Validation of Standard Lime Dosing Rate for Bassendean Sands

Gaël Rosengart

Anas Ghadounai and Liah Coggins
Civil, Environmental and Mining Engineering
The University of Western Australia

Jeremy Roberson and Stuart Masterson
CEED Client: Water Corporation

Abstract

Acid sulfate soils (ASS) are an evolving consideration for the construction industry for projects involving their disturbance either directly by excavation or by affecting the elevation of the watertable. Under the current Department of Water and Environmental Regulations (DWER) guildelines the process for handling them can be both time consuming and expensive. This study looks to build on an earlier study which hypothesised the streamlining of the process for acid sulfate soils within Bassendean sand (BS) by using a standard lime dosing rate (SLDR). BS is common along the Swan Coastal Plain and is conidered to be the best candidate for a SLDR due to its generally uniform composition. The main benefits of an SLDR would be; reduced investigation expenses from drilling, sampling, testing, and the preparation of management plans. To achieve this, data from past projects is being gathered and analysed to determine the minimum amount of lime would be required to sufficiently treat the soil for 99.99% of cases in accordance with the DWER requirements (Sullivan et al, 2016). The data is being processed through Excel spreadsheets and will later be visualised through a powerBI dashboard to help display the results. Currently around 200 data samples have been analysed and have agreed with the hypothesis from the previous study. The next step is to expand the the data set and to reassess the lime dosing rate.

1. Introduction

This project seeks to validate a study by Professor Leigh Sullivan and the Water Corporation (WC) that was carried out in 2016 that determined a standard lime dosing rate (SLDR) for Bassendean sand (BS) that had a risk of containing acid sulfate soil. The SLDR was mainly based on data gathered from the Department of Water and Environmental Regulation (DWER).

1.1 Background

As the principal provider of water and wastewater services for Western Australia, The WC is responsible for the construction and maintenance of a large and constantly expanding portfolio of water and wastewater assets. As a consequence, WC often carrys out work in areas with acid sulfate soils (ASS) present (Singh, B et al (2012)). ASS are soils, sediments or sands with high levels of sufur present often in the form of iron sulfate or pyrite. These soils are generally inert when submerged but when exposed to air, such as during excavation, undergo a series of chemical oxidation reactions resulting in sulfuric acid being formed (Davidson, W. A. (1995)). This sulfuric acid causes a number of problems including:

- Ecologically, can lead to the death of fauna and flora;
- Health and safety, it can mobilise heavy metals within the groundwater which can end up in consumer products (Ljung, K et al (2009));
- Infrastructure, it can degrade foundations, pipes and other buried components (Groger et al 2008).

1.2 Current Process

The current guidelines from DWER require the drilling of boreholes, followed by sampling and testing to assess the presence of ASS within the subsurface materials (DWER, (2015)). The results from the tests are used to determine the potential acidity of the soil and calculate a lime dosing rate for that particular material. Depending on the size of the project, this process may need to be repeated hundreds of times with potentially thousands of samples needing to be analysed. This can be costly and requires drilling crews, professional supervision,procurement of samples, laboratory analysis, and prepararation of detailed management plans. As well as being expensive this process is also very time consuming.

The treatment of ASS involves the application of a neutralising agent typically lime (calcium carbonate $CaCO_3$). Lime is a readily available option that efficiently reacts with sulfuric acid without creating any adverse by-products or polluting the sub-surface environment should it be over-treated.

The focus on BS in this project is due to its naturally uniform composition and prevalence along the Swan Coastal Plain, making it a suitable candidate for a standard dosing rate (L. Sullivan et al, 2016). It also has a lower sulfur concentration than other common ASS containing formations resulting in lower liming rates and smaller variations between regions. Despite this, it still undergoes the same testing process as other formations in accordance with the DWER guidelines.

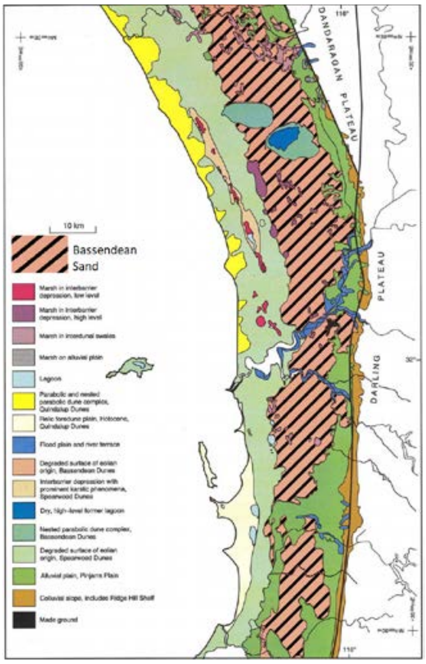

Figure 1 - Map of Swan Coastal Plain ASS Formations.

1.3 Project Aims and Benefits

The successful validation of a SLDR would seek to significantly reduce or potentially eliminate the need for drilling, sampling, and testing of BS. It would allow for a two-step identification and treatment process. The benefits from this include:

- Significantly reduce investigation costs.
- Reduced time in planning and preparation phases
- Shorter implemetation; and
- Less reliance on consultants and laboratory groups

To achieve that it is necessary to:

1. Confirm a methodology for calculating the dosing rate.
2. Gather a sufficiently large data set of relevant past projects and laboratory test results.
3. Establish an analysis system using the confirmed methodolgy, performed with a statistical analysis to set and verify the results.
4. Set up a policy and system to allow an expansion of the database and revisit of the result.

2. Methodology

2.1 Validation of Previous Work

This project seeks to build on the findings from Leigh Sullivan et al’s *Characteristics of Acid Sulfate Soils in Bassendean Sand: Identification, Behaviour and Implications for Management*. As such it is necessary to understand how the analysis was performed as well as identify any short comings or oversights (Ahern C.R et al (2004)).

The only potential oversight identified from this review was the unjustified use of a normal distribution as the analytic tool to determine the SLDR. The report did not show any indication that the data was normally distributed nor was there any explanation as to why a normal distribution-based analysis was conducted. Using new data, the use of a normal distribution was deemed appropriate as discussed in section 3.

2.2 Data Gathering

Data from as many different sources and projects as possible will allow for a better representation of the soils across the entire BS formation and result in a more robust justification of a SLDR. To achieve that, internal stakeholders within WC were contacted for leads as to the best possible sources of data. It led to a GIS layer being created overlaying past projects within the BS formation allowing for the relevant projects to be identified.

Requests for data were also made to other government groups and agencies such as the Perth Transport Authority (PTA). The response was very positive and resulted in an influx of data. The outsourced data also helps to diversify the data set.

Field observations			Field Test					Laboratory Analysis					
								Lab pH		SPOCA			
0	0.25		Not Tested										
0.25	0.5												
0.5	0.75												
0.75	1												
1	1.25												
1.25	1.5												
1.5	1.75												
1.75	2		WT @ 2.0	5.6	3.8	1.8	1						
2	2.25		-0.25	6.1	3.1	3.0	1						
2.25	2.5		-0.5	5.9	2.3	3.6	1						
2.5	2.75	SAND: Dark to pale grey, fine to medium grained, well sorted, sub-rounded to sun-angular. Roots and orgainc matter at surface. Becoming coarser with depth, tending brown.	-0.75	6.0	2.3	3.7	1						
2.75	3		-1	6.2	2.0	4.2	1						
3	3.25		-1.25	6.1	2.5	3.6	1						
3.25	3.5		-1.5	6.2	2.3	3.9	1						
3.5	3.75		-1.75	6.5	1.6	4.9	2						
3.75	4.5		-2.5	6.4	2.3	4.1	4	6.1	3.1	<0.01	0.04	0.03	0.03
DUP 17				6.4	2.2	4.2	1.00						
RPD				0.0	4.4	2.4							
4.5	4.75			5.9	2.3	3.6	4						
4.75	5		-2.75	6.4	2.4	4.0	4						
5	5.25		-3	6.8	2.4	4.4	2						
5.25	5.5	CLAYEY SAND: Blue/ grey, fine to medium grained, poor sorting, soft.	-3.25	6.7	2.3	4.4	1						
5.5	5.75		-3.5	6.8	3.8	3.0	1						
5.75	6		-3.75	6.8	3.4	3.4	1	5.9	4.0	0.01	0.02	<0.01	<0.02

Figure 2 - Example Data from single bore (some information redacted for privacy). The important values given including the depth of each sample, pH at time of collection, pH at time of lab testing and total sulfur levels.

2.3 Data Analysis

The data has been analysed in line with the processes used in the previous study by Sullivan et al 2016, as well as in accordance with DWER guildelines. This analysis includes distribution plots of %S (Sulfur) present in samples to determine sample variability and calculated dosing rate plots and tables. The dosing rate was calculated using the equation given by DWER:

$$Lime\ Needed\ \left(\frac{kg\ CaCO3}{tonne\ soil}\right) = NetAcidity\ (S\% * 30.59) * 1.028 * Safety\ Factor * \frac{100}{ENV}$$

(DWER, 2015)

ENV is the Effective Neutralisation Value and is a function of the particle size of the lime and the purity of the lime as % $CaCO_3$. For the purposes of the initial lime calculations it was always assumed to be 100%, meaning it would react perfectly, however in reality the value would be assigned based on the quality of the lime used which would affect the liming rate accordingly. Finally a safety factor of 2 was used. This was the general trend amongst reports and was assumed to be the industry standard for this application.

3. Results and Discussion

One of the first variables analysed was the distribution of sulfur in the data set. Figure 3 shows the data from 203 samples from over 70 separate bores. The figure was then used to try and identify any trend in sulfur distribution.

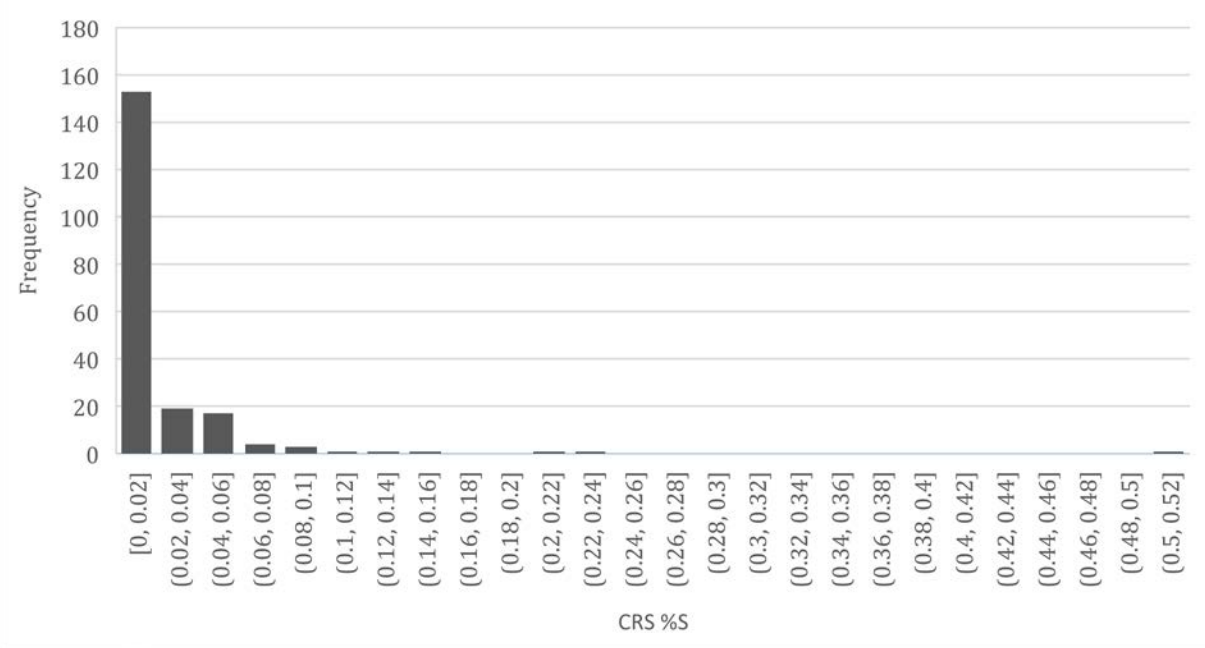

Figure 3 - Percentage Sulfur Distribution based on occurrences. Though the vast majority of data sample have sulfur % below 0.1% some samples had as much as 0.52% sulfur. These outliers are attributed to the presence of other formations and/or coffee rock.

This shows that the vast majority of the samples had less than the "action criteria" of 0.03% sulfur. When more data is gathered the trend will be revisited and updated to more accurately display sulfur distribution in areas that specifically hold sulfur concentration above a certain threshold.

There are also some major outliers to discuss including one sample that had sulfur content as high as 0.52%S. With the outliers removed the data becomes normally distributed with a tail trending to the right, giving a mean of 0.048 and a standard deviation of 0.038. Unfortunately this reduces the samples size to under 70, reaffirming the need to redo the analysis with greater data confidence. The outliers have been attributed to other ASS containing material, for example coffee rock. Coffee rock is cemented iron or organic rich sand which can contain high amounts of ASS (DWER 2, 2015). It is therefore difficult to include coffee rock in the SLDR due to its inconsistency in both presence and percentage sulfur content (%S).

Plot 4 plots the calculated dosing rate equation (DWER, 2015) vs the %S present in the material. The graph shows the linear trend for the lime dosing rate as expected and indicates that the vast majority of the data points require less than 10kg/m^3 of pure lime for neutralisation. It should be noted, once again, that this is a pure lime equivalent with 100% ENV and a safety factor of 2.

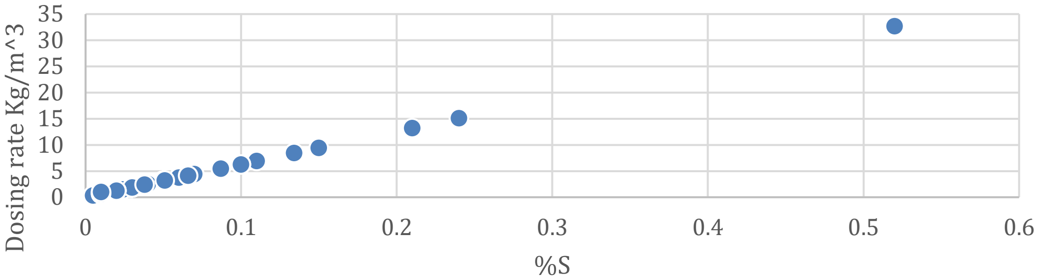

Figure 4 Lime dosing rate (kg/m^3) trend vs %S. Shows how the dosing rate changes linearly as a funciton of %S

The graph shows the linear trend for the lime dosing rate as expected and indicates that the vast majority of the data points require less than 10kg/m^3 of pure lime for neutralisation. It should be noted, once again, that this is a pure lime equivalent with 100% ENV and a safety factor of 2.

To this point the results have closely followed the results shown in the Sullivan et al report from 2016. There have been some outliers and points of contention that will be addressed as the project continues. One major point of contention is the mix of data currently being used. There are two main laboratory test methods used in the industry which are; Suspension Peroxide Oxidation Combined Acidity and Sulphur (SPOCAS) and Chromium Reducible Sufur (CRS). CRS has become the industry standard, however because a lot of the data being historical, there has been a lot of SPOCAS data present.

The data has been separated based on the laboratory test method and analysed separately. However, it is still unknown how big the differences are between the two test methods. As the project progresses the data sets will grow and hopefully allow for a comparison between the two as well as validate the trends observed so far. Currently the aim is for at least 400 real data value points (value over the 0.03% “action criteria”) with which to model and calculate a SLDR.

4. Conclusions and Future Work

Currently the results are indicating a strong correlation with the original work carried out by Leigh Sullivan et al in 2016. They do not match perfectly, however, the strong trends and similar outputs being observed is solidifying the conclusions from the previous study. As additional data is compiled a more accurate picture of the distribution of the %S within ASS risk BS be obtained and from that a more reliable calculation of the SLDR will result.

There are still a number of questions that may be left unanswered at the completion of this study. The most obvious of these is how to manage the presence of coffee rock. Coffee rock has proven to be a difficult variable to incorporate into the SLDR for BS and would warrant its own research project.

5. Acknowledgements

I would like to thank Anas Ghadounai and Liah Coggins for their unconditional support throughout the project. Jeremy Roberson and Stuart Masterson for helping me find the data, set up meetings and answer any questions I had. Ben Stone for helping me with the foundations of the project. Water Corporation and the many people who have assisted me along the way. Vinh Nguyen from PTA for his help gathering data. Jeremy Leggoe and Amanda Bolt from CEED for running the program so effectively.

6. References

Ahern C.R., M. A. (2004). Acid Sulfate Soils Labratory Methods Guidelines.
DWER. (2015). Identification and investigation of acid sulfate soils in acidic landscapes.
DWER. (2015). Treatment and management of soil and water in acid sulfate soil landscapes.
Groger, J. (2008). The potential for chemical attack by acid sulfate soils in Northern Germany - Combined acid and sulfate attack on concrete.

L. Sullivan, S. M. (2016). Characteristics of Acid Sulfate Soils in Bassendean Sand: Identification, Behaviour and Implications for Management. .

Ljung, K. M. (2009). Acid sulfate soils and human health-A Millennium Ecosystem Assessment. . *Environment International*, 38.

Singh, B. P. (2012). Acid Sulfate Soils Survey in Perth Metropolitan Region, Swan Coastal Plain WA. .