist using a spray of water or neutralising solution. The spray should be carefully managed to prevent over-wetting the material producing leachate or runoff, and should be a fine-mist to prevent desegregation of the soil from the stockpile surface; and/or
- construct erosion and sediment control structures.

The amount of neutralising agent used in the guard layer of medium term stockpiles should be based on 0.3 times the average potential and existing acidity of the stockpile/m² per vertical metre of soil that is to be temporarily placed in the stockpile. For example, if the stockpile is 2 metres high, then twice 0.3 times the neutralising agent required to neutralise the potential and existing acidity should be spread as a guard layer.

For sandy textured soils in environmentally sensitive areas, or in situations where the medium term time frame cannot be met, a higher rate of neutralising agent in the guard layer will be warranted.

4.3 Long-term stockpiles

Any stockpiling exceeding those timeframes provided in Table 2 is considered long-term stockpiling, and an appropriate management strategy is required. The management of such stockpiles would require conducting a risk assessment and obtaining approval from DEWCP. In such cases, an environmental management plan is recommended and should be forwarded to DEWCP for consideration and approval. In addition, the management strategies should include those outlined for medium-term stockpiles. Failure to manage environmental risks posed by long term stockpiling may result in actions being taken under the *Environmental Protection Act 1986*.

4.4 Stockpiles of topsoil

It is a routine practice to scrape the topsoil prior to excavation, and store it until it is required for top-dressing. Some of the management options listed under medium-term stockpiles may be appropriate for managing topsoil stockpiles, especially if they contain low levels of sulfides. Low levels of sulfides may occur in topsoils as a result of 'over-stripping' that have occurred during its collection, or it may be intrinsic to the topsoil.

All topsoil should be tested prior to stripping and stockpiling. Neutralisation of the total existing and potential acidity of the topsoil will be required. It may be cheaper and easier to neutralise the topsoil as it is scraped and placed. For example, the appropriate amount of neutralising agent can be spread over the topsoil and, using a reverse scraper, the lime incorporated prior to stripping. Further mixing will occur as the soils are placed into the stockpiles.

5.0 Neutralising acid sulfate soils

All levels of treatment and management of acid sulfate soils should be provided to DEWCP and should include details of preliminary investigations, disturbance dimensions, volume calculations, field soil test results and laboratory analysis results. Factors that will influence the level of treatment include the nature of ASS disturbance, the soil characteristics, (e.g. the variability of sulphide concentrations, bulk density, physical characteristics such as texture and inherent neutralising capacity), the surface and subsurface hydrology, the sensitivity of the surrounding environment and the past history of the site.

Table 3 provides the estimated level of aglime (CaCO_3) required to treat the total weight of disturbed ASS based on the soil analysis and the amount of aglime required to neutralise the total existing and potential acidity of the ASS soils. Aglime has a pH of about 8.2 and is the safest neutralising agent that poses least environmental risk. Because of the difficulty in mixing lime with acid sulfate soils and the low reactivity of even the fine lime, safety factors of at least 1.5 to 2 times the theoretical lime required will apply.

The tonnes of lime required for treating the total mass of ASS are provided in Table 3 at the intersection of the mass (tonnes)(row) and the existing plus potential acidity (converted to equivalent S% units)(column). Potential acidity can be determined by Chromium Reducible Sulphur (S_{cr}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOS}). For samples with pH less than pH5, the existing acidity must also be determined by appropriate laboratory analysis e.g. Titratable Actual Acidity (TAA).

Other neutralising agents besides aglime can be used to treat ASS. However factors to be considered when choosing neutralising agents include pH, solubility, neutralising value, particle size, purity of the agent, method of application and transportation costs. If other neutralising agents are used, the figures in Table 3 will need to be adjusted accordingly.

Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more analysis. Please refer to the Queensland Acid Sulfate Soil Technical Manual available on www.environ.wa.gov.au website.

5.1 Calculating the quantity of neutralising agent for acid sulfate soils

It is important to provide adequate neutralising material to reduce the potential for environmental harm or damage. The amount of neutralising materials required is based on the calculated percentile of oxidisable sulphur from the soil analysis. Table 4 provides an indication of the maximum acid that can be produced and the financial feasibility of managing the disturbance of ASS.

The rate of application must be calculated according to the neutralising value of the neutralising materials. The fineness of the neutralising agent will influence the effectiveness and reactivity of the agent. Another factor to be considered is the coating of the neutralising agent by low solubility gypsum, insoluble iron or aluminium compounds can also limit the effectiveness of the materials. A minimum safety factor of 1.5 only applies for good quality fine aglime with neutralising value of 100.

$$\text{Lime required (kg CaCO}_3\text{/tonne materials) = kg H}_2\text{SO}_4\text{/tonne of materials} \times \text{safety factor} \\ = (\text{oxidisable S\%} \times 30.59) \times 1.5$$

Table 4 – acid sulfate soil conversions (based on 1 mol pyrite producing 2 mol sulfuric acid and corresponding neutralising rate)

Oxid. S%	moles H ⁺ /kg (S% X 0.6237)	Moies H ⁺ /t ³ or moies H ⁺ /m ³ (S% X 623.7)	kgH ₂ SO ₄ /tonne KgH ₂ SO ₄ / m ³ (S% X 30.59)	kglime/tonne soil or kg lime/m ³ Safety factor = 1.5	Est. lime cost / tonne soil or cost / m ³ of soil \$	Cost/ha/m depth of soil @50/t of lime \$
0.02	0.0125	12.47	0.61	0.94	0.05	468
0.03	0.0167	18.71	0.92	1.4	0.07	702
0.06	0.0374	37.43	1.84	2.8	0.14	1,404
0.1	0.0624	62.37	3.06	4.7	0.23	2,340
0.2	0.1247	124.7	6.12	9.4	0.47	4,680
0.3	0.1871	187.1	9.18	14.0	0.70	7,020
1.0	0.6237	623.7	30.6	46.8	2.34	23,410
5.0	3.119	3119	153.0	234.0	11.7	117,000

Note – Assumes a bulk density of 1.0g/cm³ or 1 tonne/m³ (bulk density can range from 0.7- 2.0 and as low as 0.2 for peat). Where bulk density is >1g/cm³ or 1 tonne/m³ then the correction factor for bulk density will increase for lime rates/m³ soil (eg. If BD=1.6, then 1 m³ of soil with 1.0% S_{POS} will require 75 kg lime/m³ instead of 47 kg).

6.0 Neutralising acid leachate and acidic water

There are a range of neutralisation products available that can be used to treat acid waters. The rate of application of these products for treating acid water should be carefully calculated to avoid the possibility of ‘overshooting’ (i.e. making water too alkaline). Usually the optimum water pH is 6.5–8.5.

Aglime is the cheapest neutralising agent and is generally not harmful to plants, livestock, humans and most aquatic species. The limitation of its application is its insolubility in water, although it is more soluble in strongly acid water. Using aglime to increase the pH of water can be slow and costly.

More soluble neutralising agents such as sodium bicarbonate NaHCO_3 are quick to act and not subject to pH overshoot. Other cheaper, fairly soluble neutralising agents include hydrated lime (Ca(OH)_2) and quick lime (CaO) but they are difficult to manage and can result in excessively high pH. When using these strongly alkaline materials, strict protocols must be established for their safe use, handling, monitoring and their effects on the receiving environment

Soluble or caustic neutralising agents such as hydrated lime Ca(OH)_2 that has a pH 12 can quickly increase the pH and should be used with caution. Overdosing natural waterways with hydrated lime can impose environmental risks similar to acid conditions, with the potential to damage estuarine and wetland ecosystems. It should be noted that when neutralising acid water, no safety factor is used. However, the monitoring of pH should be carried out regularly during neutralisation procedure and for a suitable period afterwards to verify the appropriate pH has been achieved and maintained.

6.1 Calculating the quantity of neutralising agent for acidic water

If no other means of estimating the amount of neutralising agent is available, the amount required to neutralise a waterbody can be calculated by firstly measuring the current pH of the waterbody with a recently calibrated pH meter. The desired pH is usually between 6.5 and 8.5 (pH 7 is normally targeted).

The rate of application will vary with the solubility, the fineness of the neutralising agent, the application technique and the pH of the water. As a general guide, Table 5 shows the minimum quantities of pure aglime, hydrated lime and sodium bicarbonate needed to treat impounded water or drains of 1 megalitre (ML)(1000 m³) capacity. The calculations in this table assume that low saline water acidified by hydrogen ions (H^+) and does not take into account the considerable buffering capacity or acid producing reactions of some acid salts and soluble species of aluminium and iron.

As ASS drainage normally contains many acidic ions capable of producing acidity by hydrolysis (e.g. Fe^{3+} , Al^{3+}), a sample should be taken for laboratory analyses (for measurement of titratable acidity) to more accurately determine lime requirements. If this is not available, at least a field titration using the water and the proposed ameliorant should be undertaken to provide an estimation of dosage rates.

Table 5: Quality of pure lime neutralising agent required to raise from existing pH to pH7 for a megalitre of low salinity acid water

Current water pH	[H ⁺] (mol/L)	H ⁺ in 1 ML (mol)	Aglime to neutralise 1ML (kg pure CaCO_2)	Hydrated lime to neutralise 1 ML (kg pure CaCO_2)	Sodium bicarbonate to neutralise 1 ML (kg pure NaHCO_2)
0.5	.316	316 228	15 824	11 716	26 563
1.0	.1	100 000	5004	3705	8390
1.5	.032	12 000	1600	1185	2686
2.0	.01	10 000	500	370	839
2.5	.0032	3200	160	118	269
3.0	.001	1000	50	37	84
3.5	.00032	320	16	12	27

4.0	.0001	100	5	4	8.4
4.5	.000032	32	1.6	1.18	2.69
5.0	.00001	10	0.5	0.37	0.84
5.5	.0000032	3.2	0.16	0.12	0.27
6.0	.000001	1	0.05	0.037	0.08
6.5	.00000032	.32	0.016	0.012	0.027

Notes on Table 5:

1. $1 \text{ m}^3 = 1000 \text{ litre} = 1 \text{ kilolitre} = 0.001 \text{ Megalitre}$
2. Correlations between current water pH and $[H^+]$ (mol/L) do not account for titratable acidity. The titratable acidity component should be included in any calculations of neutralising agent requirements.
3. Agricultural lime has a very low solubility and may take considerable time to even partially react. While aglime has a theoretical neutralising value of 2 mol of acidity (H^+), this tends to be only fully available when there is excess acid. This, together with its very low solubility, means that much more aglime beyond the theoretical calculation will generally be required.
4. Hydrated lime is more soluble than aglime and hence more suited to water treatment. However, as $Ca(OH)_2$ has a high water pH, incremental addition and thorough mixing is needed to prevent overshooting the desired pH. The water pH should be checked regularly after thorough mixing and allowing sufficient time for equilibration before further addition of neutralising product.
5. Weights of material given in the table above are based on theoretical pure material and hence use of such amounts of commercial product will generally result in under treatment.
6. To more accurately calculate the amount of commercial product required, the weight of neutralising agent from the table should be multiplied by a purity factor (100/ Neutralising Value for aglime) or (148/ Neutralising Value for hydrated lime).
7. If neutralising substantial quantities of ASS leachate, full laboratory analysis of the water will be necessary to adequately estimate the amount of neutralising material required.
8. Neutralising agents such as hydrated lime $Ca(OH)_2$, quick lime CaO , and magnesium oxide MgO neutralise 2 mol of acidity (H^+), while sodium bicarbonate $NaHCO_3$ and sodium hydroxide $NaOH$ neutralise only 1 mol of acidity.

Issues to consider may include:

- the quality and purity of the neutralising agent being used;
- the effectiveness of the application technique;
- the existence of additional sources of acid leaching into the water body that may further acidify the water;
- the neutralising agent has become lumpy and sinks to the bottom of the waterbody, rendering it ineffective; and
- the neutralising agent becomes coated with insoluble salts, reducing its effectiveness.

Neutralisation may be faster if higher rates are used, but this is not recommended, as it is expensive and resource wasteful. Moreover, overdosing may result, though this is less likely to be a concern with agricultural lime.

To increase the efficiency, the neutralising agent should be mixed into a slurry before adding.

6.2 Methods of application include:

- spraying the slurry over the water with a dispersion pump;
- pumping the slurry into the waterbody with air sparging (compressed air delivered through pipes) to improve mixing once added to water;
- pouring the slurry out behind a small motorboat and letting the motor mix it in;
- incorporating the slurry into the dredge line (when pumping dredge material); or
- using mobile water treatment equipment such as the 'Neutra-mill' and 'Aqua Fix' to dispense neutralising agents to large water bodies.

In some circumstances a neutralising agent in its solid form can be used, for example by:

- placing it in a porous bag of jute or hessian and tying the bag to drums so that it floats in the water. The material will then gradually disperse. This technique should only be considered where there is significant water movement; or
- passing water across a bed or through a buffer of coarsely ground limestone CaCO_2 or other granulated neutralising agent. However, this is unlikely to be effective in the long term as coarse particles of the neutralising agent may become coated with insoluble iron or other compounds, washed away or dissolved.

When the pH of ASS leachate is below 4.5, it usually contains soluble iron and aluminium salts. When the pH is raised above 4.5, the iron precipitates as a red-brown stain/scum/solid, which can coat plants, monitoring equipment, the floors or walls of dams, drains, pipes, piezometers and creeks. In addition, the soluble aluminium is a good flocculent and may cause other minerals to precipitate or for suspended clay particles to flocculate.

Where the water contains considerable soluble iron, large quantities of acid can be generated as the pH is raised and iron hydroxides are precipitated. It is important to let any sludge settle before using treated water (otherwise it will block pipes and pumps) or before discharging treated water (to avoid adverse aesthetic and environmental harm). Chemicals can be used to reduce the settlement time if it does not settle quickly enough for the staging of the works, however care should be taken in choosing flocculating agents as these can also alter pH or cause other environmental impacts.

The large-scale dosing of waters to alter the chemical characteristics, such as may be the case in the mining industry, is a specialised and highly technical task that requires considerable expertise and experience. Professional guidance should be obtained in these situations.

The pH of the water should be checked daily during the first two weeks following application or until the pH has stabilised and then on a regular basis according to the ASS management plan. The pH should be checked at least daily if there is any discharge from the site and preferably more frequently depending on the environmental sensitivity of the receiving environment.

7.0 Further information

The Land & Water Quality Branch of the Department of Environment, Water & Catchment Protection (DEWCP) is currently drafting this series of guidance notes related to ASS. These guidance notes will initially be in draft form, and comments are welcomed. The guidance notes will be made available on the Department of Environmental Protection website at www.environment.wa.gov.au as they are developed.

It is recommended that reference also be made to guidelines and manuals developed by the NSW and Queensland State governments, in particular;

- *Queensland Acid Sulfate Soil Technical Manual 2002, Soils Management Guidelines* Queensland Acid Sulfate Soils Management Advisory Committee
- *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998*, Queensland Acid Sulfate Soils Investigation Team
- *Queensland State Planning Policy 2002, Guideline on Acid Sulfate Soils*, Department of Natural Resources and Mines and Department of Local Government and Planning
- *New South Wales Acid Sulfate Soil Manual 1998*, Acid Sulfate Soil Advisory Committee

Queries or comments relating to ASS or the guidance notes should be directed to one of the following officers of the Land & Water Quality Branch;

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8.0 Acknowledgements

The Land & Water Quality Branch would like to acknowledge the guidelines and manuals produced by the following committees and organisations which were used in the development of this guideline:

1. Queensland Government (Department of Local Government & Planning and Department of Natural Resources and Mines);
2. Queensland Acid Sulfate Soils Investigation Team; and
3. Queensland Acid Sulfate Soil Management Advisory Committee.

9.0 References

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TABLE 3 Existing treatment levels and aglime required to treat the total weight of disturbed ASS based on soil analysis developed by Ahern et al 1998a.

The tonnes (t) of pure fine agricultural lime (CaCO_3) required to fully treat the total weight/volume of acid sulfate soils (ASS) can be read from the table at the intersection of the weight of disturbed soil [row] with the existing plus potential acidity [column]. Where the exact weight or soil analysis figure does not appear in the heading of the row or column, use the next highest value.

Disturbed ASS (tonnes) ($\approx \text{m}^3$) †	Soil Analysis ^a – Potential Acidity plus Existing Acidity (converted to equivalent S% units)													
	0.03	0.06	0.1	0.2	0.4	0.6	0.8	1	1.5	2	2.5	3	4	5
1	0	0	0	0	0	0.03	0.04	0.05	0.1	0.1	0.1	0.1	0.2	0.2
5	0	0	0	0.05	0.1	0.1	0.2	0.2	0.4	0.5	0.6	0.7	0.9	1.2
10	0	0.03	0.05	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.9	2.3
50	0.1	0.1	0.2	0.5	0.9	1.4	1.9	2.3	3.5	4.7	5.9	7.0	9.4	12
100	0.1	0.3	0.5	0.9	1.9	2.8	3.7	4.7	7.0	9.4	12	14	19	23
200	0.3	0.6	0.9	1.9	3.7	5.6	7.5	9.4	14	19	23	28	37	47
250	0.4	0.7	1.2	2.3	4.7	7.0	9.4	12	18	23	29	35	47	59
350	0.5	1.0	1.6	3.3	6.6	10	13	16	25	33	41	49	66	82
500	0.7	1.4	2.3	4.7	9.4	14	19	23	35	47	59	70	94	117
600	0.8	1.7	2.8	5.6	11	17	22	28	42	56	70	84	112	140
750	1.1	2.1	3.5	7.0	14	21	28	35	53	70	88	105	140	176
900	1.3	2.5	4.2	8.4	17	25	34	42	63	84	105	126	168	211
1000	1.4	2.8	4.7	9.4	19	28	37	47	70	94	117	140	187	234
2000	2.8	5.6	9.4	19	37	56	75	94	140	187	234	281	374	468
5000	7.0	14	23	47	94	140	187	234	351	468	585	702	936	1170
10 000	14	28	47	94	187	281	374	468	702	936	1170	1404	1872	2340

L Low treatment: (≤ 0.1 tonne lime)

M Medium treatment: (> 0.1 to 1 tonne lime)

H High treatment: (> 1 to 5 tonnes lime)

VH Very High treatment: (> 5 to 25 tonnes lime)

XH Extra High treatment: (> 25 tonnes lime)

Lime rates are for pure fine agricultural lime (CaCO_3) using a safety factor of 1.5. A factor that accounts for Effective Neutralising Value is needed for commercial grade lime. An approximate soil weight (tonnes) can be obtained from the calculated volume by multiplying volume (cubic m) by bulk density (t/m^3). (Use 1.7 if B.D. is not known.)

† Tonnes approximately equal m^3 (volume) for soils with Bulk Density (BD) of 1 g/cc or t/m^3 . Dense fine sandy soils may have BD up to 1.7. Thus 100 m^3 may weigh up to 170 t.

^a Potential acidity can be determined by Chromium Reducible Sulfur (S_{CR}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOB}). Existing acidity can be determined by Titratable Actual Acidity (TAA). Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis.