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31 January 2017

Attention: Edwina Manifold
Melbourne Water
990 La Trobe St, Docklands VIC 3008
Via Email: Edwina.Manifold@melbournewater.com.au

Project Name: Cockatoo Swamp dewatering project
Project Number: IS121900

Subject: Management of acid sulfate soils during construction

1. Introduction

1.1 Background

Throughout 2015 and 2016, Jacobs have been engaged by Melbourne Water to undertake a works program to inform and prepare the drainage of the Cockatoo Creek Swamp, in an attempt to improve the environmental quality of swamp and wetlands.

As part of this works program, Jacobs (2015) confirmed the presence of acid sulfate soils (ASS) as previously reported by SGS (2014). Jacobs completed further ASS sampling during geotechnical investigations along a proposed drainage pipeline alignment (Jacobs, 2016).

2. Scope

This file note provides a framework regarding the management of soil expected to be excavated as part of the proposed drainage works.

3. Management

The currently proposed drainage works includes the excavation of:

- Levee breaks to approximately 0.5m depth (Attachment A)
- Deepening of the pipeline inlet to 1 m depth, 3 m width and 14 m length (Appendix B)

3.1 Levee breaks

Previous ASS investigations around the proposed levee breaks (P7, P8, P9, P10 – Jacobs, 2015) indicates the presence of actual acid sulfate soil (AASS), but very limited (below or at the detection level) potential acid sulfate soil (PASS).

This work was aimed at characterising the presence or absence of ASS at the site. As such, sampling was preliminary in nature and not conducted at a rate consistent with waste industrial waste resource regulations - IWRG 702 (EPA, 2009a). Given this, additional sampling of material during excavation in accordance with publication IWRG702 (EPA, 2009a) should be undertaken by contractor during excavation to confirm the nature of the material and managed accordingly.

According to the flow chart for decision-making and assessing regulatory obligations (EPA, 2009b – Appendix C), AASS material requires immediate management or treatment and disposal. The material is suitable for on-site retention and should be managed in accordance with an environmental management plan (EMP).

The hierarchy for on site management is to:

1. Avoid disturbance

2. Minimise disturbance

3. Prevent oxidation

4. Treat to reduce or neutralise acidity

5. Offsite reuse or disposal

The EMP developed should reflect this hierarchy. Jacobs recommend trying to minimise disturbance by re-using levee material around the levees that will remain on site, thereby minimising change to the existing environmental conditions. Likewise, re-burial of the excavated material in a similar stratigraphic sequence to that excavated is recommended to both minimise environmental change and limit the exposure of deeper material (that is more likely to contain PASS) to oxidising conditions.

During construction the contractor shall:

1. Sample soil material during excavation in accordance with publication IWRG702 (EPA, 2009a) and analysed for the chromium reducible sulfur suite. The sampling frequency as outlined in IWRG 702 has been included in attachment F.

2. If the material is consistent with existing results, and is manifestly indifferent to the surrounding levee bank material then the contractor may proceed to dispose of the material on-site according to step 3 and 4 below. However if the results indicate the presence of potential acid sulfate soils, the material should first be neutralised according to the requisite liming rate as indicated in laboratory reporting.

3. All material shall be retained on site and placed alongside the remaining levee sections, on either side of each break. Spoil banks, formed from the excavation, should be offset two metres from the cut and finished to the height of the remaining levee section. (refer to attachment D and the Cockatoo Swamp Levee Removal Design Report)

4. After construction the spoil banks shall be Hydromulched, if the ground conditions are dry enough to enable access of a Hydromulch truck. The Hydromulch should use a mixture of native grasses, typical to the region. If the ground conditions are too wet to allow access then hand mulching with sterile straw should take place.

3.2 Pipeline inlet

Previous ASS investigations around the proposed inlet location (S1, HA01, Jacobs – 2015, 2016) suggests the presence of AASS with limited (below or at the detection level) concentrations of PASS. However, this site is located within the current Cockatoo Creek channel and other soils in similar settings throughout the creek do contain potential acidity at concentrations of up to 0.04% S (above the action criteria for ASS). While this should be confirmed by sampling during excavation according to publication IWRG702 (EPA, 2009a – attachment F), best practice management for this material should allow for the presence of PASS.

As such, the management of this material according to Attachment C would require either on site reuse and liming, or offsite disposal. Melbourne Water has (in consultation with Jacobs) decided to dispose of this material offsite. Accordingly, the receiving landfill must either have a licence to receive ASS or must prepare an EMP for the management of the soil and have it approved by the EPA.

The excavated material is expected to be fully saturated and will therefore be stock piled on site for a short period (1-2 days) to drain. This is in order to make transportation of the material easier.

As the material will require short term stockpiling on-site prior to disposal, the stockpiles will need to be managed. As the material is expected to be predominantly fine (≥40% clay content), it is best practice to reduce the exposure time to 5 days (DSE, 2010).

As the excavated material is expected to be fully saturated, it is anticipated that there will be drainage of pore water from the soils that are stockpiled, which may be acidic or may become acidic during stockpiling. Based on an approximate drainable porosity of ~33% (silty clay), this would yield a drainable volume of 5 m^3.

Jacobs recommend constructing a shallow trench on the downhill slope of the stockpile to collect and monitor the pH of the draining pore fluids. This could facilitate on-site liming strategy if pH drops are noticed. If the water drains back towards Cockatoo Creek, it should be neutralised to a pH within 0.5 units of the current creek pH (the existing variability of creek pH as indicated by Jacobs (2015)).

During construction the contractor shall:

1. Construct a temporary strawbale structure, approximately 1m high and 10m x 5m, reinforced with star pickets (refer to the Cockatoo Swamp De-watering Pipeline Design Report).

2. Lime shall be applied to the ground within the strawbale structure and sides of the structure at a rate 1 kg $CaCO_3$ / tonne material excavated. This is built upon a an average liming rate of 5 kg $CaCO_3$ / tonne as indicated by Jacobs (2015) and a conservative estimate that up to 20% of draining leachate may infiltrate the base of the stockpile.

3. Construct a shallow trench (0.3m deep and 0.3m wide) along the downhill slope of the strawbale structure.

4. Place the excavated material within the temporary strawbale structure and allow to drain for 1-2 days.

5. During this time water collected within the trench will be tested using a standard handheld pH meter and compared to the current pH in the creek.

6. If the pH of the water in the trench is lower than the pH in the creek by more than 0.5 units, then the contractor shall neutralise the water to within 0.5 units of the creek pH. The contractor may also lime the stockpile surface to regulate the leachate pH to within 0.5 units of the creek pH.

7. Material shall be removed and sent to a landfill which is either licenced to receive ASS or must prepare an EMP for the management of the soil and have it approved by the EPA.

We trust this file note meets your requirements. Please do not hesitate to contact us should you have any queries.

Yours sincerely

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4. References

DSE – Department of Sustainability and Environment, 2010. Victorian Best Practice Guidelines for assessing and managing coastal acid sulfate soils.

EPA - Environmental Protection Agency, 2009a. Environment Protection (Industrial Waste Resource) Regulations 2009. Publication IWRG702 — June 2009.

EPA - Environmental Protection Agency, 2009b. Acid sulfate soil and rock, information bulletin. Publication 665.1. January 2009.

Jacobs, 2015. Yellingbo Nature Conservation Reserve - Acid sulfate soils investigation.

Jacobs, 2016. Cockatoo Creek Detailed Design - Acid Sulfate Soils and Geotechnical Investigation.

SGS, 2014. Acid Sulfate Soils Testing and Reporting for Yellingbo NCR and Yering Backswamp Sites. January, 2014.

5. Attachments

Attachment A: Proposed levee break locations

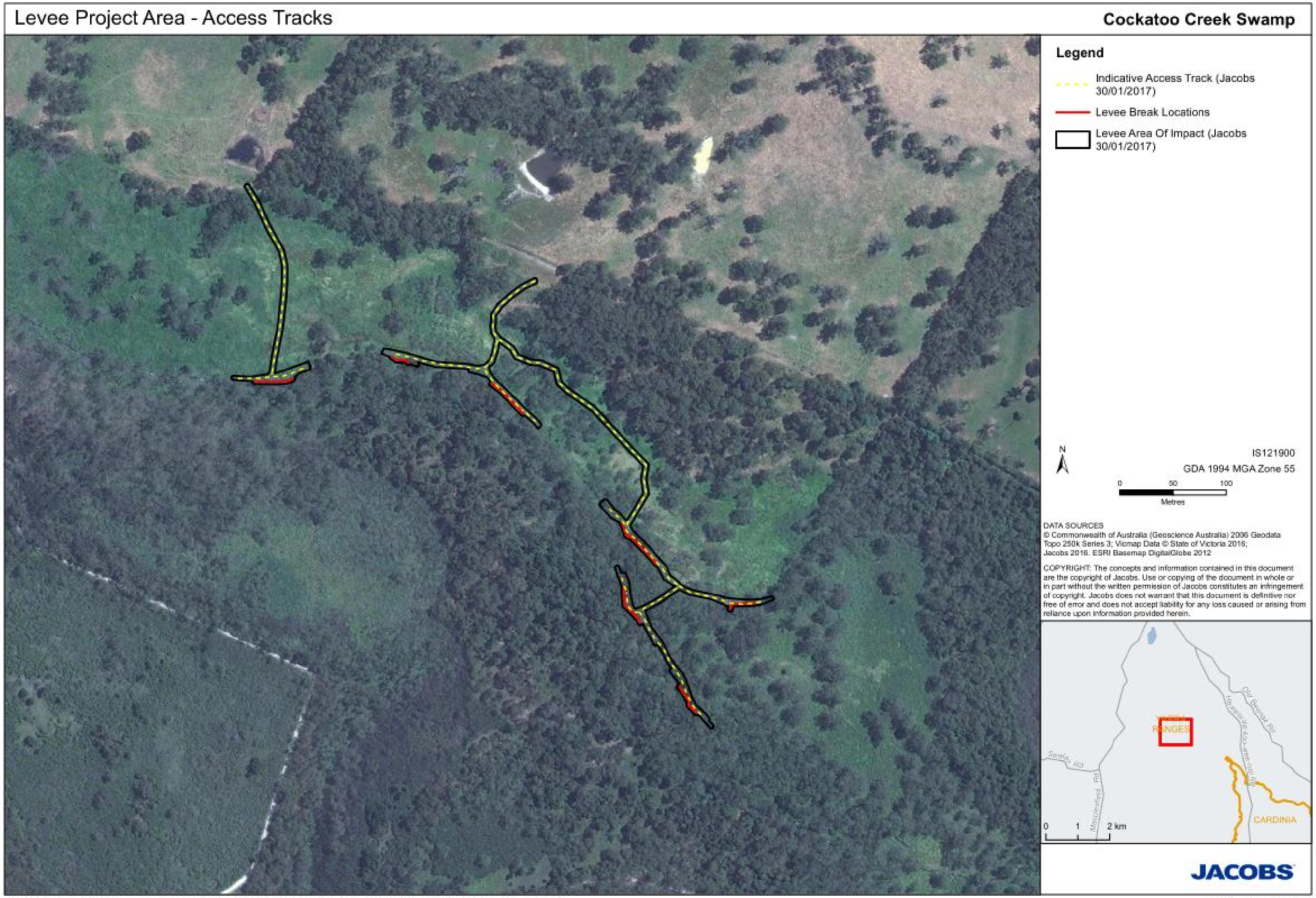
Attachment B: Proposed inlet location

Attachment C: Decision making tree

Attachment D: Example schematic for levee material management

Attachment E: Example schematic for pipeline inlet material management

Attachment F: IWRG 702. Industrial waste resource guidelines - soil sampling



DATA SOURCES
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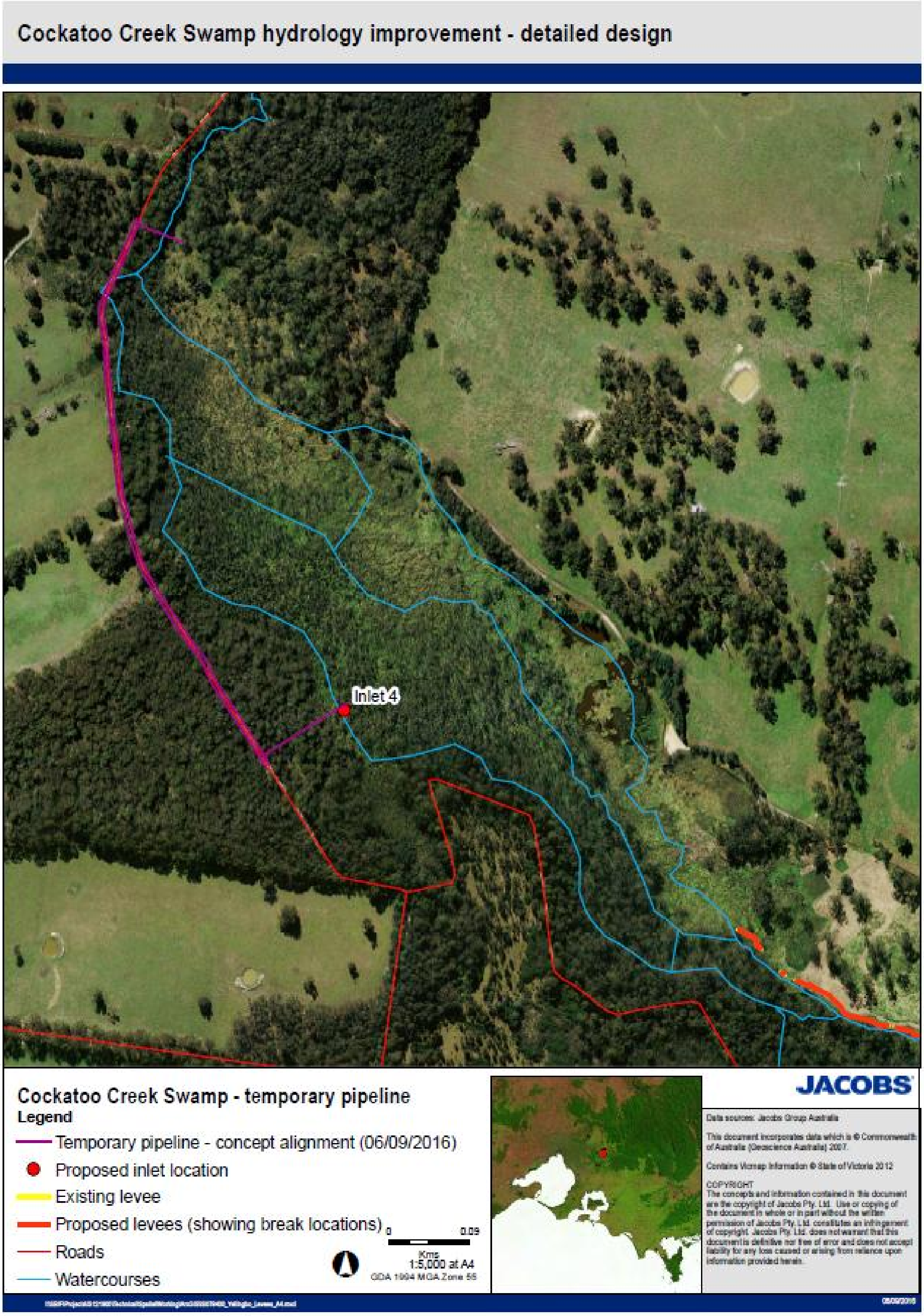
Date Published: 01 Feb 2017

Attachment A

Attachment B



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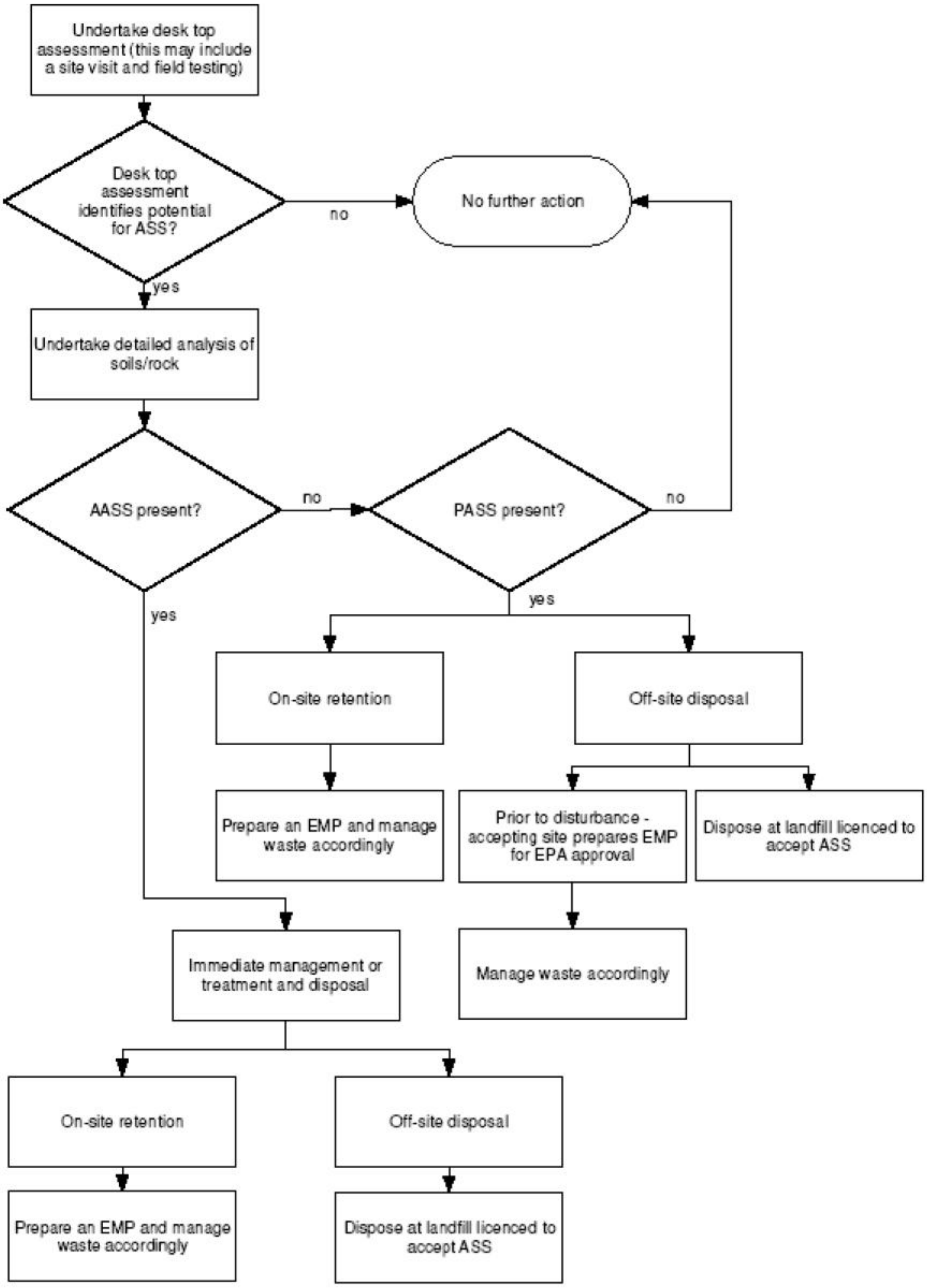
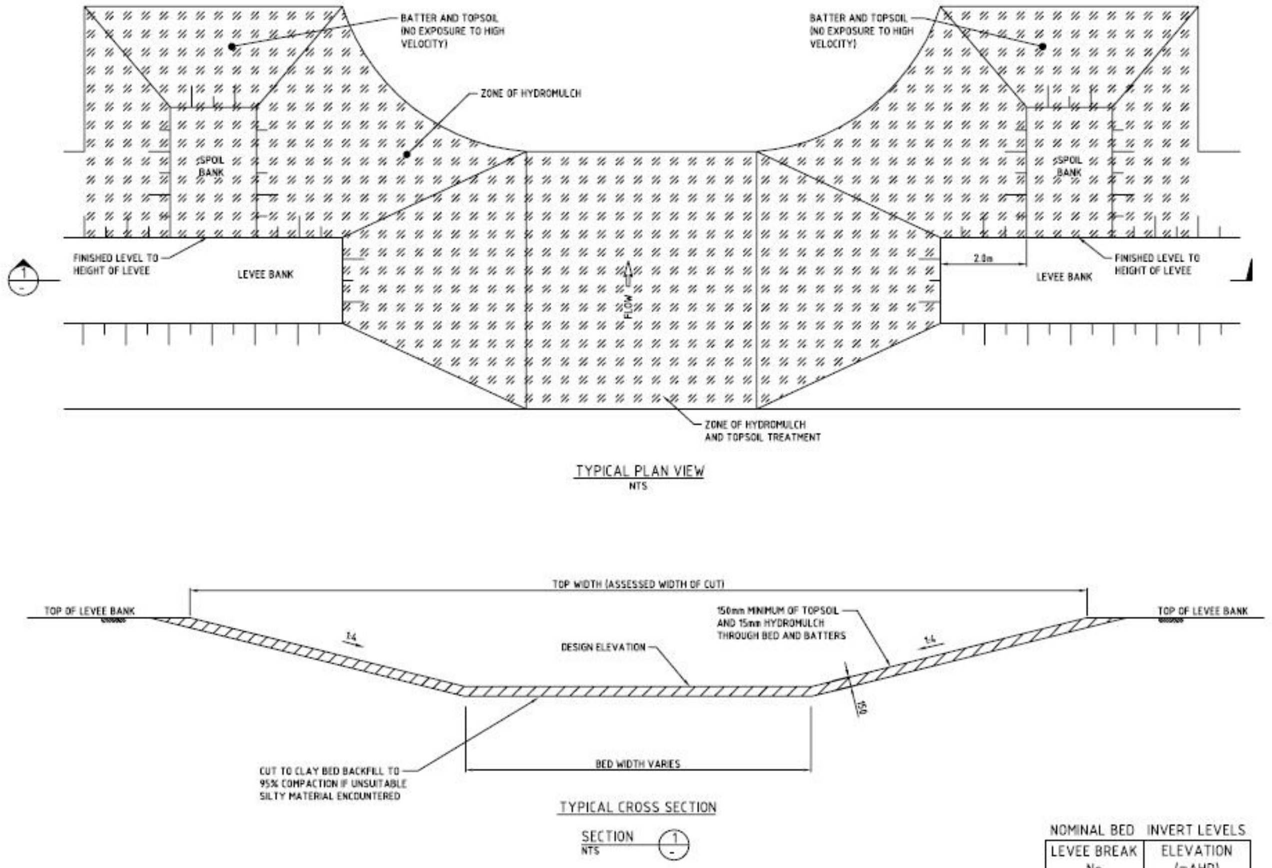




GENERAL NOTES

G1. ACCESS ROUTES SHOULD MINIMISE DISTURBANCE TO VEGETATION. ACCESS TRACKS NOMINATED ARE INDICATIVE ONLY. ECOLOGICAL SURVEY SHOULD BE UNDERTAKEN AND PROTECTION ZONES ESTABLISHED.

G2. DESIGN ELEVATIONS ARE NOMINAL, LEVEE BREAKS SHOULD BE REDUCED TO NATURAL SURFACE.

G3. DRAWINGS TO BE READ IN CONJUNCTION WITH MELBOURNE WATER STANDARD DRAWINGS AND SPECIFICATIONS UNLESS NOTED OTHERWISE.

G4. CONTRACTOR TO CLARIFY THE EXTENT OF SEDIMENTS ONSITE AND LIAISE WITH MELBOURNE WATER FOR EROSION AND SEDIMENT CONTROL.

G5. WORKS SHOULD BE PERFORMED WITHIN A DRY AUTUMN PERIOD (FEB-APRIL), WITH SUFFICIENT TIME BETWEEN THE CONCLUSION OF WORKS AND THE COMMENCEMENT OF WINTER, TO ALLOW THE GERMINATION OF SEEDING.

ENVIRONMENTAL NOTES

E1. ARBORIST REPORT TO BE OBTAINED IDENTIFYING IMPACT UPON EXISTING VEGETATION AND MITIGATION STRATEGY WHERE POSSIBLE.

E2. ENVIRONMENTAL AND SEDIMENT MANAGEMENT PLANS MUST BE DEVELOPED AND SUBMITTED FOR REVIEW.

E3. ALL DISTURBED AREAS MUST BE REINSTATED TO THE SATISFACTION OF MELBOURNE WATER.

E4. SITE ACCESS ROUTES AND STAGING AREAS MUST BE CLEARLY IDENTIFIED AND INCLUDED IN EMP.

MAPPING AND SURVEY NOTES

M1. ALL LEVELS ARE IN METRES (UNO).

M2. ALL COORDINATES ARE GDA 94 MGA ZONE 55 (UNO).

M3. ALL LEVELS AND COORDINATES MUST BE VERIFIED ON SITE.

M4. TBM AND PSM UTILIZED DURING PROJECT MUST BE CLEARLY IDENTIFIED AND DETAILS PROVIDED.

CULTURAL HERITAGE NOTES

C1. INVESTIGATION AND CONSTRUCTION WORKS MUST BE UNDERTAKEN IN ACCORDANCE WITH APPLICABLE LEGISLATION.

NOMINAL BED INVERT LEVELS

LEVEE BREAK No	ELEVATION (mAHD)
1	111.00
2	111.32
3	111.55
4	112.05
5	112.35
6	112.80
7	112.45

ISSUED FOR REVIEW

REV	DATE	DRAWN	REV'D	APP'D	REVISION
B	05.12.16	SO	TK	NL	ISSUED FOR REVIEW
A	30.11.16	SO	TK	NL	ISSUED FOR INFORMATION

DRAWING NUMBER | REFERENCE DRAWING TITLE

Melbourne Water

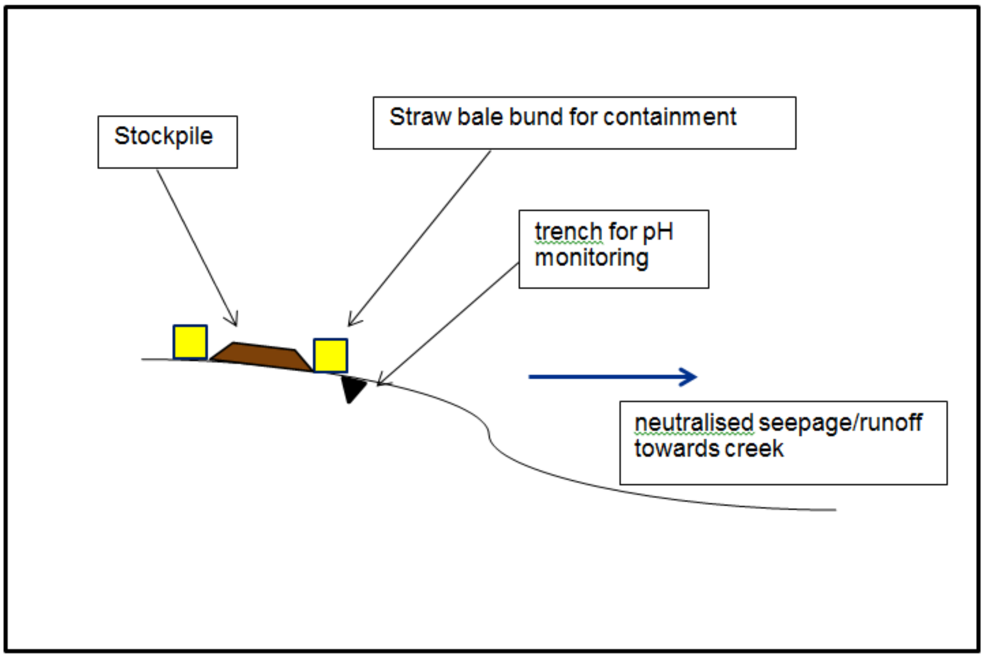
JACOBS

CLIENT MELBOURNE WATER
PROJECT COCKATOO CREEK SWAMP HYDROLOGY IMPROVEMENT
DRAWN S. ORR
DRAWING CHECK TK
REVIEWED C. DWYER
APPROVED N. LOGAN
DESIGNED T. KELLY
DESIGN REVIEW CD
DATE 30.11.16
DATE 30.11.16

TITLE LEVEE BREAK DESIGNS
TYPICAL CROSS SECTION AND GENERAL NOTES
SCALE AS SHOWN
DRAWING No IS121900-ECC-DG-0202
REV B

Attachment D

Attachment E



Attachment F

INDUSTRIAL WASTE RESOURCE GUIDELINES

SOIL SAMPLING

CONTENTS

INTRODUCTION

This guideline provides information relating to the most suitable patterns for sampling and the number of samples to be taken to ensure the appropriate hazard categorisation is applied to soils being moved off-site for reuse, treatment or disposal.

It also details the acceptance requirements for disposal facilities receiving contaminated soils to assist such facilities in meeting EPA licence acceptance criteria.

The following related documents should be used in conjunction with this document:

- Australian Standard 4482.1, *Guide to the sampling and investigation of potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds*. For information on conducting preliminary site investigations and determining if a site is potentially contaminated.
- Australian Standard 4482.2, *Guide to the sampling and investigation of potentially contaminated soil Part 2: Volatile substances*.
- Industrial Waste Resource Guideline (IWRG) *Sampling and analysis of waters, wastewaters, soils and wastes*. Details the protocols that are required for soil sample collection, handling and storage.
- IWRG *Soil hazard categorisation and management*. Details how to categorise waste soils to determine the appropriate management option.

Where a site has any potentially contaminated soil, the soil must be assigned a hazard category of A, B, C or clean fill prior to off-site reuse, or disposal, and this sampling guide should be applied.

Soils are considered **potentially contaminated** if they:

- have been mixed with any wastes

or

- consist of, or partially consist of, soil of unknown origin that has been brought onto a site

or

- arise from sites where former uses include industrial, commercial, mining or agricultural activities

or

- have had manufactured chemicals applied.

EPA requires that any waste soils be managed in accordance with the waste hierarchy of avoidance, reuse, recycling, recovery of energy, treatment, containment and disposal as set out in the *Environment Protection Act 1970*.

SAMPLING GUIDELINES

Preliminary site investigation

Prior to categorising potentially contaminated soil for off-site reuse or disposal, as a minimum, a preliminary site investigation should be conducted in accordance with Australian Standard 4482.1. The soils category should be based on the outcome of the preliminary site investigation and any subsequent information that is collected.

This guidance forms part of the Industrial Waste Resource Guidelines, which offer guidance for wastes and resources regulated under the *Environment Protection (Industrial Waste Resource) Regulations 2009*. Publication IWRG702 – June 2009.

For the purpose of categorising the soils, the site should be divided into domains[1] or stockpiles[2] representing similar material types (eg. fill, natural soil or rock), similar contamination, and other site-specific features as indicated by the site history (eg. underground storage tank areas). Note: a domain may be defined as a layer of material at a specific depth, as contamination will often vary with depth, as well as surface location.

How many samples to take

The preliminary site investigation should identify appropriate depth and corresponding soil volume, for soil to be categorised for off-site management using in-situ sampling (prior to disturbance).

Once domains and soil volume(s) have been identified, site assessors should refer to the guidance below to determine the minimum number of samples required.

Figure 1 illustrates the minimum sampling rate for soils being removed from the site.

Minimum sample numbers for soil volumes less than or equal to 200m^3

The site assessor should take, at least, the number of samples listed in Table 1 or Table 2 (depending on volume) and, after analysing all samples, determine the hazard category by using the result of the highest contaminant or leachable concentration. For example, if the results of three samples indicate that the sample with the highest concentration is Category B contaminated soil (as defined in IWRG Soil Hazard Categorisation and Management) then the entire volume must be managed as Category B soil.

Alternatively, the site manager may choose to categorise the soil volume (less than 200m^3) based on the 95%UCL$_{average}$[3] provided that a sufficient amount of sample data is available.

Table 1: Minimum number of samples for in-situ 200m^3 or less (minimum of 3 then 1:25 plus bulking factor of 33%)

Soil volume, m^3	No. of samples[*]
25 or < 25	3
50	3
75	4
100	5
125	7
150	8
175	9
200	10
>200	1:25

Table 2: Minimum number of samples for stockpile 200 m^3 or less (minimum of 3 then 1:25)

Soil volume, m^3	No. of samples[*]
25 or < 25	3
50	3
75	3
100	4
125	5
150	6
175	7
200	8
>200	1:25

Minimum Sampling Numbers for Soil Volumes Greater that 200m^3

Option 1: Samples should be taken at 1 sample per 25m^3. Soils can be categorised based on the highest sample result.

Option 2: The sampling rate can be reduced subject to a comparison of the 95%UCL$_{average}$ for the soil.

The appropriate sampling rate when comparing the 95%UCL$_{average}$ will vary depending on the homogeneity of the soil and should be assessed on a case-by-case basis. Table 3 lists the minimum sampling rate for volumes greater than 200m^3.

Site assessors should note that these are minimum sampling rates for calculation of the 95%UCL$_{average}$ and are best suited to homogenous soils. Where the site contamination is heterogeneous it may be necessary to take a higher number of samples to enable the calculation of a 95%UCL$_{average}$ that more accurately reflects contaminant levels.

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[1] Domain: is an area or layer of material on the site with same probable soil hazard category.

[2] Stockpile: refers to soils that are ex-situ. Stockpiles need to be prepared from soils of like material. Where an existing stockpile consists of materials that are likely to differ in hazard category, they should be managed as individual stockpiles for the purpose of categorisation.

[3] 95% UCLaverage is the 95% upper confidence limit of the average concentration of the sampling results.

[*] Alternatively, a 95% UCLaverage can be used.

[*] Alternatively, a 95% UCLaverage can be used.

Table 3: Minimum number of samples for soil volumes greater than 200m^3 (1:25 or 95%UCL)

Soil volume, m^3	No. of samples at 1:25m^3	Minimum No. of samples 95%UCLaverage[4]
300	12	10
400	16	10
500	20	10
600	24	10
700	28	10
800	32	10
900	36	10
1000	40	10
1500	60	10
2000	80	10
2500	100	10
3000	120	12 (1:250)
4000	160	16 (1:250)
4500	180	18 (1:250)
5000	200	20 (1:250)
>5000	1:25	1:250

Calculation of 95%UCL$_{average}$

The 95%UCL$_{average}$ demonstrates with 95% confidence that the average contaminant concentration of the soil represented by the data set is at or below the concentration stated.

EPA recommends a minimum of ten samples for 95%UCL$_{average}$ calculation. For large soil volumes (i.e. >2500m^3) the minimum sampling rate should not be less than 1 sample per 250m^3.

US EPA has software available called ProUCL that, at the time of writing, was free to download from:

www.epa.gov/nerlesd1/tsc/download.htm

This software enables the user to calculate the 95%UCL$_{average}$ using various methods and to check data normality. The software also calculates confidence limits for non-normal or unknown distributions.

Instructions to download are featured on this website and the ProUCL User's Guide is also avaliable free of charge.

The 95%UCL$_{average}$ only needs to be calculated for contaminants that exceed the relevant threshold in IWRG *Soil Hazard categorisation and management***.**

Each domain or stockpile should be categorised separately.

EPA accepts the use of ProUCL to categorise material. To calculate the 95%UCL$_{average}$ manually, see Appendix 2 and Appendix 3 for worked examples.

Non-detect samples need to be included in calculations of 95%UCL$_{average}$. Historically, non-detect values have commonly been substituted with a value of half of the detection limit of the laboratory apparatus. This may be appropriate where the detection limit is insignificant in comparison to the categorisation threshold. However, where detection limits are similar to the categorisation threshold (as may be the case for leachable criteria) assuming a value of half the detection limit may not be appropriate. For more information on handling non-detect values refer to the ProUCL User's Guide, which includes worked examples for using ProUCL to calculate 95%UCL$_{average}$ with non-detects.

Sampling grid and depth of samples

A systematic grid-sampling pattern is recommended for both in-situ and stockpile sampling .

For in-situ categorisation, the sampling depth should correspond to the depth of contamination and the grid of sampling locations should be selected to be representative of the site being sampled (as determined by the site preliminary investigation). This should be based on obtaining sufficient samples to meet the sampling rates outlined above.

For stockpiles, a 3-dimensional systematic grid sampling design should be applied to account for spatial variability. Surface sampling from the stockpile will not be sufficient to categorise its contents and is not appropriate where volatile contaminants are present. Sampling should be uniformly distributed throughout the stockpile, including sampling at depth.

Figure 2 illustrates a three-dimensional systemic grid sampling pattern.

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[4] Minimum sampling rates specified in Table 3 are to provide a sufficient amount of data to calculate the 95%UCLaverage, and therefore the bulking factor is not included for in-situ soils (>200m3) categorised using a 95%UCLaverage. For soil volumes >200m3, in-situ receivers of the soils should be aware that volumes delivered may be greater than the volume sampled in-situ.

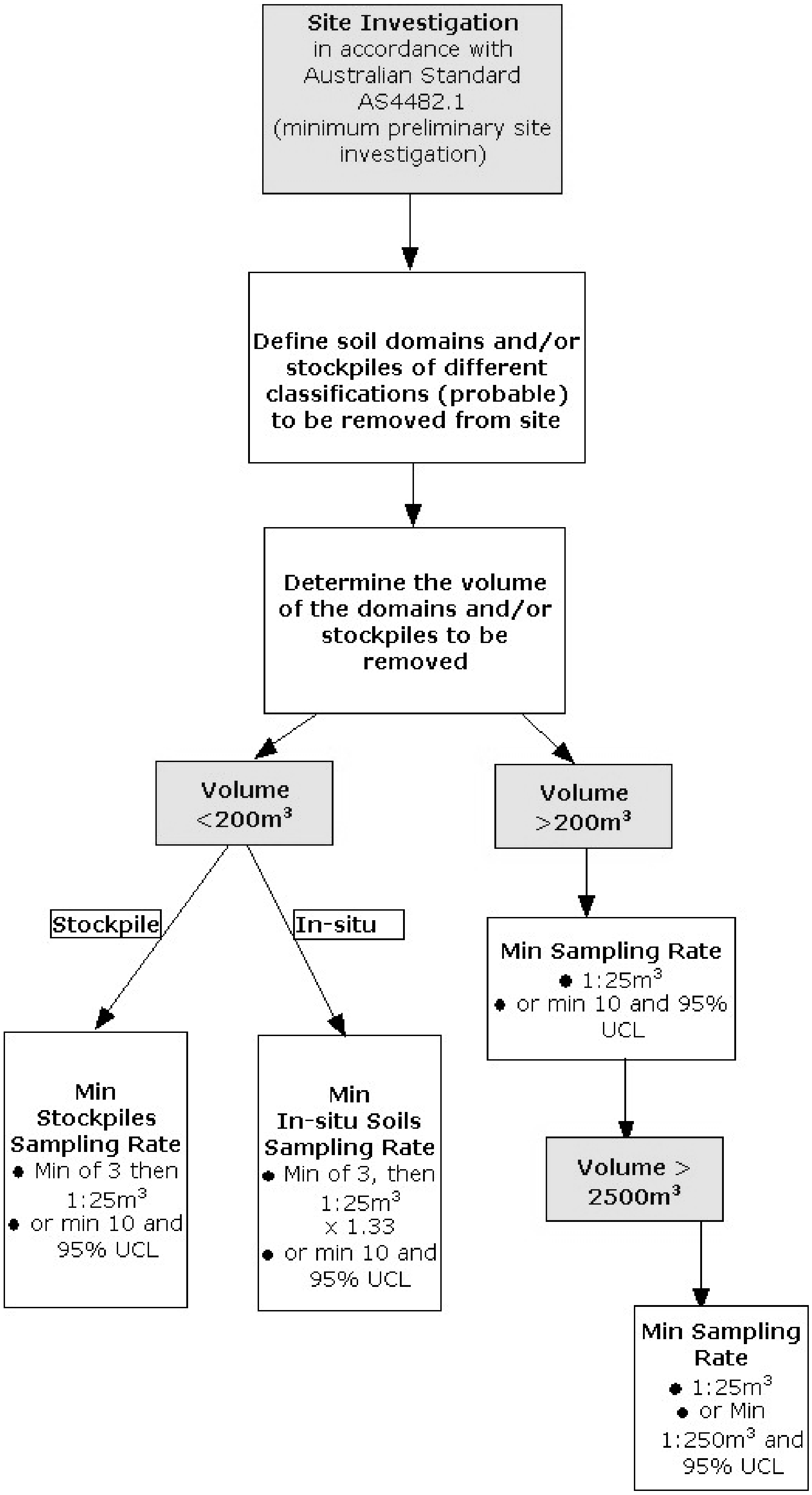

Figure 1: Flow chart for determining the minimum sampling rate for soils being removed from site

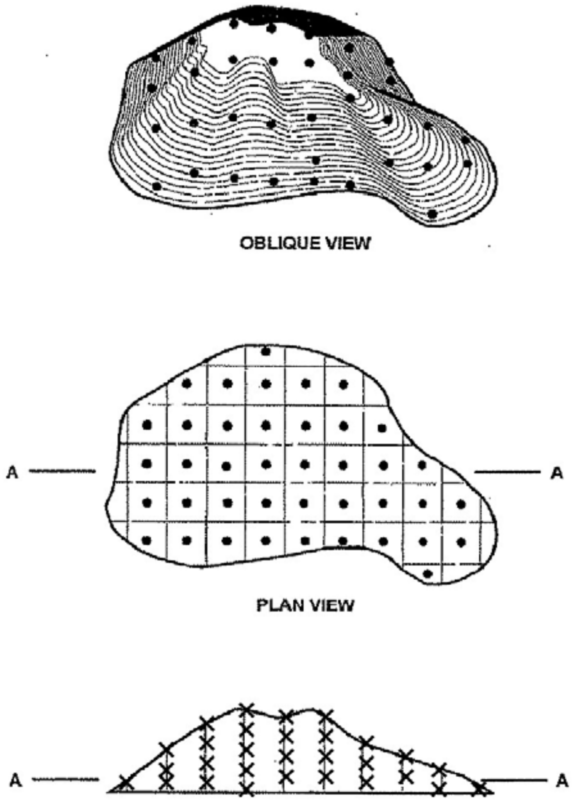

Figure 2: Three-dimensional systemic grid sampling pattern

(Reprinted, with permission from D 6009-96(2006) Standard Guide for Sampling Waste Piles, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428. A copy of the complete standard may be purchased from ASTM International, www.astm.org)

Stockpile sampling techniques

Two documents that provide useful guidance on the techniques for sampling of soils from stockpiles are:

- Australian Standard 1141.3.1 *Methods for sampling and testing aggregates*, Method 3.1: Sampling – Aggregates
- Cement Concrete & Aggregates Australia *Guideline to SAMPLING for the Extractive Industry*, August 2006.

Quality assurance (QA) samples

The Australian Standard 4482.1 provides appropriate guidance for taking QA samples, including blind replicates, split samples and rinsate blanks.

Leachate testing

Categorising wastes in accordance with IWRG *Soil hazard categorisation and management* requires that soils be tested for total concentrations and leachable concentrations.

'Twenty Times Rule': Leachate analysis is not required for Category C soils when the total concentration results are less than 20 times the leachable concentration threshold for each contaminant.

For example, a sample result with total concentration Zinc = 5000mg/kg.

Referring to IWRG *Soil hazard categorisation and management*, the maximum leachable concentration of Zinc (Category C) is 300 mg/kg, therefore 20 times the leachable concentration is 6000mg/kg.

With a total concentration result for Zinc of 5000mg/kg (less than 300 mg/kg times 20), leachable testing is not required for zinc, for this sample.

CATEGORISING SOILS

IWRG *Soil hazard categorisation and management* describes how soil is categorised. The category will determine whether the soil can be reused or disposed of.

Categorisation of the soils can be based on in-situ sampling or stockpile sampling. The values used to determine the hazard category can be either the highest sample result or the 95%UCL$_{average}$ value for each individual contaminant. Sufficient samples must be collected and analysed to meet the minimum number of samples listed above.

The contaminants listed in IWRG *Soil hazard categorisation and management* represent a broad range of common contaminants analysed in contaminated soil. (Note: individual contaminants are listed in the notes section). An assessment of the soil, including site history, will identify which contaminants to analyse to determine the hazard category, but does not preclude the analysis of other contaminants that are not specifically listed. If the waste contains a contaminant that is potentially poisonous (acute), toxic (delayed or chronic) and/or ecotoxic and is not listed, the waste generator must apply to EPA for a determination of the hazard category.

ACCEPTANCE PROTOCOLS FOR RECEIPT OF CATEGORY C OR B CONTAMINATED SOIL

This section outlines requirements for facilities receiving contaminated soil. A facility's EPA licence may include requirements in addition to those listed here.

The facility should have a quality assurance program in place to ensure that the contaminated soils received are consistent with those analysed and documented by the generator.

The following protocols should be followed by generators and facilities licensed to receive contaminated soil:

1. Each vehicle load must be accompanied by an EPA waste transport certificate, in accordance with the *Environment Protection (Industrial Waste Resource) Regulations 2009*.
2. For each domain or stockpile with a different hazard category, the generator of the waste soil should provide to the receiving facility:
    a. a copy of the NATA-accredited laboratory analysis (must be provided)
    b. the number of samples taken
    c. the site assessor's report detailing the hazard category of the waste and how it has been calculated.
3. All information should be sent to the receiving facility and approved before the soils are transported. Appendix 1 details the information that the soil generator should provide to the receiving facility.
4. Receiving facilities must only accept soils, in accordance with their licence, which meet the relevant limits set out in IWRG *Soil hazard categorisation and management*, based on:

    (a) the highest concentration result

    or

    (b) a comparison of the 95%UCL$_{average}$from the sampling results.
5. The facility operator should conduct a visual inspection of each load at the receiving gate and at the tipping face, to ensure other wastes have not been concealed in the soil.
6. Facilities receiving contaminated soils should implement a sampling program of incoming loads to enable the operator to compare their sampling results with those received from the soil generator. EPA will develop an appropriate sampling program with each landfill through the site's Environmental Improvement Plan.

FURTHER INFORMATION

ASTM International, D 6009-96(2006) *Standard Guide for Sampling Waste Piles*, 2006.

Australian Standard 1141.3.1 Methods for sampling and testing aggregates, Method 3.1: Sampling – Aggregates.

Cement Concrete & Aggregates Australia Guideline to SAMPLING for the Extractive Industry, August 2006.

Environment Protection Authority, New South Wales, *Contaminated Sites – Sampling Design Guidelines*, September 1995.

EPA Victoria, publication IWRG701, June 2009, *Sampling and analysis of waters, wastewaters, soils and wastes*.

EPA South Australia, publication 584/05 Composite soil sampling in site contamination assessment and management (Issued March 2005)

Gilbert RO, 1987, *Statistical Methods for Environmental Pollution Monitoring*, Chapter 13, page 170, Van Nostrand Reinhold.

Standards Australia, 1999, AS 4482.2-1999 *Australian Standard: Guide to the Sampling and Investigation of Potentially Contaminated Soil. Part 2: Volatile Substances*.

Standards Australia, 2005, AS 4482.1-2005, *Australian Standard: Guide to the Sampling and Investigation of Potentially Contaminated Soil. Part 1: Non-volatile and Semi-volatile compounds*.

United States Environmental Protection Agency, *ProUCL Version 4.0 User Guide*, April 2007.

APPENDIX 1: INFORMATION THAT THE SOIL GENERATOR SHOULD PROVIDE TO THE RECEIVING FACILITY. NOTE: ALL NATA ANALYTICAL LABORATORY REPORTS ARE REQUIRED BY THE RECEIVING FACILITY.

Details of soil sampling completed

Volume of soil to be disposed (m^3)	**Number of samples taken**	**How were samples taken**	**Soil categorised by highest concentration or using 95%UCL$_{average}$**	**Hazard category of contaminated soil. State whether soils are Category B, or C.** Note: It is a criminal offence to dispose category A waste to landfill.
		In-situ ☐ **Ex-situ** ☐	**High conc.** ☐ **95%UCL$_{average}$** ☐	

Analytical summary sheet checklist for receiving facility

Contaminant	**Soil analytical results**		**Maximum contaminant concentration allowed by EPA licence** **(See IWRG *Soil hazard categorisation and management*)**		**Complies with licence condition?** **Yes / No**	
	Contaminant concentration (total) mg/kg dry weight	**Leachable Concentration ASLP (mg/L)**	**Maximum contaminant concentration (total) mg/kg dry weight**	**Maximum leachable concentration ASLP (mg/L)**		
List of: **Contaminants analysed from IWRG *Soil hazard categorisation and management.*** **If contaminant not tested provide explanation (eg. Site investigation)**						
Any additional contaminants listed in licence						
Other contaminants of concern not specifically listed						

APPENDIX 2: WORKED EXAMPLE OF 95% UCL AVERAGE (NORMAL DISTRIBUTION)[5]

Reference: Gilbert, R.O., 1987, *Statistical Methods for Environmental Pollution Monitoring*, Chapter 13, page 170, Van Nostrand Reinhold.

A 250 cubic metre stockpile needs to be removed from site and requires categorisation as fill material or contaminated soil (category A, B or C) according to IWRG *Soil hazard categorisation and management*. The preliminary site investigation demonstrates a contaminant of concern is arsenic.

Solution

1. A stockpile of 250 m^3 requires:
    i. samples to be taken at 1 in 25 m^3 (total of 10 samples) and for the soil to be categorised based on the highest concentration sample result, or
    ii. the soils may be categorised using 95% $UCL_{average}$, as demonstrated below.

The soil site history and visual inspection indicate that the soil is well characterised. The site assessor decides to categorise the soil using a 95% $UCL_{average}$. A minimum of 10 samples needs to be taken and tested for total concentrations and the leachable concentration.

The arsenic concentrations in these 10 samples are:

5, 10, 18, 20, 25, 28, 30, 40, 43, 45 mg/kg

2. Mean = 26.4 mg/kg, Standard deviation (S) = 13.59 mg/kg

The coefficient of variation (CV) = S/Mean = 0.515

CV < 1.2, indicating that the data is normally distributed.

3. Determine the t value from the table in Appendix 4. For 10 samples, with 95% confidence, t (for n-1) = 1.833

4. Determining the 95% $UCL_{average}$ concentration:

Equation 1: $$UCL\ mean = \bar{x} + t_{\alpha, n-1} \frac{S}{\sqrt{n}}$$

Where:

UCL mean = Upper confidence limit of the arithmetic mean concentration of the sampling area at the $1\text{-}\alpha$ confidence level.
α = The probability that the ‘true’ mean concentration of the sampling area might exceed the UCL mean determined by the above equation 6.
n = Number of sample measurements.
$\bar{x}$ = Arithmetic mean of all sample measurements.
$t_{\alpha, n-1}$ = A test statistic (Student’s *t* and a α level of significance and *n-1* degrees of freedom).
S = Standard deviation of the sample measurements.

UCL *mean* = 26.4 + [(1.833)*((13.59/√10))] = 34.28

Based on the 95% $UCL_{average}$ concentration = 34.28 mg/kg, arsenic, this soil is not suitable for fill material.

5. The leachability of the soils now needs to be determined. The leachable concentration for categorisation can be calculated using the same 95% $UCL_{average}$ methodology discussed above. Note: where the CV is greater than 1.2, the leachate concentration may need to be calculated using the method outlined in Appendix 3. For the purposes of this example the 95% $UCL_{average}$ leachable concentration = 0.5 mg/L.

6. According to IWRG *Soil hazard categorisation and management*, the soil is categorised as Category C contaminated soil.

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[5] Normal distribution: is a data set that is normally distributed. To determine if the data is normal, the coefficient of variation (CV) needs to be < 1.2. If the CV is > 1.2 it indicates that the data may be log normal and may need to be calculated using method outlined in Appendix 3.

APPENDIX 3: WORKED EXAMPLE OF 95% UCL AVERAGE FOR LOGNORMAL DATA

Reference: Gilbert RO, 1987.

A site has 5000m^3 in-situ soil which needs to be removed from site, and requires categorisation as fill material or contaminated soil (category A, B or C) according to IWRG *Soil hazard categorisation and management*. Preliminary site investigation indicates a contaminant of concern is copper.

Solution:

1. The site history and visual inspection indicate that the soil is well characterised. The site assessor determines that sampling at the minimum rate (1 in 250 m^3) should be sufficient to categorise the soil. Twenty soil samples are taken and analysed chemically for copper resulting in the follow results (mg/kg):

   500, 510, 155, 150, 121, 100, 99, 95, 92, 90, 55, 50, 49, 47, 18, 15, 40, 38, 29, 25.

The results indicate the soil contamination is heterogeneous. Therefore, the site assessor should check the adequacy of the domains to ensure that all possible measures, including additional sampling, have been taken to segregate areas of varied contamination.

2. Calculate the CV (as detailed in Appendix 2). The CV = 1.229.
3. The CV > 1.2 indicates the distribution of the soil is lognormal and the 95% UCL$_{\text{average}}$ needs to be calculated using Equation 2.

Equation 2: $$UCL\ mean = \exp\left(\bar{y} + 0.5Sy^2 + \frac{S_yH}{\sqrt{n-1}}\right)$$

Where:

UCL mean = Upper confidence limit of the arithmetic mean concentration at the % confidence level.

$\bar{y}$ = Arithmetic mean of the log-transformed sample measurements.

Sy^2 = Variance of the log-transformed sample measurements.

n = Number of sample measurements.

H = A statistical constant. Its value is dependent on the values of S_y and *n*.

exp = Exponential function, i.e. 2.7183 to the power of the value inside the brackets.

4. Logarithmically transform the sample measurements. Let $y_i = \ln x$, where x is the original sample measurement.

Sample result *(x)*	**y_i = log of sample result *(x)***
500	6.214608
510	6.234411
155	5.043425
150	5.010635
121	4.795791
100	4.60517
99	4.59512
95	4.553877
92	4.521789
90	4.49981
55	4.007333
50	3.912023
49	3.89182
47	3.850148
18	2.890372
15	2.70805
40	3.688879
38	3.637586
29	3.367296
25	3.218876

5. Compute $\bar{y}$.

$$\bar{y} = \sum y_i \Big/ n = 4.26$$

6. Compute $S_y{}^2$ and S_y.

$$S_y{}^2 = \sum(\bar{y} - y_i)^2 \Big/ n-1 = 0.89$$

$$S_y = \sqrt{S_y{}^2} = 0.95$$

7. Determine the value of H from Appendix 5. For values of S_y and n that are not listed in the tables, use interpolation.

$H = 2.545$.

8. Compute the % UCL mean from Equation 2 above.

95% UCL mean concentration = 193 mg/kg, Copper.

9. The leachability of the soils now needs to be determined. The leachable concentration for categorisation can be calculated using the same 95% $\text{UCL}_{\text{average}}$ methodology discussed above. Note: where the CV is >1.2 the leachate concentration may need to be calculated using the lognormal method outlined above. For the purposes of this example the 95% $\text{UCL}_{\text{average}}$ leachable concentration = 100 mg/L.

10. The soils are categorised as Category C contaminated soils based on the concentration (total) of 193 mg/kg and the leachable concentration of 100 mg/L.

APPENDIX 4: VALUES OF STUDENT'S T AT α = 0.05 (THIS GIVES 95% UCL)

Reference: Gilbert, R.O, 1987.

α	0.05 (95%)	α	0.05 (95%)
Number of Samples		**Number of Samples**	
1	6.314	16	1.746
2	2.920	17	1.740
3	2.353	18	1.734
4	2.132	19	1.729
5	2.015	20	1.725
6	1.943	21	1.721
7	1.895	22	1.717
8	1.860	23	1.714
9	1.833	24	1.711
10	1.812	25	1.708
11	1.796	26	1.706
12	1.782	27	1.703
13	1.771	28	1.701
14	1.761	29	1.699
15	1.753	30	1.697
		40	1.684
		60	1.671
		120	1.658
		∞	1.645

APPENDIX 5: VALUES OF $H_{1-\alpha} = H_{0.95}$ FOR COMPUTING A ONE-SIDED UPPER 95% CONFIDENCE LIMIT ON A LOGNORMAL MEAN

Reference: Gilbert, R.O., 1987.

S_y	Number of samples (n)									
		5	7	10	12	15	21	31	51	101
0.10		2.035	1.886	1.802	1.775	1.749	1.722	1.701	1.684	1.670
0.20		2.198	1.992	1.881	1.843	1.809	1.771	1.742	1.718	1.697
0.30		2.402	2.125	1.977	1.927	1.882	1.833	1.793	1.761	1.733
0.40		2.651	2.282	2.089	2.026	1.968	1.905	1.856	1.813	1.777
0.50		2.947	2.465	2.220	2.141	2.068	1.989	1.928	1.876	1.830
0.60		3.287	2.673	2.368	2.271	2.181	2.085	2.010	1.946	1.891
0.70		3.662	2.904	2.532	2.414	2.306	2.191	2.102	2.025	1.960
0.80		4.062	3.155	2.710	2.570	2.443	2.307	2.202	2.112	2.035
0.90		4.478	3.420	2.902	2.738	2.589	2.432	2.310	2.206	2.117
1.00		4.905	3.698	3.103	2.915	2.744	2.564	2.423	2.306	2.205
1.25		6.001	4.426	3.639	3.389	3.163	2.923	2.737	2.580	2.447
1.50		7.120	5.184	4.207	3.896	3.612	3.311	3.077	2.881	2.713
1.75		8.250	5.960	4.795	4.422	4.081	3.719	3.437	3.200	2.997
2.00		9.387	6.747	5.396	4.962	4.564	4.141	3.812	3.533	3.295
2.50		11.67	8.339	6.621	6.067	5.557	5.013	4.588	4.228	3.920
3.00		13.97	9.945	7.864	7.191	6.570	5.907	5.388	4.947	4.569
3.50		16.27	11.56	9.118	8.326	7.596	6.815	6.201	5.681	5.233
4.00		18.58	13.18	10.38	9.469	8.630	7.731	7.024	6.424	5.908
4.50		20.88	14.80	11.64	10.62	9.669	8.652	7.854	7.174	6.590
5.00		23.19	16.43	12.91	11.77	10.71	9.579	8.688	7.929	7.277
6.00		27.81	19.68	15.45	14.08	12.81	11.44	10.36	9.449	8.661
7.00		32.43	22.94	18.00	16.39	14.90	13.31	12.05	10.98	10.05
8.00		37.06	26.20	20.55	18.71	17.01	15.18	13.74	12.51	11.45
9.00		41.68	29.46	23.10	21.03	19.11	17.05	15.43	14.05	12.85
10.00		46.31	32.73	25.66	23.35	21.22	18.93	17.13	15.59	14.26